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USING IOT TO SUPPORT OPERATIONS IN THE CONSTRUCTION SECTOR

BY

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ABSTRACT

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Title: Using IoT to Support Operations in the Construction Sector

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The concept of the Internet of Things (IoT) has become widely accepted within a variety of industries. Many companies have already adopted and implemented the technology. Construction companies today are striving to achieve their targets by using the latest technologies at the lowest possible cost while ensuring maximum security and safety. growing number of construction companies are focusing more on the benefits of the internet in their projects to improve processes, reduce waste and optimally utilize their resources and the Internet of Things (IoT) is making this possible in a much more efficient way than before. IoT has now become the newest technology that is being used in the construction industry. This paper aims to improve the understanding of the importance of IoT and its implementation in the construction industry. The paper examines how the Internet of Things can be applied to the construction industry based on various studies done by researchers. This article discusses the factors influence the adoption of based on the results of surveys conducted and identifies future work needs related to the use of IoT in various fields.

Survey has been conducted and data has been collected from 375 workers and 142 staff and the data has been analyzed. descriptive analysis, reliability & correlations were conducted on the survey given and then followed by multiple regression to validate the significant variables which are specified in the research, and we found that we have resistance and safety in the stuff model were insignificant. However, in the worker survey, we found ease of use, security & accessibility & dependability of IoT

technology are insignificant which has been discussed thoroughly in the “Division of results section “

Keyword: IoT, Internet of Things

DEDICATION

I dedicate this research to my beloved family, whom I credit for pushing me to continue this MBA program and who have suffered from my shortcomings due to the amount of time I have invested in the MBA program and my work as well. Thank you for your patience and being the support, I needed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background information

The search for new opportunities begins by recognizing information technology as a major driver of many of the developments that our society has witnessed recently, especially in the field of industrial development, IT is always evolving and facilitating business like no other.

In addition to enabling organizations, partners, workers, and customers, information technology (IT) has been at the forefront of effectively automating and expediting several business processes. Besides enabling simple and complex company procedures, IT has now effectively invaded every industrial category to provide newer and more customer-centric business solutions.

In a nutshell, IT can both create and improve business outputs and expectations to a large extent. A strategic collaboration between businesses and IT is ensuring that companies become and remain updated, adaptable, scalable, and instant-on enterprises.

The Internet is at the heart of this IT revolution, as the Internet is always expanding and creating new applications and enterprises. Technology advancements are expanding the Internet's limits, increasing its relevance to society, and providing new value through its expansion as well as further use. Even in developing countries, broadband Internet access is becoming more and more affordable and commonplace. Also, devices are getting smaller, and their processing power and storage capacity keeps growing. This not only changes the way individuals access the Internet but also opens a variety of new opportunities for businesses.

Digitalization, distribution, and decentralization have led to renewed interest in realizing a legion of digitized objects that are termed and promoted as smart objects that are derived from everyday objects. That is, common and casual things are being empowered or modernized to possess some of the IT capabilities such as computing, networking, communication, sensing, actuation, and display. So, not only computers and electronic devices but also everyday objects and artifacts become part of mainstream computing. In short, the combination of minimization, integration, collaboration, consolidation, and automation technologies provides affordable, connected, reliable, context-aware, and dependable devices. Which is supporting the move toward an "always connected" paradigm, also known as the "Internet of Things" (IoT) (Coetzee and Eksteen, 2011).

The Internet of Things where things start to think. is a new approach to thinking about connected things When physical objects are added to the Internet, it expands the Internet and makes it smarter and more useful. As part of the IoT paradigm, all tangible things will become digitalized, so they can have the sensors and communication capabilities they need to be able to participate in the main computing process. A lot of devices and things will become connected to the Internet, objects can be transformed into useful, usable, and extraordinary artifacts with each of them providing data and information, and some even offering services. This allows them to use their unique functionalities and features to meet the needs of people and businesses in a variety of ways.

The Internet of Things is already having an impact on a wide range of applications in lot of industries, from Green IT and energy efficiency to logistics, Also, there are many benefits from applying IoT to construction projects, and these advantages can be related to improving the efficiency of the project, safety, and performance. These benefits can also be achieved by the implementation of a robust and real-time method of collecting data and information. Also, construction sites equipment’s will be interconnected through networking so that they can work collaboratively together. Schedules and reports might be automatically updated with the help of drones, Off-site prefabrication will be done, and on-site assembly will be completed. The technology of the future is now available, but implementation is the challenge(Jackson, 2021).

1.2 Purpose of the research

Focusing on using IoT to support operations in construction, the purpose of this study is answering the following research questions:

- How does the IoT contribute to achieving value in construction industry, and what are its potential applications?
- What are the challenges facing any potential application of the IoT in construction industry?
- What are the factors that are influencing the adoption of IoT in construction industry?

In this paper we will deepen the reader's understanding of the importance and the practical application of IoT in the construction industry and the major challenges that might hinder any potential application of IoT. The paper presents a comprehensive study on IoT's use in the construction industry based on the research that has been done by various researchers in the field. As part of our research, we reviewed the findings of their work. Also, we provided a discussion about the factors that might influence the adoption of construction stakeholders for any future implementation of IoT in construction industry.

1.3 The scope of the study

In the scope of the study, there are two categories of construction stakeholders working in Qatar. In the first category, we studied blue-collar workers, examining their acceptance of the use of IoT technology during work, while in the other category, we studied decision makers, examining their willingness to invest in IoT technology.

1.4 Motivation of the study

Constantly increasing competition and challenges for construction enterprises in combination with the rapid development of information and communication technologies require digitalization of business processes related to this industry, We argue that one of the key steps for construction companies toward a better future in the industry is to recognize a "planned IoT ecosystem", where a systematic processing of high volumes of sensor and machine data in real time to extract actionable insights is essential for providing true business value. Even though IoT offers numerous benefits to the construction industry, the adoption of IoT systems faces many challenges. Therefore, this study aims to identify which of the factors influence IoT adoption in Qatar and how they can be overcome. To ensure that any potential implementations of IoT systems in Qatar overcome these challenges and deliver their intended benefits to construction business as well as organizations.

1.5 Benefits of the study

Construction stakeholders and those interested in the industry are expected to find this study useful in many ways. Starting from clarifying the advantages that the construction industry can gain from the application of IoT technology, in addition to studying the challenges that may hinder any potential application of IoT in the construction industry, passing through putting useful insights in the hands of decision makers to enable them from developing an IoT implementation plan based on data collected from construction stakeholders to increase the possibility of the success of any potential application of the Internet of things and ensuring obtaining the best desired results, taking into consideration the dispelling of fears that may circulate in the minds of service beneficiaries at the construction site and, on the other hand, decision makers themselves and facilitating the decision-making process of investing in IoT technology in construction.

1.6 Structure of the study

This study developed and evaluated a conceptual model with number of hypotheses, which was based on the abovementioned explanations and assumptions. In order to present the results and the practical implications of this study, the paper is divided into five sections: The Introduction (Chapter -1), The literature review (Chapter-2), which includes the key factors that underlie the conceptual model and hypotheses beside the potential applications of IoT in construction sector, The research methodology (Chapter-3). The data which has been analyzed by using SPSS IBM (Chapter-4). The discussion of results and practical implications of the study (Chpapter-5), then concludes with the outcome and lessons learned (Chapter-6).

CHAPTER 2: LITERATURE REVIEW

In the past few years, it has become the aim of construction companies to employ the latest technologies to attain their targets in the shortest time as well as maintain a high level of safety and security. The construction industry is paying more attention to the benefits connected to the internet regarding improving processes, reducing waste, and maximizing efficiency, and the Internet of Things (IoT) is making this possible more efficiently than ever before. Currently, the Internet of Things has quickly become among the newest technologies in the construction industry. In this context, it is important to note the envisioned scale of the IoT, where billions of items transmitting data, many of them having the potential to act and impact the world around them. With usage of intelligent data analytics, it is possible that we will be able to make better decisions and provide more effective services to the community (Coetzee and Eksteen, 2011). Based on the forecast and analysis of future benefits of the IoT by the McKinsey Global Institute in 2015, the output value of these fields is expected to reach USD 3.9 trillion to 11.1 trillion in 2025, accounting for 11% of the total GDP. In terms of building construction, the estimated output value is projected to reach USD 70 billion to 150 billion by 2025 (McKinsey Global Institute [MGI], 2015). As result, IoT and the wider concept of digital transformation (DT) are becoming a more prominent topic of discussion among academics as well as practitioners.

A. How does the Internet of Things contribute to achieving value in the construction industry, and what are its potential applications?

With the steady development in everything related to information technology, it is clear the impact that the Internet of Things may have on many aspects, including the societal, environmental, and economic impact. The availability of accurate information about the state, location and identity of things and the surrounding environment is an important element in the mechanism for smart decision-making. IoT concepts have been demonstrate its capability in a variety of fields, including logistics, transportation, asset tracking, smart homes to energy, defense, and agriculture. And still the Internet of Things has the potential to greatly affect all aspects of our life (Coetzee and Eksteen, 2011).

Recently, Multinational Construction companies have been among the adopters of IoT, examining the benefits of using the embedded intelligence and network connectivity of IoT devices to improve their own systems and products. Companies are most interested in instrumenting their operations, looking for events that are a warning of impending failure in systems, or squeezing additional efficiency out of their operations. These are instances of simply upgrading or enhancing existing hardware in factories, refineries, office buildings, and other physical plants with IoT goodness.

Internet of things presents great opportunities for the development of the smart construction with many of potential application for IoT and digital solutions in general (Häikiö et al., 2020).

Here we will try to answer the important question, which is how the construction industry can benefit from the Internet of things and what are the applications made by some companies in the field of the construction industry through a quick review of some published literature for a group of researchers.

2.1 IoT Applications

2.1.1 Safety

The construction industry is a challenging domain from the perspective of occupational health and safety. According to reports from different countries the mortality rate and fatal accidents in the construction industry showed an upward trend from 2011 to 2015; resulting construction industry to be considered as one of the most hazardous industries (Kim et al., 2020).

Although the increased number of non-fatal and fatal accidents at the construction work site a lot of attention has been paid to monitoring the construction site itself, while safety has remained relatively less addressed (Häikiö et al., 2020). Recently this has been changed and there has been expanded concern with respect to workers safety at within the construction industry due to the nature of work which mainly takes place outside and requires high levels of physical activity (Kim et al., 2020).

In addition to accidents on the built environment, construction workers have high tendencies to suffer from occupational illnesses, such as heat-related illness due to their work which mainly takes place outside specially in gulf area and making construction from top three sectors to suffer from work related injuries in Qatar (Mehmood et al., 2018).

Traditionally, construction workers' health conditions are measured by subjective methods, corresponding to surveys. However, due to the character of self-reported questionnaires, these measurements could also be partly biased. Additionally, surveys usually ensue throughout break times; therefore, they will not mirror a worker's condition whereas they are active. (Kim et al., 2020). Therefore, the demand for sensing and warning-based technologies are increased in the construction industry for occupational health and safety (OHS) monitoring and management (Antwi-afari et al., 2019)., moreover tracking of daily activities, stress, sleep, and any other type of health-related measure gaining an importance (Choe et al., 2014), as it gives the opportunity for better decision making based on trusted and real time data.

Recently, with the wide spread of wearable wristbands and smart watches and using them to locate position or to check the physiological status, multiple attempts have been made to replace traditional physiological test methods and adopting the new technology in many areas including construction industry with potential usage to locate workers position in large construction sites and track assets in real time (Kim et al., 2020), beside monitoring the physical activities and movements to reduce the over-exertion and prevent any potential life risk specially in high temperature places (Häikiö et al., 2020).

Kim et al., 2020 discussed an implementation of wearable smart band designed for construction workers, the proposed platform collects a worker's physiological data through a wearable armband that consists of three sensors (photoplethysmographic(PPG) sensor ,temperature sensor, accelerometer sensor), to work in harmonized way to measures the volume of blood flow by detecting changes in the intensity of the reflected light through the PPG sensor, and tracking the current location of worker through the accelerometer sensor, and the temperature sensor will be responsible for reporting the skin temperature of the worker, the collected date is transferred directly to web deployed service for analysis and reporting any potential risk.

The main purpose of the platform is observing the physiological conditions to protect field workers from potential heat-related risk and specifying their need for break time and their ability to continue working within the current environment. Giving the opportunity for Personal Management System (PMS) to monitor individual health status and report the individual risk assessment based the recorded behavior and the collected data. The platform keeps notifying the construction manager through smartphone about any potential risk to take the proper preventive action.

