FEASIBILITY STUDY OF INTERNET OF THINGS (IoT) IN CONSTRUCTION INDUSTRY

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DEDICATED TO,

MY LOVING FAMILY

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ABSTRACT

As the enhancement of Internet of Things (IoT) networks and its vast use by various industry, it is one fear may arise that construction industry may have left behind the other industry. That is why the construction industry should start the use of applications offered by IoT to ascertain the smoothness and fast progress of the construction process. At present, developing countries like India, needs fast development of infrastructure and construction projects, so the better solution is to use IoT applications to boost the speed of construction. This dissertation aims to check the feasibility of IoT in the construction industry and to find out the IoT applications which are utilized for fast and quality development of construction, through a designed questionnaire survey. After conducting a survey the nominal analysis is to be done for the ranking of the IoT applications used in the industry. The top 3 applications and 3 least used applications are considered for ranking in this thesis about the utilization of IoT applications in the construction industry, particularly for the area where the survey was conducted. As a result, AutoCAD and other softwares, Social media, E-mail and Net banking are the applications which occupy the highest usage and are ranked as top 3 applications in usage. The least used 3 applications are Robotics, Primavera and Sensors for waste management.

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NOMENCLATURE

AR	Augmented Reality
BIM	Building Information Modelling
BMS	Building Management System
DSS	Decision Support System
E-mail	Electronic Mail
FEM	Finite Element Method
GPRS	General Packet Radio Service
GPS	Global Positioning System
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
ICT	Information and Communication Technologies
IoT	Internet of Things
IP	Internet Protocol
ITS	Intelligent Transportation Systems
RFID	Radio Frequency Identification
SMS	Short Message Service
UIDs	Unique Identifiers
WSN	Wireless Sensor Network

CHAPTER: 1

INTRODUCTION

1.1. Definition

Internet of Things (IoT) is a human-designed technology conceptualized by intelligent virtual objects, which are capable of knowing all matter and permit the devices around themselves to interact automatically without human's control.

In simple words, IoT is a network of sensors, appliances and devices competent of sending and receiving data about changes to their current physical situation and environment nearby them over the internet.

The figure 1.1 provides the simplest understanding of the IoT, as this is superior to all type of interactions like machine to machine, machine to environment, human to human, human to machine, machine to human, machine to environment and also than a cyber-physical system.

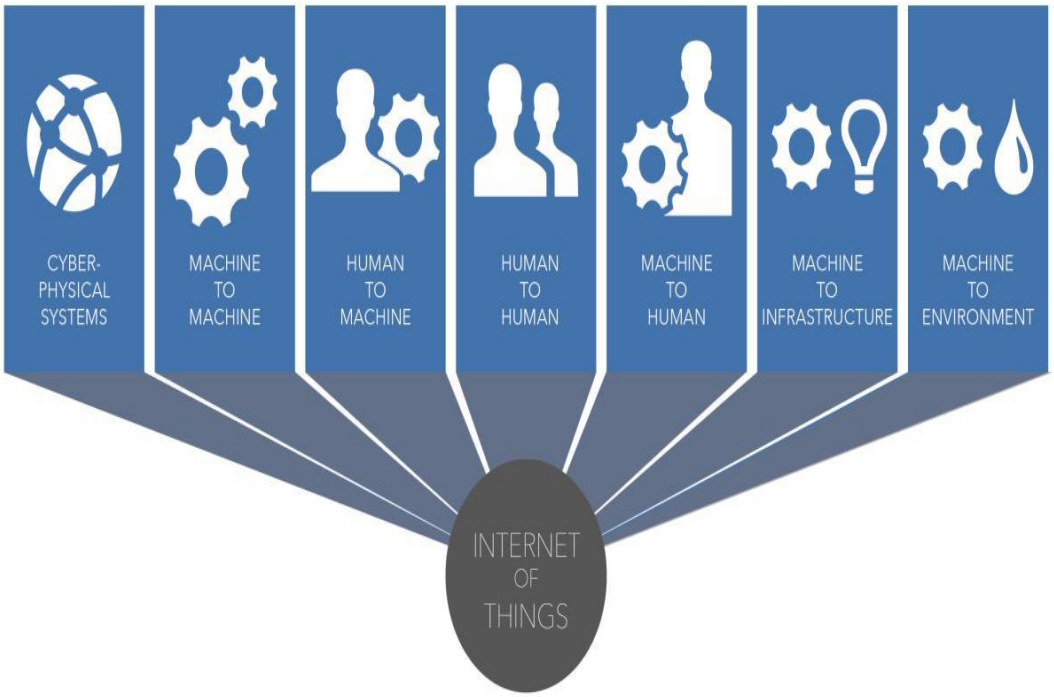

Figure 1.1: Internet of Things Environment

(Source: Internet of Things Applications, AIOTI WG01 – IERC, Release 1.0, 2015)

1.2. Evolution of Internet

The below discussed stages explains the evolution of internet:

1. **Pre-Internet:** There was face to face conversation, Short Message Service (SMS), Phone are used before the era of internet.
2. **Internet of Content:** After the internet introduced, it was used to send information between people via network. E.g. Electronic Mail (E-Mail).

3. **Internet of services:** Then after that internet was utilized as a service to make or transfer the money. E.g. E-commerce, E-business.
4. **Internet of people:** Internet is for the people and it is created by the people and so it is utilized by the people. E.g. Social media like facebook, Instagram, goggle plus etc.
5. **Internet of Things**: In IoT is interaction between machine and devices, so no human interaction is required. E.g. Automation, Identification, tracking, monitoring & control can be done by the machine with the help of Internet and Information Systems.

1.3. Background and Current Statistics

In 1990, John Romkey connected the first 'thing' to the internet, a Sunbeam Radiant Control toaster. This experiment is totally odd, which intended to prove that internet could be used to control an object physically, and that experiment was successful. He used the internet to make toast. This fun hack was the first instance of what would eventually become a global trend.

The term 'Internet of Things' did not appear until about nine years after internet toast experiment, but now it is become a one of the biggest used concept throughout the all industries. Now-a-days the entire world is covered with the internet as shown in figure 1.2.

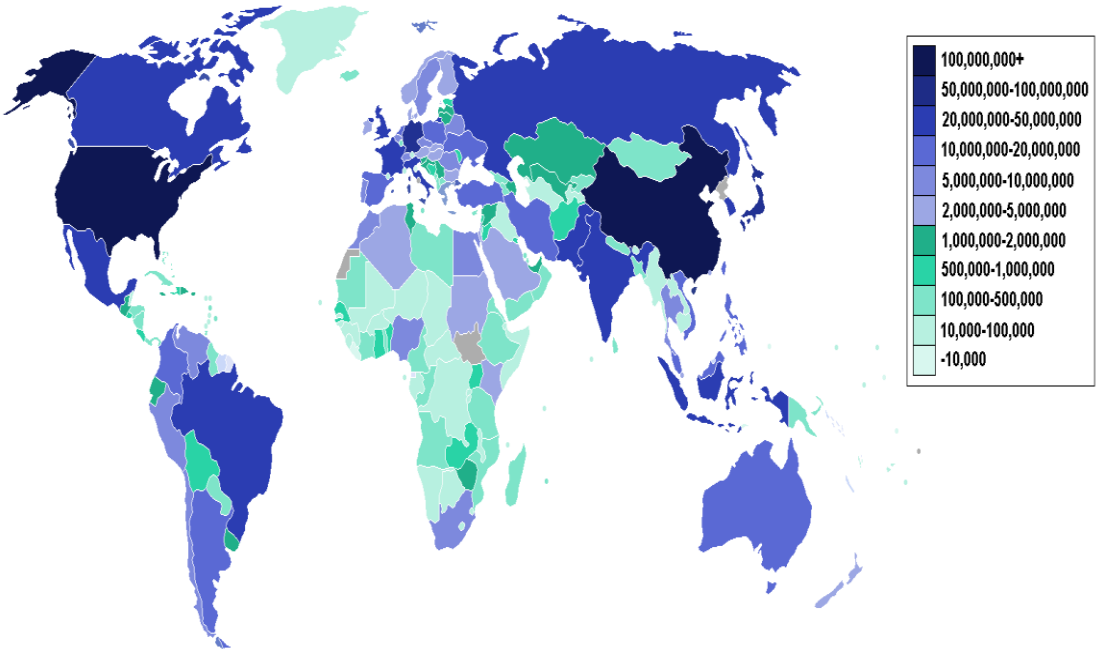

Figure 1.2: Numbers of internet users by country world map

That is why the scope of internet of things around the world is vast and it becomes more popular after 2008, the statistics data shows huge growth of connected devices in last decade given in figure 1.3.