2.1.2 Maintenance of Machinery and Equipment

Equipment maintenance work is vital to avoid additional expenses due to unexpected damages. Internet of Things using the sensor installed on equipment allowing it to send data regarding the present status or any requirement for any maintenance or repair. construction machinery is usually equipped with sensors wherever these sensors will monitor remotely any sign of the mandatory maintenance like temperature fluctuations, excessive vibrations so on. In addition, the long usage of equipment most probably will require maintenance on the equipment. Through the connected IoT sensors, work time are often logged giving better opportunity for planning the required maintenance without affecting work progress.

(Xiaoli, Yunbo and Guoxin, 2011) introduced the concept of "IITEM" to outline the main functionalities of IoT based equipment maintenance system.

1- Through the information network, provide technical support for remote equipment fault diagnosis and scientific maintenance, provide feedback control signals for optimal equipment operating status control, implement optimal equipment operating status control, and ensure that the equipment operates in a secure zone or in an energy-efficient and environmentally friendly state.

2- When an equipment's dynamic operating parameters surpass a predetermined threshold value, an alert will be triggered immediately and automatically to notify the appropriate personnel of the problem's progress. Not only does it keep an eye on how well a piece of equipment is working, but it may also pinpoint the source of the problem and identify the malfunctioning component.

3- Make early predictions about the possible failure of the equipment, figure out when the work status is poor enough that the equipment needs to be shut down for maintenance, and give a scientific and technological foundation for moving from traditional time-based preventive maintenance to condition-based predictive maintenance.

2.1.3 Remote Operation

(Mahmud, Assan, and Islam, 2018) highlighted the possibility of using the Internet of Things to undertake remote operations. Because construction is exposed to a variety of conditions, efficient observation is required to ensure that the project runs smoothly. Through the Internet of Things, instructions from remote sources may be generated if equipment are physically connected or wirelessly connected to the Internet. A linked device can receive directions and then function independently in the connected locations after receiving the directives. Take, for example, using a drone as a tool to monitor worker health and safety while also periodically checking on the progress of building projects.

2.1.4 Power, Fuel and Energy Savings

Unmanaged fuel and energy consumption will result in waste affecting the cost of the project through the Internet of Things approach the site can send information on the amount of electricity and fuel used and the use of lighting after work hours can be adjusted to save energy In addition machinery can be controlled to automatically shut down if they are not moving within specific period of time to save fuel (Mahmud, Assan and Islam, 2018).

2.1.5 Prefabricated Buildings

Prefabricated buildings, consist of manufactured building elements being created in factories in advance which are transported to the construction site and then assembled on-site, prefabricated buildings are traditionally fully fitted with all required utilities and ready for immediate use when delivered and connected ,prefabricated buildings are widely promoted as one of sustainable construction ways for the benefits of a short construction time, high quality, low cost and less energy consumption, however, with the increased demand for prefabricated buildings, it is found that the low degree of informatization in the construction industry is one of the challenges for more efficient application of prefabrication of buildings, therefore, the application of IoT technology to facilitate the integration of project planning, design, build, operation and maintenance of the smart building system for prefabricated buildings will contribute greatly to achieving breakthroughs in addressing the current bottleneck in information interaction in prefabricated buildings (Wang et al., 2020).

Wang et al., (2020) explained the implementation of IoT-based Intelligent Construction System for Prefabricated Buildings (ICSPB-IoT) to achieve efficient management of engineering quality, safety, cost, and schedule depending on technologies like RFID, GPS, machine vison, and sensors to strengthens the coordination and communication between all stages of prefabricated buildings.

The ICSPB-IoT, is a complex set of integrated systems and functions, to effectively improve coordination and control within construction processes. Besides ensuring that the information of the whole construction process is always in a shared environment and accessible for all stakeholders to optimize the process of prefabricated building. The implementation of ICSPB-IoT system can support the construction of prefabricated building in the entire life cycle from design, component production, transportation, lifting, product delivery and assembly.

This system is giving the opportunity to "transform construction resource elements into intelligent construction objects (SCOs) that have the characteristics of awareness, communicativeness and autonomy" (Wang et al., 2020).

2.1.6 Building Information Modeling (BIM)

The construction industry has been doing the same for years. Concrete is poured and set, bricks are mounted on bricks, and heating and water systems are designed in corners and on multiple floors, same process were repeated and executed in isolation without having a proper way of communication and sharing information between stakeholders, Internet of Things (IoT) and Building Information Modeling (BIM) have the potential to transform the current construction management behaviors and improve the experience for all the construction stakeholder (Dave et al., 2018).

Building Information Modeling (BIM) is an innovative model has recently attained widespread attention in the Architectural, Engineering and Construction (AEC) industry, that incorporates interactive strategies, processes and technologies to produce approaches to building production and information management throughout their life cycle , depending on a digital representation of the project that integrate data from different sources to simulate the planning, design, construction and operation of a facility , giving the opportunity for project stakeholders to visualize what is to be built in simulated environment and to identify potential design, construction or operational problems. (Machado and Ruschel, 2018) ; (Azhar, Hein and Sketo, 2007), BIM-based technologies can be strongly beneficial for construction industry through platforms using IoT technology for collecting and analyzing data to manage and control people, material and equipment's giving the opportunity to enhance construction site management (Tagliabue and Ciribini, 2018).

With the rising popularity of the BIM platforms and increased demand to adopt BIM concepts as abasis for future construction some governments started to mandate BIM for example The UK government mandated BIM in April 2016 in every construction project which requires that all projects funded by central government be delivered with 'fully collaborative 3D BIM'. , so there is a chance to leverage this technology to build open platforms that synchronize with various data sources like wireless sensors and building automation systems to close the gap in integrating built environment data with IoT standards (Dave et al., 2018).

Various researchers have begun to explore the potential integration between BIM and IoT in construction environment, Research has been conducted demonstrating the usefulness of IoT in breaking down traditional silos in the built environment throughout the entire life cycle from design to construction to delivery (Dave et al., 2018), giving examples of the proposed integration to address some classes of problems: Occupational Health and Safety Management, Smart Objects Detection and Tracking, and Visualization, Energy Efficiency Awareness, Instrumentation and Structural Health Monitoring, Intelligent Systems Planning, Indoor Environmental Quality, Interaction and Communication between stakeholders in the workplace (Machado and Ruschel, 2018).

The built environment provides significant opportunities to benefit from BIM-IoT technology, While the IoT deployment in the built environment is growing exponentially a gap in integrating these two technologies through open standards and systems might be there. Therefore, efforts to develop a platform that integrates the built environment data with IoT sensors has to be taken carefully (Dave et al., 2018).

2.1.6.1 BIM and IoT based Smart Objects Detection and Tracking

Pursuing the objective of accurately and efficiently monitor construction progress in real time to allow project managers to detect schedule delays early and make corrective decisions, the dependency on virtual models to simulate the physical representations on the construction site have proved increased benefits in construction progress monitoring (Akanmu, Anumba and Messner, 2012), Also, (Machado and Ruschel, 2018) reflected on the development of RFID BIM solution to track the position and state of objects at built environment and integrate the collected information into the digital model through Autodesk Navisworks application, to monitor production progress in real time and verify consistencies related to planning , to help with logistics control and supply chain management.

2.1.6.2 BIM and IoT based Visual Energy Conservation System

Recently, energy consumption of buildings and environmental pollution have become increasingly serious issues and concepts like green building and smart buildings has arisen to achieve more comfort and convenience of people in the building space (Wu and Liu, 2020).

Wu and Liu, (2020) introduced an IoT-BIM based system focused on "persuasive energy conservation" through utilization of wireless sensing technology to collect physical data of a real-world environment, and with the parameterization and visualization functions of the proposed BIM multi-dimensional model data will be presented using graphs and tables in the user interface. Through utilization of this system, the gap between virtual models and real space could be reduced, so that system users and space managers had more reference paths and tools to improve the operational efficiency and objective comfort perception of the space, space users, and heating and cooling equipment giving the opportunity to achieve the purpose of energy saving.

2.1.6.3 BIM and IoT based Facilities Management.

Use of BIM, and IoT technologies allow developing new kinds of applications in many fields, including Facility Management (FM).

(Chang, Dzeng and Wu, 2018) discussed a proposed platform to integrate data generated by data collection sensors into BIM model for visualization through usage of Dynamo (Plugin for Revit) and Arduino, and then using Python programming language to perform a Predicted Mean Vote analysis, the platform is transforming sensor data to context-based visualized data (comfort level in this case) and presenting the resulting color visualization via a BIM model. Such visualization allows a facility manager to see the distribution of values from the perspective of the desired context, and thus make appropriate decisions about any required adjustments.

(Nguyen, 2016) also discussed case study for integration of BIM and IoT sensors to improve the indoor climate of Tyréns headquarter building through real time data collection of temperature by sensors.

2.1.7 Tracking trades by room

Integration between Building Information Modeling (BIM) and Internet of Things (IoT) can help to provide a continuous progress monitoring function through tracking the location of trades assigned to interior finishing tasks, (Teizer et al., 2017) discussed a proposed approach focused on tracking and monitoring several trades in a construction project to avoid spatial overlap of the trades in built environment. Through assigning and coordinating the right workplace, the times to begin and finish the work, etc. for a different type of trades that are concurrently present inside a building project is critical to achieve a continuous production flow, the proposed approach is using nD-BIM for planning the project topology to present the workplaces and locations in conjunction with other date related to resource-loaded processes like quantity, cost and required resources , then linking the geometric information to the construction schedule, enabling the authorized users to have all the combined data in one central repository, the proposed mechanism for this approach is happening through usage of Bluetooth Low Energy wireless sensors (BLE) beacons installed at the work places for example mounted inside the rooms at a wall, ceiling, or door frame and it is responsible for transmit their signals as soon as a worker enters the work station. And communicate the data in a real time connection to the IoT cloud-based platform for further data processing. Time recordings per second or higher become feasible. Knowing the presence of workers at a lower frequency might offer an opportunity to comply with potential privacy regulations that are present in many countries. The same technology works for asset tracking, including tools and materials. In such a use case, smaller BLE beacons are installed or embedded inside the tools' casing or material, respectively. Combining the traceability of the personnel's location and timestamp enabled the IoT/BIM-platform to collect and visualize actual presence and duration of trades by workplace.

To make this study more understandable, Table 1 summarizes all the IoT technologies and construction fields studied by the researchers in the above-reviewed literature.

Table 1 : Summary of IoT technologies

Author	Technology	Application
Kim et al.	Wireless Sensor Network (WSN) Structural	Occupational health and safety
Xiaoli, Yunbo and Guoxin	RFID, GPS	Maintenance of Machinery and Equipment
Mahmud, Assan, and Islam	WAN, LAN	Remote Operations
Wang et al.	RFID, GPS, Machine Vision	Prefabricated Buildings
Machado and Ruschel	RFID, BIM	Object Detection & Tracking
Chang, Dzeng and Wu	BIM, Python, Dynamo	Facility Management
Teizer et al.	Bluetooth, BIM	Trades Tracking

B. What are the challenges facing any potential application of the Internet of Things in the construction industry?

The IoT, comes with its own challenges, including a lack of standards, the ability to scale globally, security concerns, and an immature ecosystem. For vendors, there is no homogeneous IoT market—each industry and application are different. Also, there are discussions on IoT-related issues focusing on technical enablers and inhibitors of the next-generation IoT applications (Figure 1).

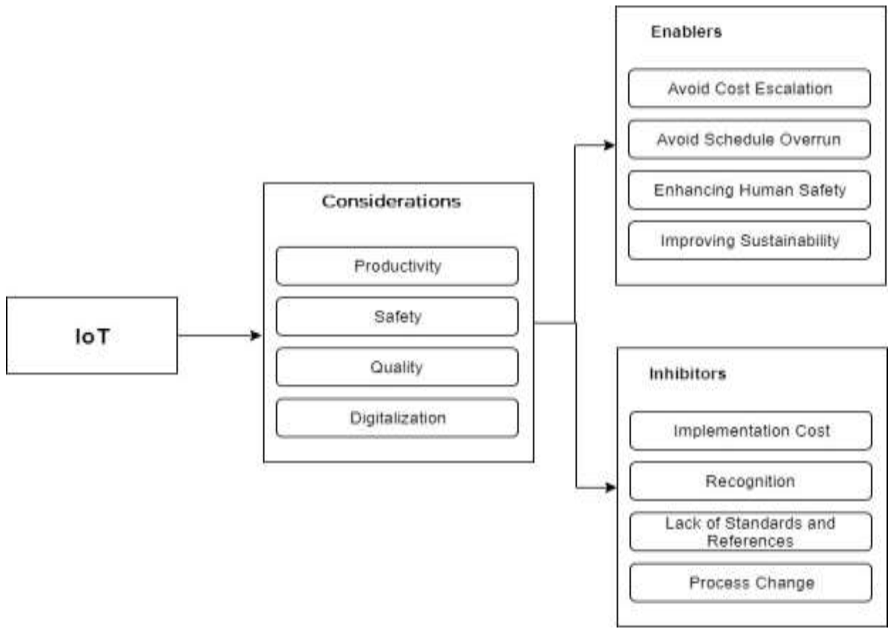

Figure 1: Inhibitors and enablers of IoT

2.2 Challenges

2.2.1 Technological challenges

Internet of Things technology (IoT) is considered somewhat new, so there are many efforts to put its definitions in addition to the well-known and distinctive nature of it by finding a means of communication between different devices through network connection This diversity and the lack of a specific definition of what may fall within the scope of Internet of things technology and what are not permitted to be clearly defined within their scope, it is extremely difficult, even complex, to set limits, in order to clearly define the technologies that fall within its scope.

2.2.2 Scalability Challenge

There is no limit for the number of devices could be connected through IoT, "Even though full interoperability is not always feasible across products and services"(Tawalbeh et al., 2020) managing the relationship and interoperability between this number of connected devices is a challenge as the number of connected objects seen to be outnumbered the current Internet capacity and poorly planned IoT gadgets would possibly mean that there'll be a negative consequence for the networking resources that they connect to.

Moreover, some several factors and concerns might have an impact on compromising the efforts to maintain interoperability within IoT environment like Cryptography.

2.2.3 Energy Usage Challenge

Energy has always been a significant factor in any initiative related to technological development. And major challenge due to the limited energy sources, the need to save and harvest energy will always be taken into consideration with any implementation for new technology like IoT.

2.2.4 Security Challenges

Sensitive and aggregated data must be protected from security breaches and data leaks, encryption is crucial to confirm the integrity and reliability of data when it is processed, transmitted and stored(Ahmed, Alwan and Ali, 2018).

IoT security system must ensure that all parts of the framework are secure, which can present a complex challenge for obtaining adequate security on devices with limited capabilities that must be addressed and resolved convincingly. Likewise, technological infrastructure that maintains respect for privacy must be developed and used as a basis for any future development of IoT environment (Villamil, Hernández and Tarazona, 2020).

The nature of the interconnection of the IoT devices means if a tool is poorly secured and connected it has the potential of touching the safety and the resilience of the whole network. Besides the potential of some devices to be ready to automatically bond with other devices, it means the users and the developers of IoT all have an obligation of guaranteeing that they are not exposing the opposite users.

Typically, IoT deployment consists of a group of similar or nearly identical devices with similar characteristics. This similarity amplifies the size of any vulnerability that could significantly affect many of them (Tawalbeh et al., 2020).

2.2.5 Privacy Challenges:

The perspective of the quality of the IoT depends on however it will respect the privacy choices of people. issues concerning the privacy and the potential harms that come back together with IoT may be important in holding back the total adoption of IoT. it is essential to grasp that the rights of privacy and user privacy respect are basic in making certain users' confidence and sureness within the net of Things, the connected device, and connected services offered. tons of labor are being undertaken to confirm that IoT is redefining the privacy problems such things because the increase of surveillance and tracking. the explanation for the privacy issues is attributable to the ubiquitous intelligence integrated artifacts wherever the sampling method and the data distribution within the IoT is also done nearly in any place. the ever-present property via the web access is additionally a necessary issue that helps in understanding this downside because of unless there is a novel mechanism place in place, then it will be by all odds more leisurely to access the private information from any corner of the world (Tawalbeh et al., 2020).

2.2.6 Ethical Challenges

Queries regarding issues that individuals could have regarding living in a future connected environment raised in polling regarding IoT, especially after founding that Some companies collect information about their employees and it was sold to third parties which raises not only privacy issues, but also ethical issues arising from corporate responsibility (Woodhead, Stephenson and Morrey, 2018).

C. What are the factors influencing the adoption of IoT in the construction industry?

Identifying the factors influencing the adoption of IoT technology requires an understanding of the theoretical models contributing to the adoption process. To achieve the objective of this research, a literature review has been conducted, looking for the best model to justify technology acceptance and defining factors that impact the adoption of IoT.

2.3 Technology Adoption Theories

The acceptance and adoption of new technologies by users is affected by numerous factors. These factors can be described, for example, by Davis' "Technology Acceptance Model" (TAM), as shown in Figure 1. According to the TAM, the technological acceptance models are built on the assumption that user intention is influenced by two major factors: perceived usefulness and perceived ease of use to determine their willingness to use the technology, The TAM theory derives from the influence of user beliefs on attitudes, the influence of intent, and the influence of behavior on technology adoption (Davis, 1989).

According to (Chen *et al.*, 2020) TAM model depends on the five main variables which are described below:

1- Perceived usefulness: This relates to how strongly users believe that the use of specific information technology is considered as being a way of improving their own performance and productivity.

2- Perceived ease of use: This refers to the extent to which the technology is perceived as easy to use. Where users will be more likely to adopt a positive attitude toward.

3- Use attitude. The perceived usefulness and ease of use of a technology have an impact on the attitude of users.

4- Willingness of use: Information systems are used when users are willing to engage with them, which is determined by both the individual's attitude toward technology and the perceived usefulness of that technology.

5- External variables: external variables such as the environment in which the user is located, the characteristics of the system, convenience and the personal characteristics of the user also have a high impact on how useful and easy the system is perceived by the user.

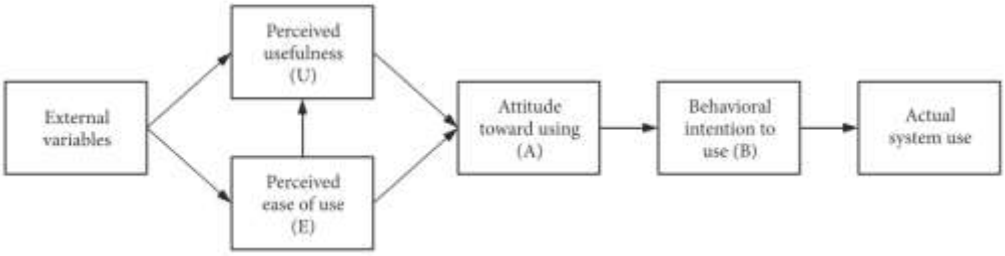

Figure 2 : Technology Acceptance Model, TAM

There are a variety of different theories about how people are going to react to new technology in various areas.

Ajzen and Fishbein (1975) developed a theory of reasoned action in social psychology. According to the theory, individuals' actions and behaviors can be explained and predicted. A fundamental hypothesis of the theory is that individuals are rational. An individual, to determine whether to perform a certain behavior, is likely to consider the meaning of the behavior itself and its result before choosing whether to perform it or not.

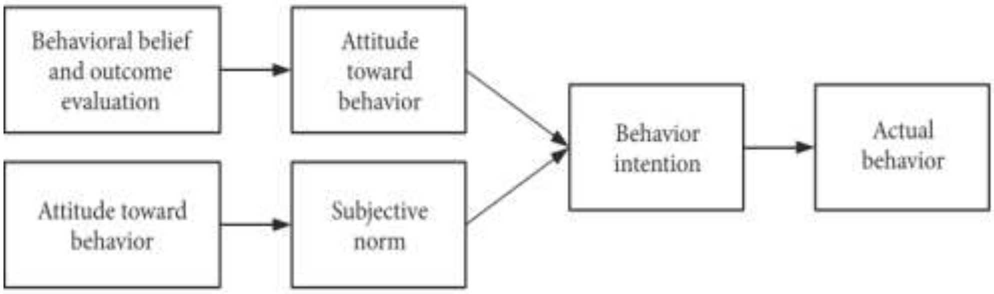

Figure 3 :Theory of Reasoned Action Model, TRA

In order to make the theory of reasoned action perform better. Ajzen (1991) developed the theory of planned behavior in response to the difficulty of utilizing the theory of reasoned action to predict and explain behavior where individuals are affected by factors such as coordination problems or self-ability problems. As opposed to rational action theory, this theory holds that individual behavioral decisions aren't entirely controlled by the will, but also by resources and opportunities.

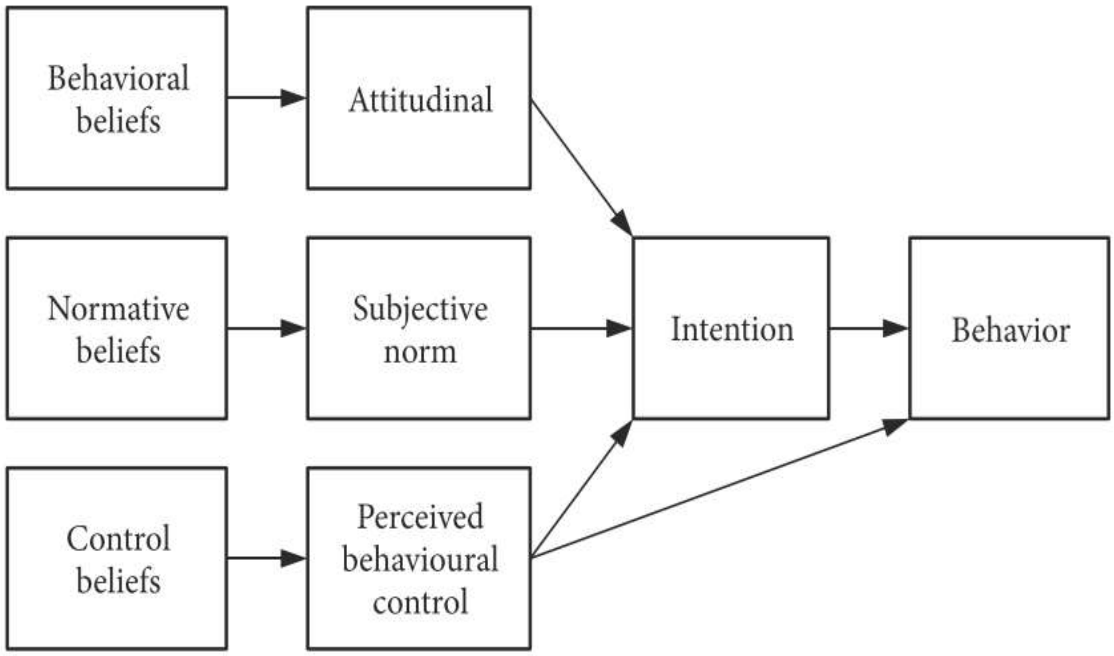

Figure 4 :Theory of Planned Behavior Model, TPB+

2.4 Research Model and Hypotheses Development

The main objective of this research is to evaluate the readiness of construction industry stakeholder to introduce and use IoT applications. Based on the outcome of two questionnaires targeting construction workers and decision makers (Staff) in construction industry. First, we use the technology acceptance model (TAM), as the basis for examining user readiness to adopt new information systems, then integrates the theory of reasoned action (TRA) and the theory of planned behavior (TPB). to explore the key factors influencing the willingness of construction industry stakeholders to introduce and use IoT applications into their work.

Based on the above, in this paper we developed a set of assumptions that would affect the extent to which the concerned parties accept the use of IoT, and they have been divided into two groups as follows

2.4.1 Workers

The hypotheses developed to assess the readiness of construction workers to adopt IoT and the relation between their overall satisfaction and the developed hypotheses explained Figure 4:

H1: Privacy is positively related to the intention to adopt IoT.
H2: The Ease of use is positively related to the intention to adopt IoT.
H3**:** Accessibility level is positively related to the intention to adopt IoT.
H4: Health & Safety is positively related to the intention to adopt IoT.
H5**:** Security is positively related to the intention to adopt IoT.

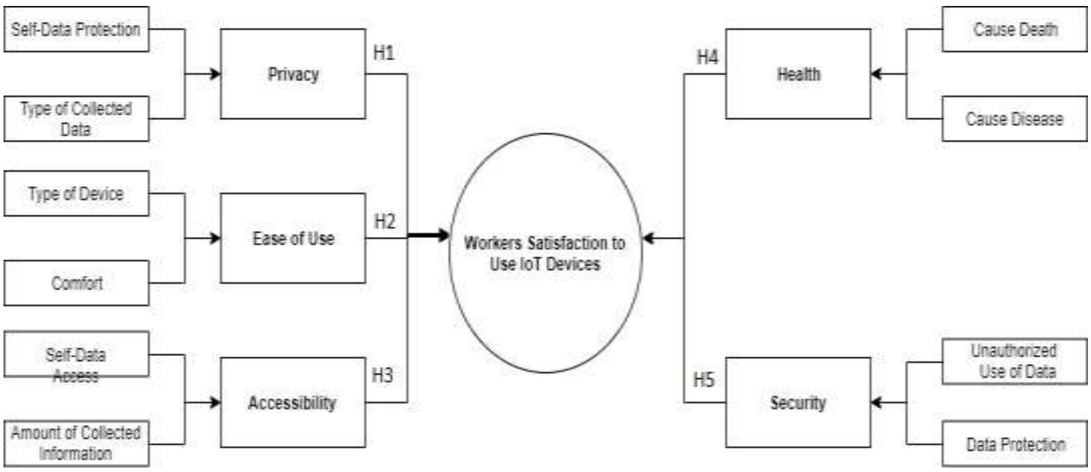

Figure 5 :Conceptual model for workers

2.4.2 Managers

The hypotheses developed to assess the readiness of decision makers (Staff) in construction to adopt IoT and the relation between their overall satisfaction and the developed hypotheses explained Figure 5:

H1: The productivity is positively related to the intention to adopt IoT.
H2: Implementation Cost is positively related to the intention to adopt IoT.

H3: The Ease of use is positively related to the intention to adopt IoT.
H4: Safety is positively related to the intention to adopt IoT.
H5**:** Technology is positively related to the intention to adopt IoT.

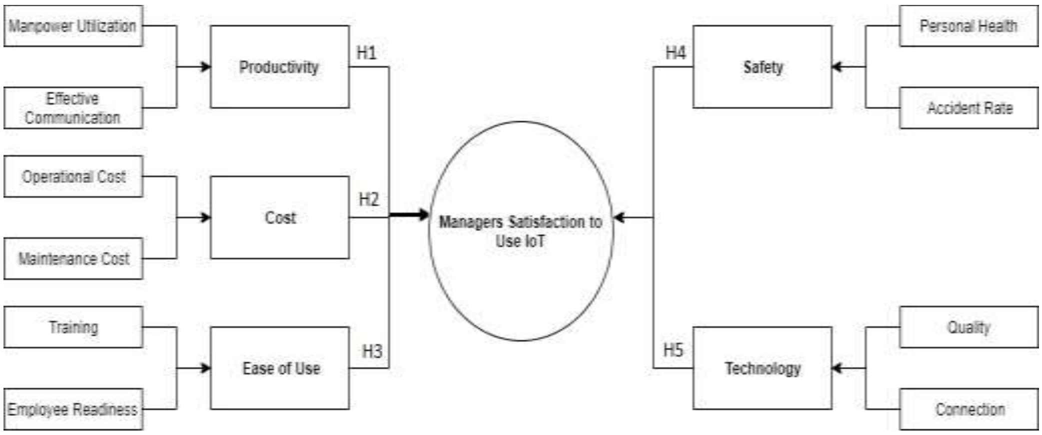

Figure 6 : Conceptual model for managers

CHAPTER 3: RESEARCH METHOD

The aim of the study is to explore the usage of Internet of Things (IoT) to support operations in construction sector and to measure up to what extent the construction stakeholders are willing to use IoT, also assessing the challenges that may face any potential application of IoT technology in the construction sector and the factors that help the success of the application and provide the necessary support and adoption from all concerned parties.

Based on the review of the literature about the factors influence the adoption of IoT, questionnaire and research hypotheses developed, the study uses a 5-point Likert type scale questionnaire forms as an instrument for obtaining quantitative data.

3.1 Research Instrument

Since it is difficult for worker to use online based questionnaire, a simple on paper questionnaire was used in a survey to determines the factors that explore the usage of IoT to support operations in the construction sector.

The questions contain two sections with the first (staff) has general information about age, years of experience. knowledge and previous interaction with IoT whereas the second sections determine the level of agreement/disagreement of satisfaction with regards to productivity, cost, recognition, safety and technology.

Also, we made a questionnaire which contains two sections for Workers has general information about age, years of experience in construction, education level knowledge and previous interaction with IoT whereas the section determines the level of agreement/disagreement with privacy, ease of use, healthy usage, security and dependability of IoT technology.

We have selected 5 different answers rating from 1 – 5, and the score provided by participants based on the importance of each factor. The questionnaire used to carry out the survey provided the participants with the opportunity to give their ratings with no interference. Questions has been asked by workers to make sure they understand the questionnaire due to the language problem despite the fact that we have translated all their questions in their language (Hindi).

Also, we have circulated the questionnaire to 475 (staff) and only 142 has replied voluntarily and circulated 700 questionnaires to workers and only 375 has provided answers. These participants were not required to provide their names or ID details. Also, before starting filling the forms, we gave time about 15 minutes. Please see the questionnaire used in the study in the appendix section.

3.2 Sample and Data Collection Procedure

The main target population of the research is divided into two groups. The first group is the category of workers in the construction industry who will use IoT devices in the building environment, to measure their ability to participate and work on the Internet of Things environment. The second category is a group of participants in the decision-making to clarify the extent of their ability to invest in the work environment of the Internet of things and the extent of their confidence in that technology, in addition to knowing the extent of their expectations for the desired results from using the IoT.

The recruitment of potential participants from Urbacon Trading & Contracting which is classified as the largest construction company in Qatar followed the below steps.

- Forwarding IRB-approved recruitment materials to Urbacon Trading & Contracting company to nominate potential participants for workers & managers surveys.
- Distributing or displaying flyers, presenting potential participants with information about the study, prior to their enrollment, to help establish interest

and willingness to serve as research subjects.

Questionnaire data has been collected through hard copies distributed at main camp for workers and head / site office for managers.

A total of 700 responses were obtained from workers out of which 375 responses were usable, representing a response rate of 100% and forming the sample of workers data analysis. For managers, A total of 475 responses were obtained, out of which 142 responses were usable, representing a response rate of 100% and forming the sample of managers data analysis. The data were collected from 17th April to 24th April,2022,a as a hard copy, then we have summarized it into two separate spread sheet, one for worker and one for staff and transferred the data in to SPSS for data analysis.

Then the data were analyzed using Perform Regression analysis on the collected data to measure the effect of the identified variables on the overall readiness and satisfaction of construction stakeholders to use IoT. The analysis is then presented in the form of graphs and tables.

CHAPTER 4: DATA ANALYSIS

In order to test the hypotheses formulated and to further analyze the data collected, many statistical methods such as frequencies, means, reliability, descriptive analysis, correlations and regressions were used. The collected responses were analyzed using the IBM SPSS statistics software, which provided additional statistical analysis of the data. SPSS developed descriptive tables to display the frequencies of each variable that further helped to describe and compare variables numerically. The used statistical analysis investigated the level of perceptions of respondents and tested the research model.

4.1 Data Demographics

The sample represented 142 staff and 375 workers and included 517 responses from Managers, Project Directors, Executive Directors and Workers . The scale used is divided into two parts, Section – 1 General Information (i.e Age, Experience, IoT Knowledge and previous interaction with IoT for Managers/ Staff and for workers Age, experience, education, IoT knowledge and previous interaction with IoT and Section 2, determine your level of agreement/disagreement with the following items by choosing one of the answers (1=Strongly Disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly Agree . The demographics of data are shown in Table 2 & 3. The respondents were asked about their age and experience. Most of the respondents, 16 % were ages between 18-25, 70.9% between 26-40, 12.3% 41-55 and 0.8% between >55 for workers and Managers ages between 44.4% ages between 26-40, 43% between 41-55 and 12.7% were >55. 65.10 % workers are having IoT Knowledge and 34.90% do not have IoT knowledge and 47.50% workers are having previous interaction with IoT and 52.50% do not have it. Whereas 61.30% of staff has IoT knowledge and 38.70% do not have it and 22.50% of staff has previous interaction with IoT and 77.50% do not have previous interaction with IoT. Finally, the sample of firms were 100% contracting firms.

Table 2 : Demographics details of the respondents – Managers / Staff

Age	Frequency	Percentage
18- 25 Years	0	0.00%
26-40 years	63	44.40%
41-55 years	61	43.00%
>55 years	18	12.70%
Experience	**Frequency**	**Percentage**
0-5 years	2	1.40%
6-10 years	12	8.50%
11-20 years	71	50.00%
>20 years	57	40.10%
IoT Knowledge	**Frequency**	**Percentage**
Yes	87	61.30%
No	55	38.70%
Previous interaction with IoT	**Frequency**	**Percentage**
Yes	32	22.50%
No	110	77.50%

Table 3 : Demographics details of the respondents – Workers

Age	Frequency	Percentage
18 - 25 Years	60	16.00%
26 - 40 Years	266	70.90%
41 - 55 Years	46	12.30%
>55 Years	3	0.80%

Experience	Frequency	Percentage
0 - 5 Years	112	29.90%
6 - 10 Years	240	64.00%
11 - 15 Years	21	5.60%
16 - 20 Years	1	0.30%
>21 Years	1	0.30%
Education	**Frequency**	**Percentage**
5th Grade Completed	103	27.50%
No Schooling	139	37.10%
Reading / Writing	133	35.50%
IoT Knowledge	**Frequency**	**Percentage**
Yes	244	65.10%
No	131	34.90%
Previous interaction with IoT	**Frequency**	**Percentage**
Yes	178	47.50%
No	197	52.50%

4.2 Item Descriptive Analysis

The first step involved a descriptive test of items levels, including the evaluation of all items means and standards deviations. Table 4 depicts the results.

Table 4 : Item Descriptive Analysis – Managers / Staff

	Survey Questions	N	Mean	Std. Deviation
	Satisfaction with IoT in construction			
Q1	SC1 I’m satisfied with using IoT devices in my company	142	*4*	0.923
Q2	SC2 I recommend that all construction companies should use IoT	142	*3.99*	0.949

	Survey Questions	N	Mean	Std. Deviation
Q3	SC3 I believe it is feasible to use IoT in construction	142	*4.04*	0.846
	Productivity-related concern			
Q4	PRC1 I think IoT will improve workers utilization	142	*4.06*	0.827
Q5	PRC2 I think IoT could help to eliminate poor workmanship	142	*3.7*	0.907
Q6	PRC3 I think IoT increase the ability of tracking workers condition	142	*4.15*	0.762
Q7	PRC4 I think IoT could establish effective communication in construction field	142	*4.05*	0.775
Q8	PRC5 I think IoT could help in eliminating obsolete equipment	142	*4.1*	0.784
Q9	PRC6 I think IoT could help reduce the rate of reworks	142	*3.55*	0.896
	Cost-related concern			
Q10	CRC1 I recommend IoT as a strategic investment	142	*3.84*	0.839
Q11	CRC2 I recommend allocating budget for IoT implementation	142	*3.86*	0.804
Q12	CRC3 I think IoT implementation will not increase the overall project budget significantly	142	*3.46*	0.881
Q13	CRC4 I think IoT could Reduce operational costs	142	*3.79*	0.849
Q14	CRC5 I think IoT could help in resources' cost monitoring	142	*4.06*	0.801
	Resistance			
Q15	RES1 I think my company employees are ready to use IoT technology	142	*3.39*	0.906
Q16	RES2 I think my company employees require minimal training to deal with IoT devices	142	*3.87*	0.89
Q17	RES3 I think IoT is creating new opportunity instead of replacing current function	142	*3.66*	0.841

	Survey Questions	N	Mean	Std. Deviation
Q18	RES4 I think implementing IoT will be smooth and easy	142	*3.31*	0.916
	Safety			
Q19	SF1 I think IoT implementation will increase safety in construction.	142	*3.78*	0.976
Q20	SF2 I think IoT could help in Identification of personal health risks and wellbeing at work	142	*3.85*	0.902
Q21	SF3 I think IoT devices could help in preventing fire accidents in construction field	142	*3.51*	1.009
	Technology			
Q22	TG1 I recommend total reliance on IoT to evaluate the work	142	*3.35*	0.892
Q23	TG2 I am confident that the IoT technology can be applied in the construction.	142	*3.85*	0.833
Q24	TG3 I trust the quality of devices and materials available in supporting IoT functionalities.	142	*3.54*	0.796
Q25	TG4 I trust my company have the ability to manage the device updates and compatibility issues.	142	*4.24*	0.798

The majority of means for staff are considered high (means between 3.31 – 4.24). The results shown in above table indicate that IoT is safe to be used and will reduce the cost and it is a good technology for better productivity and can rely on it. Consistency were shown by most of the value for standard deviation which indicates that data is around the mean.

Table 5 : Item Descriptive Analysis – Workers

	Survey Questions	N	Mean	Std. Deviation
	Satisfaction with IoT devices			
Q1	I'm satisfied with using IoT devices in my company	375	3.98	0.827
Q2	I recommend that all construction companies should use IoT	375	4.03	0.819
Q3	I'm satisfied with the amount of information collected about me	375	3.98	0.816
Q4	I'm satisfied with wearing apparel (wearables) with an embedded IoT device during work	375	4.07	0.87
	Privacy-related concern			
Q5	I agree to collect data about my health	375	4	0.929
Q6	I agree to collect data about my work activities	375	3.98	0.926
Q7	I agree to share my data with my work colleagues	375	3.99	0.845
Q8	I agree to share my data with third parties	375	4.06	0.86
	Health-related concern			
Q9	I don't think IoT technology has influence on my health during work	375	4.02	0.807
Q10	I don't think IoT technology has influence on my health on the long term	375	4.01	0.751
Q11	I don't think that IoT technology could cause death	375	4	0.779
Q12	I think IoT devices could help me monitor my health during work	375	4.05	0.774
Q13	I recommend using IoT devices to evaluate my health condition	375	4.03	0.796
	Ease of Use			

Survey Questions		N	Mean	Std. Deviation
Q14	I think IoT will not prevent me from doing normal work activities	375	4.08	0.823
Q15	I think I'm not required to do extra work to handle IoT device	375	4.03	0.851
Q16	I think I need minimal training to be able to use IoT technology	375	4.06	0.889
Q17	Using IoT technology is not complex	375	4.08	0.943
Security & Accessibility				
Q18	I trust my employer's ability to protect my data	375	3.99	0.864
Q19	My company have the latest security technology	375	4.07	0.908
Q20	I think my Employer will not use the collected data against my interest	375	4.06	0.899
Q21	I think I will be allowed to review the data collected about me	375	4.05	0.821
Q22	I think my data will not be shared with third parties	375	4.06	0.822
Q23	I Can select/define what information to be collected during my work	375	4.06	0.86
Q24	All my data will be destroyed after I leave the company	375	4.1	0.825
Dependability of IoT technology				
Q25	IoT technology is dependable	375	4.07	0.781
Q26	I highly trust IoT technology	375	4.11	0.747
Q27	IoT will yield accurate data	375	4.11	0.749
Q28	IoT technology would always be available (even at risky situations).	375	4.13	0.769

The majority of means for workers are considered high (means between 3.98–

4.13). The results shown in above table indicate that IoT is safe to be used and will reduce the cost and it is a good technology for better productivity and can relay on it. Consistency were shown by most of the value for standard deviation which indicates that data is around the mean.

4.3 Reliability and Cronbach's alpha

Reliability is conducted to determine internal consistency which is measured by Cronbach's alpha that represents a measure of the correlations between items within the same construct. The value recommended for staff and worker is higher than 0.8 (values above 0.90 are considered excellent)) (F.Hair, Black, Babin & Anderson,2010). These results confirm the validity of the used instrument and its consistency if used in further research.

Table 6 : Cronbach's alpha value of major constructs – Managers / Staff

Staff - Overall	
Cronbach's Alpha	N of Items
0.865	5

	N	Number of Items	Cronbach's Alpha if Item Deleted
Productivity	142	6	0.835
Cost-related concern	142	5	0.821
Resistance	142	4	0.843
Safety	142	3	0.859
Technology	142	4	0.824

Table 7 : Cronbach's alpha value of major constructs – Workers

Worker - Overall	
Cronbach's Alpha	N of Items
0.906	5

	N	Number of Items	Cronbach's Alpha if Item Deleted
Privacy-related concern	375	4	0.886
Health-related concern	375	5	0.882
Ease of Use	375	4	0.873
Security & Accessibility	375	7	0.884
Dependability of IoT technology	375	4	0.899

4.4 Correlation

It is important to evaluate the correlations between the variables to find out if there is a possibility of multicollinearity. The correlations shown in table 5 indicate significant bivariate correlations between the dependent variable and the independent variables, this means that the variables are selected accurately and based on a solid conceptual basis. Moreover, the correlations presented in table 8 are within the accepted range < 0.85 (Jason Fernando, Margarte James & Vikki Velasquez). If the correlations are over 0.85 a question of multicollinearity could be considered. In addition, regression analysis enables us to test for multicollinearity.

Table 8 : Pearson's Correlation Matrix – Managers / Staff

	Productivity	Cost-related concern	Resistance	Safety	Technology
Productivity	1				

	Productivity	Cost-related concern	Resistance	Safety	Technology
Cost-related concern	.656**	1			
Resistance	.492**	.590**	1		
Safety	.563**	.563**	.481**	1	
Technology	.601**	.638**	.646**	.554**	1

Table 9 : Pearson’s Correlation Matrix – Workers

	Productivity	Cost-related concern	Resistance	Safety	Technology
Privacy-related concern	1				
Health-related concern	.706**	1			
Ease of Use	.711**	.747**	1		
Security & Accessibility	.649**	.639**	.708**	1	
Dependability of IoT technology	.569**	.585**	.628**	.659**	1

4.5 **Regression Analysis**

The last step is to test the assumed hypotheses therefore multiple regression techniques were used for testing the research model. A Beta value inspection of each predictor is used to test its hypotheses. The regression test estimates all predictors for the dependent variable together. However, the test has been conducted twice using an enter method based upon the assumed model and I removed the unsignificant variables.

Table 10 indicates that the prediction of satisfaction for staff is significant and resulted in an R^1 = 0.771 (Adjusted R^2 = 0.585) with an F (67.299) .The regression test has run twice to get a result to support the hypothesis with a significance more or less than 0.0 or <0.001. Accordingly, the overall multiple regression equation can be written as follows: -

S = + 0.333 p + 0.276 CRC + 0.495 TG

We can see that when we removed two variables (resistance and safety), we found the R has increased from 0.597 to 0.771.

The same exercise has been done for worker also. The regression test estimates all predictors for the dependent variables together. However, the test has been done twice after we removed the insignificant variables. Table 11 indicate that the prediction of satisfaction for labors are significant and resulted in an R =0.809 and R^2 = 0.653 for health-related concern and privacy related concern and found all variables are significant. Accordingly, the multiple regression equation can be written as follows: -

S = + 0.533 + 0.568 PRC + 0.3 HRC

We can see that we have removed three variables to make the model more significant which are (ease of use, security and dependability) in order to make it more significant, despite the fact that both models has the same R & R^2.

S = + 0.333 PRC + 0.276 CRC + 0.495 TG

Table 10 : Multiple regression coefficient – Manager / Staff

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.22	0.313		-0.702	0.484
Productivity	0.356	0.103	0.27	3.454	<.001
Cost Cost-related concern	0.293	0.095	0.254	3.068	0.003

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Resistance	0.007	0.091	0.005	0.073	0.942
Safety	-0.063	0.065	-0.069	-0.958	0.34
Technology	0.513	0.104	0.407	4.916	<.001

a. Dependent variable : Satisfaction

Table 11 : Multiple regression coefficient – Workers

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.446	0.16		2.796	0.005
Privacy-related concern	0.553	0.046	0.576	11.907	<.001
Health-related concern	0.289	0.055	0.263	5.217	<.001
Ease of Use	-0.033	0.051	-0.035	-0.638	0.524
Security & Accessibility	0.063	0.051	0.06	1.23	0.22
Dependability of IoT technology	0.017	0.049	0.015	0.35	0.727

CHAPTER 5: RESULTS

5.1 Summary of Findings

The main purpose of the study is to answer the research questions which were the factors that are influencing the adoption of IoT in the construction industry. The statistical data analysis and results obtained from Chapter-4. 375 workers and 142 staff has replied to a questionnaire in the attached appendix -10 & 11 from my company which were surveyed for the study.

Frequencies, means, descriptive analysis, reliability analysis (Cronbach's alpha), correlations & multiple regression techniques were executed in SPSS. In the staff survey most of the respondents have an aged between 26-40 (mode) 44.40 % with experience 11-20 years (50%), and knowledge of IoT with 61.3%. We have requested to determine the satisfaction of use devices to use it in IoT in construction and we found the 75.56% of the staff agreed and strongly agreed to use it. Staff has considered the 75.48 and a mean have agreed and strongly agreed that productivity will improve tremendously if we use IoT. Also, a mean at 68.2% has agreed and strongly agreed that it is cost effective to use. A mean of 55.275% has responded agreed and strongly agreed they will have resistance to use IoT. Almost 65% has responded to agreed and strongly agreed that using IoT is safe.

Accordingly, we could conclude from the descriptive analysis (Appendix – 3) that most of the answers are between (3.5 – 4.17) agreed and strongly agreed (see Appendix -2) which shown the mode of 4.0 (agreed). Adopting IoT in construction, multi regression done twice to get a better model with significant = about < 0.01, we removed two variables (resistant and safety) and we found that R has increased from 0.597 to 0.771. Accordingly, the multi regression equation has been derived for statistics as follows :-

S = - 0.204 + 0.333 P + 0.276 CRC + 0.495 TG
With a $P < 0.001$

In the worker survey, we found that 70.90% of the survey of 375 participated are aged between 26 – 40 years and 64% of them are between 6-10 years of experience and only 27.5% has completed 5th grade education. Also, we found that 57.5% has no previous knowledge about IoT. Before we introduced what is IoT in a presentation to them in their language, the survey is done in their language as attached in Appendix – 12.

The average / mean satisfaction with IoT devices was about 4.0 (agreed) which is a good result. An average of 80 – 85% of worker agreed that to have privacy on their data, 83 – 85% agreed that the IoT devices will not have an effect in their health & 882 – 85% agreed that it is very easy to use. 86% agreed that personal data will not be use.

Accordingly, we could conclude from the descriptive analysis (Appendix - 4) that most of the workers answered agree with using the IoT in construction. Multi regression has been done tice to eliminate the non-significant variables and to get a better model with P < o.001. We have removed the variable (ease to use, security & dependability) and we got the following best regression model for prediction.

S = + 0.533 + 0.568 PRC + 0.3 HRC

With a $R^2 = 0.808$ & adjusted $R^2 = 0.651$. The reliability status shows a value of 0.968 for all the 28 items.

5.2 Discussion of Findings

One explanation for the insignificance of resistance and safety in the staff model is the high level of competition within the job market in Qatar that is creating an organizational culture focused on productivity and profitability. Managers also in Qatar tend to adopt a techno-centric attitude towards technology focusing only on the benefits the technology can bring to the workplace. Future research should measure these possible explanations plus support for the sustainability goals. As for the laborers, again they are facing high competition and are focused on the financial gains they receive from working in Qatar given also the conditions in their home countries.

CHAPTER 6: CONCLUSION

IoT is a rapidly emerging technology. The main purpose of this study is to explore the factors that influence users' readiness to use IoT applications. It analyses how external factors and variables can affect the adoption of stakeholders towards any potential IoT implementation in the construction sector. With the analysis of data collected from two different categories of stakeholders in construction, The results show that there are some factors that affect construction worker's willingness to use IoT, in particular, privacy, the ease of use, and safety, which are indicative of the users' feelings toward IoT applications and whether those applications can contribute to improving their work performance, whether they find them easy to use, whether their private data will be protected and will not be used against them and the degree to which influential people around them support their use of the system are the most important factors affecting workers acceptance to use IoT.

Also, The results show that there are some factors that affect construction decision-makers willingness to use IoT, in particular, productivity, the ease of use, cost, and safety, indicating their feelings toward IoT applications and whether those applications can contribute to improving productivity, whether they find them easy to use and are easy to learn by their subordinates , whether the cost of implementation will negatively affect the project budget and the degree to which other stakeholders around them support the use of the system are the most important factors affecting decision-makers acceptance to use & invest in IoT, As a result, it is recommended that when IoT applications are introduced by an organization, the organization should not only consider whether the system can improve work productivity, but also ensure that the application is easy to use.

However, the scale of IoT applications is still small. Therefore, there remain a lot of opportunities for the development of facilities related to IoT. The construction industry can achieve positive results from IoT application if the selectivity and variety of future applications increases, and the relevant conditions of use are met, and if future applications are diverse and meet the rights requirements.

6.1 Implications and Recommendations

As reviewed in the literature, a considerable number of studies propose a theoretical framework that can be used for evaluating the feasibility of different projects. Construction is one of the largest industries, but when it comes to adopting new technologies, it is very conservative.

This study has significant consequences for real-world companies. It gives information for management to properly coordinate the adoption of an IoT system throughout the organization. When deploying a complex system such as IoT, organizations must understand and acknowledge organizational, individual, and technological issues. It is critical to improve end users' perceived usefulness and perceived ease of use in order to encourage IoT acceptance.

A wide range of industries in construction sector can benefit from the Internet of Things (IoT). Site facilities and materials management is one example. To track and locate items and machinery, it is possible to use RFID tags in conjunction with Building Information Modeling (BIM) to collect structural geometry information, which makes it possible for managers to create deployment plans that save time and effort by locating materials and other facilities. The prefabrication business is another area where RFID sensors may be quite useful. The integration of BIM and IoT technologies allows for the direct visualization in the BIM model of the real-time visibility and traceability of various prefabricated building components. In order to monitor the progress of the project without relying on phone conversations and e-mails.

Also, IoT can prevent accidents on construction sites, which are the leading cause of fatalities. Worker safety can be enhanced by alerting them if heavy machinery or vehicles are nearby. Accidents can be prevented and a safe working environment developed. As well as monitoring the workers' activity at sites, IoT can alert them if the working environment deteriorates and poses a health risk.

Taking advantage of IoT technology creates an opportunity for the construction organizations to enhance the quality of their work by implementing the technology in smart objects and smart homes. With the arrival of 5G technology , there will be vast opportunities for the construction organizations to enhance their performance with this technology, which in turn will build a better future.

6.2 Limitations and Future Directions

According to data analysis results, usage behavior is positively connected with different factors influencing the stakeholder's decisions. in terms of practical applications, the IoT is still in the development stage. Given that technical improvements are immature and unstable, considering the nature of the construction industry as a high-risk, low-profit sector, implementing new information technology systems will almost certainly raise operational costs. Given that the public sector is frequently interested in saving costs by adopting the lowest attainable standards, the added cost of implementing IoT applications competes with manufacturers' goals. Furthermore, the advantages of IoT applications in the construction industry requires more study. While the Internet of Things has proven beneficial in other businesses, the construction industry may be different from others that produce significant money through IoT applications. This study was designed for construction workers and decision makers. However, the industries represented in the construction sector are quite diverse, and the respondents' decision-making powers differed. There is still a lack of in-depth discussion concerning behavioral intention and actual behavior now. Follow-up researchers might compare and discuss other important areas or conduct surveys for workers in a specific job area to give a reference for real-world application. There are several definitions and ways for measuring behavioral intention. Also, Different research approaches and a larger sample size might be utilized to go deeper into the issue and build more appropriate theoretical models, which will enable a better opportunity in predicting user intention and behavior in the use of technology and better understanding the relationships between them.

Also, future research should measure the insignificant sector that we found in both models, plus the support for the sustainability goals.

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APPENDIX

Appendix – 1 : Demographics details of the respondents – Managers/Staff

Age

	N	%
26-40 years	63	44.40%
41-55 years	61	43.00%
>55 years	18	12.70%

Experience

	N	%
0-5 years	2	1.40%
6-10 years	12	8.50%
11-20 years	71	50.00%
>20 years	57	40.10%

IoT Knowledge

	N	%
Yes	87	61.30%
No	55	38.70%

Prev. IoT Knowledge

	N	%
1 Yes	32	22.50%
2 No	110	77.50%

Appendix – 2 : Demographics details of the respondents – Workers

Age

	N	%
18 - 25 Years	60	16.00%
26 - 40 Years	266	70.90%
41 - 55 Years	46	12.30%
>55 Years	3	0.80%

Experience

	N	%
0 - 5 Years	112	29.90%
6 - 10 Years	240	64.00%
11 - 15 Years	21	5.60%
16 - 20 Years	1	0.30%
>21 Years	1	0.30%

Education

	N	%
5th Grade Completed	103	27.50%
No Schooling	139	37.10%
Reading / Writing	133	35.50%

knowledge about IoT

	N	%
Yes	244	65.10%
No	131	34.90%

Previous interaction with IoT

	N	%
Yes	178	47.50%
No	197	52.50%

Appendix – 3 : Item Descriptive analysis – Managers / Staff

	N	Range	Min.	Max.	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Age	142	2	2	4	2.68	0.058	0.688	0.473
Experience	142	3	1	4	3.29	0.057	0.68	0.462
IoT Knowledge	142	1	1	2	1.39	0.041	0.489	0.239
Prev. Interaction with IoT	142	1	1	2	1.77	0.035	0.419	0.176
SC1	142	4	1	5	4	0.077	0.923	0.851
SC2	142	4	1	5	3.99	0.08	0.949	0.901
SC3	142	4	1	5	4.04	0.071	0.846	0.715
PRC1	142	4	1	5	4.06	0.069	0.827	0.684
PRC2	142	4	1	5	3.7	0.076	0.907	0.823
PRC3	142	4	1	5	4.15	0.064	0.762	0.581
PRC4	142	4	1	5	4.05	0.065	0.775	0.6
PRC5	142	4	1	5	4.1	0.066	0.784	0.614
PRC6	142	4	1	5	3.55	0.075	0.896	0.803
CRC1	142	3	2	5	3.84	0.07	0.839	0.704
CRC2	142	3	2	5	3.86	0.067	0.804	0.647
CRC3	142	4	1	5	3.46	0.074	0.881	0.775
CRC4	142	3	2	5	3.79	0.071	0.849	0.721
CRC5	142	3	2	5	4.06	0.067	0.801	0.641
RES1	142	3	2	5	3.39	0.076	0.906	0.821
RES2	142	4	1	5	3.87	0.075	0.89	0.792
RES3	142	4	1	5	3.66	0.071	0.841	0.708
RES4	142	4	1	5	3.31	0.077	0.916	0.839
SF1	142	4	1	5	3.78	0.082	0.976	0.952
SF2	142	3	2	5	3.85	0.076	0.902	0.813
SF3	142	4	1	5	3.51	0.085	1.009	1.018
TG1	142	4	1	5	3.35	0.075	0.892	0.795
TG2	142	4	1	5	3.85	0.07	0.833	0.694
TG3	142	4	1	5	3.54	0.067	0.796	0.633
TG4	142	3	2	5	4.24	0.067	0.798	0.637
	142							

Appendix – 4 : Item Descriptive analysis – Workers

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Age	375	3	1	4	1.98	0.561	0.315
Experience	375	4	1	5	1.77	0.581	0.338
Education	375	2	1	3	2.08	0.79	0.625
IoT Knowledge	375	1	1	2	1.35	0.477	0.228
Prev.Interaction with IoT	375	1	1	2	1.53	0.5	0.25
SD1	375	4	1	5	3.98	0.827	0.684
SD2	375	4	1	5	4.03	0.819	0.67
SD3	375	4	1	5	3.98	0.816	0.665
SD4	375	4	1	5	4.07	0.87	0.758
PC1	375	4	1	5	4	0.929	0.864
PC2	375	4	1	5	3.98	0.926	0.858
PC3	375	4	1	5	3.99	0.845	0.714
PC4	375	4	1	5	4.06	0.86	0.74
HC1	375	4	1	5	4.02	0.807	0.652
HC2	375	4	1	5	4.01	0.751	0.564
HC4	375	4	1	5	4	0.779	0.607
HC5	375	4	1	5	4.05	0.774	0.6
HC6	375	4	1	5	4.03	0.796	0.633
EU1	375	4	1	5	4.08	0.823	0.678
EU2	375	4	1	5	4.03	0.851	0.723
EU3	375	4	1	5	4.06	0.889	0.79
EU4	375	4	1	5	4.08	0.943	0.889
SA1	375	4	1	5	3.99	0.864	0.746
SA2	375	4	1	5	4.07	0.908	0.824
SA3	375	4	1	5	4.06	0.899	0.809
SA4	375	4	1	5	4.05	0.821	0.674
SA5	375	4	1	5	4.06	0.822	0.675
SA6	375	4	1	5	4.06	0.86	0.739
SA7	375	4	1	5	4.1	0.825	0.681
DT1	375	4	1	5	4.07	0.781	0.609
DT2	375	4	1	5	4.11	0.747	0.558
DT13	375	4	1	5	4.11	0.749	0.561
DT14	375	4	1	5	4.13	0.769	0.591
Valid N (listwise)	375						

Appendix – 5 : Cronbach's alpha value of major constructs – Managers / Staff

Reliability Statistics

Cronbach's Alpha	N of Items
0.924	29

Item-Total Statistics

Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Age	101.45	183.441	0.098	0.926
Experience	100.85	184.345	0.051	0.926
IoT Knowledge	102.75	187.609	-0.157	0.927
Prev. interaction with IoT	102.36	188.898	-0.289	0.928
SC1	100.13	170.954	0.578	0.92
SC2	100.14	169.157	0.636	0.919
SC3	100.1	168.146	0.77	0.917
PRC1	100.07	170.435	0.678	0.919
PRC2	100.44	172.914	0.504	0.921
PRC3	99.99	173.603	0.576	0.92
PRC4	100.08	172.248	0.634	0.92
PRC5	100.04	177.921	0.345	0.923
PRC6	100.58	171.28	0.583	0.92
CRC1	100.3	169.841	0.695	0.919
CRC2	100.27	170.754	0.683	0.919
CRC3	100.67	172.067	0.559	0.92
CRC4	100.35	168.767	0.737	0.918
CRC5	100.07	172.08	0.62	0.92
RES1	100.75	172.772	0.51	0.921
RES2	100.26	177.57	0.311	0.924
RES3	100.47	171.145	0.631	0.919
RES4	100.82	171.791	0.546	0.921
SF1	100.35	169.251	0.612	0.92
SF2	100.29	170.349	0.62	0.92
SF3	100.62	168.691	0.612	0.92
TG1	100.79	172.863	0.516	0.921
TG2	100.28	170.785	0.655	0.919
TG3	100.59	172.328	0.612	0.92
TG4	99.89	173.301	0.562	0.921

Appendix –6 : Cronbach's alpha value of major constructs – Workers

Reliability Statistics

Cronbach's Alpha	N of Items
0.957	33

Item-Total Statistics

Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Age	119.99	295.906	-0.103	0.959
Experience	120.2	294.471	-0.029	0.959
Education	119.89	291.905	0.063	0.959
IoT Knowledge	120.62	294.626	-0.038	0.958
Prev. interaction with IoT	120.45	294.472	-0.029	0.958
SD1	117.99	274.698	0.687	0.955
SD2	117.94	274.125	0.717	0.955
SD3	117.99	274.38	0.71	0.955
SD4	117.9	273.392	0.698	0.955
PC1	117.97	270.437	0.75	0.954
PC2	117.99	270.866	0.738	0.954
PC3	117.98	272.721	0.745	0.954
PC4	117.91	274.166	0.678	0.955
HC1	117.95	274.289	0.721	0.955
HC2	117.96	275.939	0.71	0.955
HC4	117.97	275.17	0.714	0.955
HC5	117.93	275.069	0.723	0.955
HC6	117.94	274.013	0.743	0.954
EU1	117.89	273.83	0.724	0.954
EU2	117.94	272.841	0.735	0.954
EU3	117.91	270.077	0.799	0.954
EU4	117.89	268.581	0.801	0.954
SA1	117.98	275.556	0.625	0.955
SA2	117.9	272.822	0.686	0.955
SA3	117.91	274.277	0.643	0.955
SA4	117.92	272.919	0.761	0.954
SA5	117.91	273.646	0.732	0.954
SA6	117.91	273.325	0.709	0.955
SA7	117.87	274.623	0.692	0.955
DT1	117.9	277.147	0.634	0.955
DT2	117.86	277.836	0.636	0.955
DT13	117.86	277.177	0.661	0.955
DT14	117.85	277.024	0.649	0.955

Appendix –7 : Pearson's Correlation Matrix - Managers / Staff

Correlations (Staff)

		Productivity	Cost-related concern	Resistance	Safety	Technology
Productivity	Pearson Correlation	1	.656**	.492**	.563**	.601**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001
	N	142	142	142	142	142
Cost-related concern	Pearson Correlation	.656**	1	.590**	.563**	.638**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001
	N	142	142	142	142	142
Resistance	Pearson Correlation	.492**	.590**	1	.481**	.646**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001
	N	142	142	142	142	142
Safety	Pearson Correlation	.563**	.563**	.481**	1	.554**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001
	N	142	142	142	142	142
Technology	Pearson Correlation	.601**	.638**	.646**	.554**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	
	N	142	142	142	142	142

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix –8 : Pearson's Correlation Matrix - Workers

		Satisfaction with IoT devices	Privacy-related concern	Health-related concern	Ease of Use	Security & Accessibility	Dependability of IoT technology
Satisfaction with IoT devices	Pearson Correlation	1	.784**	.691**	.623**	.587**	.515**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001	<.001
	N	375	375	375	375	375	375
Privacy-related concern	Pearson Correlation	.784**	1	.706**	.711**	.649**	.569**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001	<.001
	N	375	375	375	375	375	375
Health-related concern	Pearson Correlation	.691**	.706**	1	.747**	.639**	.585**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001
	N	375	375	375	375	375	375
Ease of Use	Pearson Correlation	.623**	.711**	.747**	1	.708**	.628**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001	<.001
	N	375	375	375	375	375	375
Security & Accessibility	Pearson Correlation	.587**	.649**	.639**	.708**	1	.659**
	Sig. (2-tailed)	<.001	<.001	<.001	<.001		<.001
	N	375	375	375	375	375	375
Dependability of IoT technology	Pearson Correlation	.515**	.569**	.585**	.628**	.659**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	<.001	
	N	375	375	375	375	375	375

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix –9 : Multiple regression coefficient – Managers / Staff

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.771[a]	0.594	0.585	0.50232

a. Predictors: (Constant), Technology Technology, Productivity Productivity, Cost Cost-related concern

b. Dependent Variable: Satisfaction Satisfaction

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	50.944	3	16.981	67.299	<.001[b]
	Residual	34.821	138	0.252		
	Total	85.765	141			

a. Dependent Variable: Satisfaction Satisfaction

b. Predictors: (Constant), Technology Technology, Productivity Productivity, Cost Cost-related concern

Appendix –10 : Multiple regression coefficient – Workers

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809[a]	0.655	0.65	0.44141

a. Predictors: (Constant), Dependability of IoT technology, Privacy-related concern, Security & Accessibility , Health-related concern, Ease of Use
b. Dependent Variable: Satisfaction with IoT devices

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	136.343	5	27.269	139.95	<.001[b]
	Residual	71.896	369	0.195		
	Total	208.239	374			

a. Dependent Variable: Satisfaction with IoT devices
b. Predictors: (Constant), Dependability of IoT technology, Privacy-related concern, Security & Accessibility , Health-related concern, Ease of Use

Appendix –11 : The Questionnaire (Survey) – Managers / Staff

Using IoT to Support Operations in the Construction Sector (Managers Survey)

We constantly strive to improve the quality of our work environment and services to give an awesome experience to our workers and community. We would like to invite you to participate in this research study (Using IoT to Support Operations in the Construction Sector) approved by (QU-IRB board) under the number (QU-IRB 1706-E/22). For inquiries or questions about the ethical compliance of the study, contact the committee on the email: QU-IRB@qu.edu.qa.

The study aims at exploring the factors influencing the satisfaction with IoT in the construction sector. The study will contrast both managers and workers perspectives. This survey is directed to managers only.

** The Internet of things (IoT) describes an environment of physical objects (or people carrying such objects) that are embedded with sensors to exchange data with other devices and systems over the Internet or other communications networks.

Section 1:

General Information

1- Age: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ >55
2- Years of experience in construction: ☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ >20
3- I have some knowledge about IoT: ☐ Yes ☐ No
4- I have a previous interaction with IoT: ☐ Yes ☐ No

Section 2:

Determine your level of agreement/disagreement with the following items by choosing one of the answers:

1=Strongly Disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly Agree

	Satisfaction with IoT in construction	**1**	**2**	**3**	**4**	**5**
1	I'm satisfied with using IoT devices in my company					
2	I recommend that all construction companies should use IoT					
3	I believe it is feasible to use IoT in construction					
	Productivity-related concern	**1**	**2**	**3**	**4**	**5**
4	I think IoT will improve workers utilization					

5	I think IoT could help to eliminate poor workmanship					
6	I think IoT increase the ability of tracking workers condition					
7	I think IoT could establish effective communication in construction field					
8	I think IoT could help in eliminating obsolete equipment					
9	I think IoT could help reduce the rate of reworks					
	Cost-related concern	**1**	**2**	**3**	**4**	**5**
10	I recommend IoT as a strategic investment					
11	I recommend allocating budget for IoT implementation					
12	I think IoT implementation will not increase the overall project budget significantly					
13	I think IoT could Reduce operational costs					
14	I think IoT could help in resources' cost monitoring					
	Resistance	**1**	**2**	**3**	**4**	**5**
15	I think my company employees are ready to use IoT technology					
16	I think my company employees require minimal training to deal with IoT devices					
17	I think IoT is creating new opportunity instead of replacing current function					
18	I think implementing IoT will be smooth and easy					
	Safety	**1**	**2**	**3**	**4**	**5**
19	I think IoT implementation will increase safety in construction					
20	I think IoT could help in Identification of personal health risks and wellbeing at work					
21	I think IoT devices could help in preventing fire accidents in construction field					
	Technology	**1**	**2**	**3**	**4**	**5**
22	I recommend total reliance on IoT to evaluate the work					
23	I am confident that the IoT technology can be applied in the construction					
24	I trust the quality of devices and materials available in supporting IoT functionalities					
25	I trust my company have the ability to manage the device updates and compatibility issues					

If you have any extra comments, please feel free to write in the space below:

____

INFORMED CONSENT FORM

Using IoT to Support Operations in the Construction Sector**

We constantly strive to improve the quality of our work environment and services to give an awesome experience to our workers and community. We would like to invite you to participate in this research study (Using IoT** to Support Operations in the Construction Sector), The study is approved by the Qatar University Institutional Review Board with the approval number QU-IRB 1706-E/22 If you have any question related to ethical compliance of the study you may contact them at QU-IRB@qu.edu.qa .

This questionnaire will be used to collect the necessary data for the mentioned study to prepare for the graduation project within the requirements of the MBA degree at the College of Business and Economics at Qatar University.

The expected time to complete the questionnaire is 10 minutes. The information provided by you will be kept strictly confidential. Your participation in this study is voluntary and confidential.

Risks or discomforts: The risks of participating in this study are no greater than what is experienced in daily life.

Benefits: While there are no benefits to you as a participant, your assistance in this research will help gauge public opinion on the use of IoT to benefit construction industry and could possibly provide a basis for the adoption of such use.

Compensation: There is no compensation offered for taking part in this study.

Confidentiality of records: Your individual information will be protected in all data resulting from this study. Your responses to this survey will be anonymous. No personal information will be collected other than basic demographic descriptors.

Contact: If you have any questions or would like additional information about this study, please contact Salim Jarrar, sa2000060@student.qu.edu.qa, or the faculty member overseeing this project, Prof. Emad Ahmed Abushanab, eabushanab@qu.edu.qa.

Voluntary Participation: Your participation in this study is completely voluntary. You may discontinue your participation at any time without penalty.

Please answer YES if you wish to participate, confirming that you have read, reviewed, and agreed to participate.

☐ Yes ☐ No

**The Internet of things (IoT) describes physical objects or people that are embedded with sensors to exchange data with other devices and systems over the Internet or other communications networks.

Appendix –12 : The Questionnaire (Survey) – – Workers (English)

Using IoT to Support Operations in the Construction Sector (Workers Survey)

We constantly strive to improve the quality of our work environment and services to give an awesome experience to our workers and community. We would like to invite you to participate in this research study (Using IoT to Support Operations in the Construction Sector) approved by (QU-IRB board) under the number (QU-IRB 1706-E/22). For inquiries or questions about the ethical compliance of the study, contact the committee on the email: QU-IRB@qu.edu.qa.
The study aims at exploring the factors influencing the satisfaction with IoT in the construction sector. The study will contrast both managers and workers perspectives. This survey is directed to workers only.

** The Internet of things (IoT) describes an environment of physical objects (or people carrying such objects) that are embedded with sensors to exchange data with other devices and systems over the Internet or other communications networks.

Section 1:
General Information

1- Age: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ >55
2- Years of experience in construction: ☐ 0-5 ☐ 6-10 ☐ 11-15 ☐16-20 ☐ >20
3- Educational Level: ☐ No schooling ☐ Reading/Writing ☐ 5th Grade Completed
4- I have some knowledge about IoT: ☐ Yes ☐ No
5- I have a previous interaction with IoT: ☐ Yes ☐ No

Section 2:
Determine your level of agreement/disagreement with the following items by choosing one of the answers:
1=Strongly Disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly Agree

	Satisfaction with IoT devices	**1**	**2**	**3**	**4**	**5**
1	I'm satisfied with using IoT devices in my company					
2	I recommend that all construction companies should use IoT					
3	I'm satisfied with the amount of information collected about me					
4	I'm satisfied with wearing apparel (wearables) with an embedded IoT device during work					
	Privacy-related concern	**1**	**2**	**3**	**4**	**5**
5	I agree to collect data about my health					
6	I agree to collect data about my work activities					

7	I agree to share my data with my work colleagues					
8	I agree to share my data with third parties					
	Health-related concern	**1**	**2**	**3**	**4**	**5**
9	I don't think IoT technology has influence on my health during work					
10	I don't think IoT technology has influence on my health on the long term					
11	I don't think that IoT technology could cause death					
12	I think IoT devices could help me monitor my health during work					
13	I recommend using IoT devices to evaluate my health condition					
	Ease of Use	**1**	**2**	**3**	**4**	**5**
14	I think IoT will not prevent me from doing normal work activities					
15	I think I'm not required to do extra work to handle IoT device					
16	I think I need minimal training to be able to use IoT technology					
17	Using IoT technology is not complex					
	Security & Accessibility	**1**	**2**	**3**	**4**	**5**
18	I trust my employer's ability to protect my data					
19	My company have the latest security technology					
20	I think my Employer will not use the collected data against my interest					
21	I think I will be allowed to review the data collected about me					
22	I think my data will not be shared with third parties					
23	I Can select/define what information to be collected during my work					
24	All my data will be destroyed after I leave the company					
	Dependability of IoT technology					
25	IoT technology is dependable					
26	I highly trust IoT technology					
27	IoT will yield accurate data					
28	IoT technology would always be available (even at risky situations).					

If you have any extra comments, please feel free to write in the space below:

INFORMED CONSENT FORM
Using IoT to Support Operations in the Construction Sector**

We constantly strive to improve the quality of our work environment and services to give an awesome experience to our workers and community. We would like to invite you to participate in this research study (Using IoT** to Support Operations in the Construction Sector), The study is approved by the Qatar University Institutional Review Board with the approval number QU-IRB 1706-E/22 If you have any question related to ethical compliance of the study you may contact them at QU-IRB@qu.edu.qa .

This questionnaire will be used to collect the necessary data for the mentioned study to prepare for the graduation project within the requirements of the MBA degree at the College of Business and Economics at Qatar University.

The expected time to complete the questionnaire is 10 minutes. The information provided by you will be kept strictly confidential. Your participation in this study is voluntary and confidential.

Risks or discomforts: The risks of participating in this study are no greater than what is experienced in daily life.

Benefits: While there are no benefits to you as a participant, your assistance in this research will help gauge public opinion on the use of IoT to benefit construction industry and could possibly provide a basis for the adoption of such use.

Compensation: There is no compensation offered for taking part in this study.

Confidentiality of records: Your individual information will be protected in all data resulting from this study. Your responses to this survey will be anonymous. No personal information will be collected other than basic demographic descriptors.

Contact: If you have any questions or would like additional information about this study, please contact Salim Jarrar, sa2000060@student.qu.edu.qa, or the faculty member overseeing this project, Prof. Emad Ahmed Abushanab, eabushanab@qu.edu.qa.

Voluntary Participation: Your participation in this study is completely voluntary. You may discontinue your participation at any time without penalty.

Please answer YES if you wish to participate, confirming that you have read, reviewed, and agreed to participate.

☐ Yes ☐ No

**The Internet of things (IoT) describes physical objects or people that are embedded with sensors to exchange data with other devices and systems over the Internet or other communications networks.

Appendix –13 : The Questionnaire (Survey) – – Workers (Hindi)

निर्माण क्षेत्र में संचालन का समर्थन करने के लिए IoT (आईओटी) का उपयोग करना (श्रमिक सर्वेक्षण)

हम अपने कर्मचारियों और समुदाय को एक शानदार अनुभव देने के लिए अपने काम के माहौल और सेवाओं की गुणवत्ता में सुधार करने के लिए लगातार प्रयास करते हैं। हम आपको (क्यू-आईआरबी बोर्ड) द्वारा अनुमोदित संख्या (QU-IRB 1706-E/22) के तहत इस शोध अध्ययन (निर्माण क्षेत्र में समर्थन संचालन के लिए आईओटी का उपयोग) में भाग लेने के लिए आमंत्रित करना चाहते हैं। अध्ययन के नैतिक अनुपालन के बारे में पूछताछ या प्रश्नों के लिए, ईमेल पर समिति से संपर्क करें: QU-IRB@qu.edu.qa।

अध्ययन का उद्देश्य निर्माण क्षेत्र में आईओटी के साथ संतुष्टि को प्रभावित करने वाले कारकों की खोज करना है। अध्ययन प्रबंधकों और श्रमिकों दोनों के दृष्टिकोणों के विपरीत होगा। यह सर्वेक्षण केवल श्रमिकों के लिए निर्देशित है।

** इंटरनेट ऑफ थिंग्स (IoT) भौतिक वस्तुओं (या ऐसी वस्तुओं को ले जाने वाले लोग) के वातावरण का वर्णन करता है जो इंटरनेट या अन्य संचार नेटवर्क पर अन्य उपकरणों और प्रणालियों के साथ डेटा का आदान-प्रदान करने के लिए सेंसर के साथ एम्बेडेड होते हैं।

अनुभाग एक:
सामान्य जानकारी

1- आयु: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ >55

2- निर्माण में वर्षों का अनुभव: ☐ 0-5 ☐ 6-10 ☐11-15 ☐16-20 ☐ >20

3- शैक्षिक स्तर: ☐ कोई स्कूली शिक्षा नहीं ☐ पढ़ना/लिखना ☐ 5वीं कक्षा पूर्ण

4- मुझे IoT के बारे में कुछ जानकारी है: ☐ हाँ ☐ नहीं

5- IoT के साथ मेरी पिछली बातचीत हुई है: ☐ हाँ ☐ नहीं

धारा 2:
निम्नलिखित में से किसी एक उत्तर को चुनकर अपनी सहमति/असहमति का स्तर निर्धारित करें:
1= पूरी तरह से असहमत 2= असहमत 3= तटस्थ 4= सहमत 5= पूरी तरह से सहमत

	IoT उपकरणों से संतुष्टि	**1**	**2**	**3**	**4**	**5**
1	मैं अपनी कंपनी में IoT उपकरणों के उपयोग से संतुष्ट हूं					

2	मेरा सुझाव है कि सभी निर्माण कंपनियों को IoT . का उपयोग करना चाहिए					
3	मैं अपने बारे में एकत्र की गई जानकारी की मात्रा से संतुष्ट हूं					
4	मैं काम के दौरान एक एम्बेडेड IoT डिवाइस के साथ परिधान (पहनने योग्य) पहनने से संतुष्ट हूं					
	गोपनीयता से संबंधित चिंता	**1**	**2**	**3**	**4**	**5**
5	मैं अपने स्वास्थ्य के बारे में डेटा एकत्र करने के लिए सहमत हूं					
6	मैं अपनी कार्य गतिविधियों के बारे में डेटा एकत्र करने के लिए सहमत हूं					
7	मैं अपने डेटा को अपने कार्य सहयोगियों के साथ साझा करने के लिए सहमत हूं					
8	मैं अपना डेटा तृतीय पक्षों के साथ साझा करने के लिए सहमत हूं					
	स्वास्थ्य संबंधी चिंता	**1**	**2**	**3**	**4**	**5**
9	मुझे नहीं लगता कि काम के दौरान IoT तकनीक का मेरे स्वास्थ्य पर कोई प्रभाव पड़ता है					
10	मुझे नहीं लगता कि IoT तकनीक का मेरे स्वास्थ्य पर दीर्घकालिक प्रभाव पड़ता है					
11	मुझे नहीं लगता कि IoT तकनीक मौत का कारण बन सकती है					
12	मुझे लगता है कि IoT डिवाइस काम के दौरान मेरे स्वास्थ्य की निगरानी करने में मेरी मदद कर सकते हैं					
13	मैं अपनी स्वास्थ्य स्थिति का मूल्यांकन करने के लिए IoT उपकरणों का उपयोग करने की सलाह देता हूं					
	उपयोग में आसानी	**1**	**2**	**3**	**4**	**5**
14	मुझे लगता है कि IoT मुझे सामान्य कार्य गतिविधियों को करने से नहीं रोकेगा					

15	मुझे लगता है कि IoT डिवाइस को संभालने के लिए मुझे अतिरिक्त काम करने की आवश्यकता नहीं है					
16	मुझे लगता है कि IoT तकनीक का उपयोग करने में सक्षम होने के लिए मुझे न्यूनतम प्रशिक्षण की आवश्यकता है					
17	IoT तकनीक का उपयोग करना जटिल नहीं है					
	सुरक्षा और अभिगम्यता	**1**	**2**	**3**	**4**	**5**
18	मुझे अपने डेटा की सुरक्षा करने के लिए अपने नियोक्ता की क्षमता पर भरोसा है					
19	मेरी कंपनी के पास नवीनतम सुरक्षा तकनीक है					
20	मुझे लगता है कि मेरा नियोक्ता मेरी रुचि के विरुद्ध एकत्रित डेटा का उपयोग नहीं करेगा					
21	मुझे लगता है कि मुझे अपने बारे में एकत्र किए गए डेटा की समीक्षा करने की अनुमति दी जाएगी					
22	मुझे लगता है कि मेरा डेटा तीसरे पक्ष के साथ साझा नहीं किया जाएगा					
23	मैं अपने कार्य के दौरान एकत्रित की जाने वाली जानकारी का चयन/परिभाषित कर सकता/सकती हूं					
24	मेरे कंपनी छोड़ने के बाद मेरा सारा डेटा नष्ट हो जाएगा					
	IoT प्रौद्योगिकी की निर्भरता					
25	IoT तकनीक भरोसेमंद है					
26	मुझे IoT तकनीक पर बहुत भरोसा है					
27	IoT सटीक डेटा देगा					
28	IoT तकनीक हमेशा उपलब्ध रहेगी (जोखिम भरी परिस्थितियों में भी)।					

यदि आपके पास कोई अतिरिक्त टिप्पणी है, तो कृपया नीचे दिए गए स्थान में बेझिझक लिखें:

सूचित सहमति प्रपत्र

निर्माण क्षेत्र में संचालन का समर्थन करने के लिए IoT** का उपयोग करना

हम अपने कर्मचारियों और समुदाय को एक शानदार अनुभव देने के लिए अपने काम के माहौल और सेवाओं की गुणवत्ता में सुधार करने के लिए लगातार प्रयास करते हैं। हम आपको इस शोध अध्ययन में भाग लेने के लिए आमंत्रित करना चाहते हैं (निर्माण क्षेत्र में संचालन का समर्थन करने के लिए IoT** का उपयोग करके), इस अध्ययन को कतर विश्वविद्यालय संस्थागत समीक्षा बोर्ड द्वारा अनुमोदन संख्या के साथ अनुमोदित किया गया है QU-IRB 1706-E/22 यदि अध्ययन के नैतिक अनुपालन से संबंधित आपके कोई प्रश्न हैं, तो आप उनसे QU-IRB@qu.edu.qa पर संपर्क कर सकते हैं।

इस प्रश्नावली का उपयोग कतर विश्वविद्यालय में बिजनेस एंड इकोनॉमिक्स कॉलेज में एमबीए डिग्री की आवश्यकताओं के भीतर स्नातक परियोजना की तैयारी के लिए उल्लिखित अध्ययन के लिए आवश्यक डेटा एकत्र करने के लिए किया जाएगा।

प्रश्नावली को पूरा करने का अपेक्षित समय 10 मिनट है। आपके द्वारा दी गई जानकारी को पूर्णतया गोपनीय रखा जाएगा। इस अध्ययन में आपकी भागीदारी स्वैच्छिक और गोपनीय है।

जोखिम या परेशानी: इस अध्ययन में भाग लेने के जोखिम दैनिक जीवन में अनुभव किए गए जोखिम से अधिक नहीं हैं।

लाभ: जबकि एक भागीदार के रूप में आपको कोई लाभ नहीं है, इस शोध में आपकी सहायता से निर्माण उद्योग को लाभ पहुंचाने के लिए IoT के उपयोग पर जनता की राय जानने में मदद मिलेगी और संभवतः इस तरह के उपयोग को अपनाने के लिए एक आधार प्रदान कर सकता है।

मुआवज़ा: इस अध्ययन में भाग लेने के लिए कोई मुआवज़ा नहीं दिया जाता है।

रिकॉर्ड की गोपनीयता: आपकी व्यक्तिगत जानकारी इस अध्ययन के परिणामस्वरूप सभी डेटा में सुरक्षित रहेगी। इस सर्वेक्षण के प्रति आपकी प्रतिक्रिया गुमनाम होगी। बुनियादी जनसांख्यिकीय विवरणकों के अलावा कोई भी व्यक्तिगत जानकारी एकत्र नहीं की जाएगी।

स्वैच्छिक भागीदारी: इस अध्ययन में आपकी भागीदारी पूरी तरह से स्वैच्छिक है। आप बिना किसी दंड के किसी भी समय अपनी भागीदारी बंद कर सकते हैं।

संपर्क करें: यदि आपके कोई प्रश्न हैं या इस अध्ययन के बारे में अतिरिक्त जानकारी चाहते हैं, तो कृपया सलीम जरार, sa2000060@student.qu.edu.qa, या इस परियोजना की देखरेख करने वाले संकाय सदस्य, प्रो. इमाद अहमद मोहम्मद अबुशानाब, eabushanab@qu.edu.qa से संपर्क करें।

यदि आप भाग लेना चाहते हैं, तो कृपया हां में उत्तर दें, यह पुष्टि करते हुए कि आपने भाग लिया है, समीक्षा की है और भाग लेने के लिए सहमत हैं।

□ हाँ □ नहीं

**इंटरनेट ऑफ थिंग्स (IoT) भौतिक वस्तुओं या लोगों का वर्णन करता है जो इंटरनेट या अन्य संचार नेटवर्क पर अन्य उपकरणों और प्रणालियों के साथ डेटा का आदान-प्रदान करने के लिए सेंसर के साथ एम्बेडेड हैं।

Appendix –14 : QU IRB Approval

جامعة قطر
QATAR UNIVERSITY

Qatar University Institutional Review Board **QU-IRB**

QU-IRB Registration: IRB-QU-2020-006, QU-IRB, Assurance: IRB-A-QU-2019-0009

DATE:	April 19, 2022
TO:	Salim Jarrar
FROM:	Qatar University Institutional Review Board (QU-IRB)
PROJECT TITLE:	1881450-1Using IoT to Support Operations in the Construction Sector
QU-IRB REFERENCE #:	QU-IRB 1706-E/22
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	April 19, 2022
REVIEW CATEGORY:	Exemption category # 2

Thank you for your submission of New Project materials for this project. The Qatar University Institutional Review Board (QU-IRB) has determined this project is EXEMPT FROM IRB REVIEW according to Qatar Ministry of Public Health regulations. Please note that exempted proposals do not require renewals however, any changes/modifications to the original submitted protocol should be reported to the committee to seek approval prior to continuation.

We will retain a copy of this correspondence within our records.

Documents Reviewed:

- Application Form - IRB Application.pdf (UPLOADED: 02/26/2022)
- Application Form - application material checklist.pdf (UPLOADED: 02/26/2022)
- Consent Form - Consent.docx (UPLOADED: 04/13/2022)
- Consent Form - Consent-Hindi.docx (UPLOADED: 04/13/2022)
- Proposal - MBA-ProposalV2.docx (UPLOADED: 02/26/2022)
- Qatar University - IRB Application - Qatar University - IRB Application (UPLOADED: 03/29/2022)
- Questionnaire/Survey - IoT Workers survey V2 - Hindi.docx (UPLOADED: 03/29/2022)
- Questionnaire/Survey - IoT Workers survey V2.docx (UPLOADED: 03/29/2022)
- Questionnaire/Survey - IoT Managers Survey V2.docx (UPLOADED: 03/29/2022)
- Training/Certification - citiCompletion certificate (Prof).pdf (UPLOADED: 02/26/2022)
- Training/Certification - CTI Program Certificate.pdf (UPLOADED: 02/26/2022)
- Training/Certification - Completion Report.pdf (UPLOADED: 02/26/2022)

If you have any questions, please contact QU-IRB at 4403 5307 or qu-irb@qu.edu.qa. Please include your project title and reference number in all correspondence with this committee.

Best wishes,

Dr. Mohamed Emara
Chairperson, QU-IRB

Institutional Review Board
(IRB)
Office Of Academic Research

This letter has been issued in accordance with all applicable regulations, and a copy is retained within Qatar University's records.

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