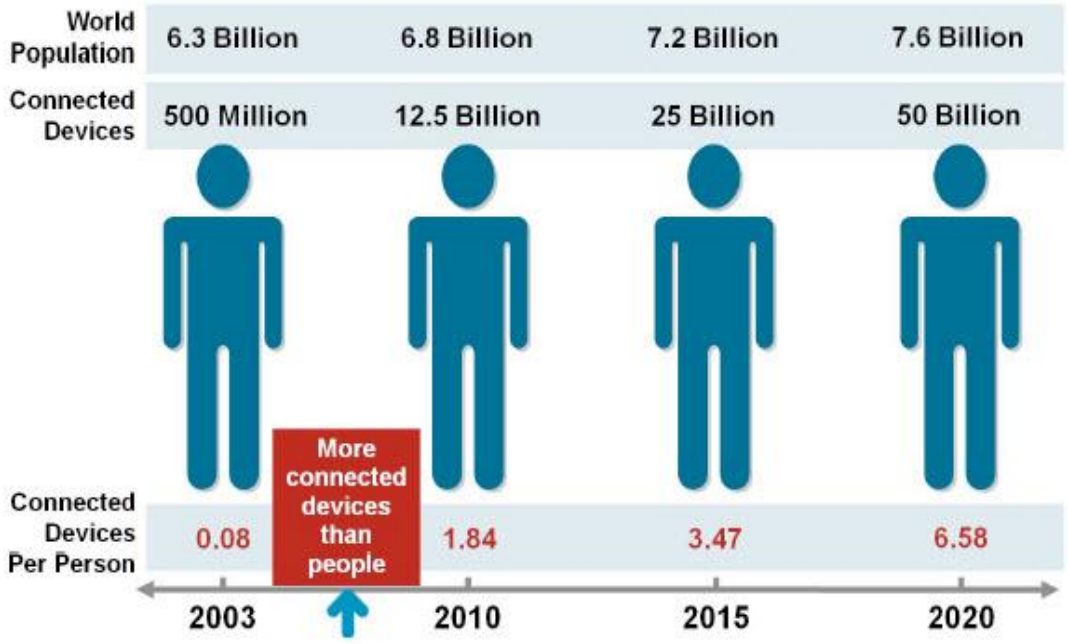

Figure 1.3: Number of connected devices around the world: Statistics

(Source: Cisco IBSG, April 2011)

1.4. Brief of Internet of Things (IoT)

The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. A "thing" in the internet of things can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned an Internet Protocol (IP) address and is able to transfer data over a network.

1.4.1. Working System of IoT

An IoT ecosystem includes embedded systems and internet connected smart device. Examples of embedded systems processors, sensors, or some kind of communication hardware. Which collect, send, and process as per requirement. Sometimes, these devices communicate with other related devices and act on the

information they get from one another. The devices do most of the work without human interaction, although people can interact with the devices - for example, to set them up, give them instructions or access the data.

The IoT helps people to live better and smart life. These offers several smart devices to automate houses as well as industries. IoT provides businesses with a real-time monitoring look into how their systems really work, delivering insights into everything from the performance of machines to supply chain and logistics operations. IoT enables companies cut down on waste and improves service delivery, making it less expensive to manufacture and deliver goods, as well as offering transparency into customer transactions.

The internet of things offers various benefits to organization. Some of the common benefits of IoT enable businesses to:

1. Monitor overall business tasks and processes;
2. Improve the customer experience;
3. Saving money and time;
4. Increase productivity of employees;
5. Integrate and adapt business models;
6. Make quality decisions for business; and
7. More revenue to be generated.

1.4.2.Advantages of IoT

Some of the advantages of IoT include the following:

1. Ability to access information from anywhere at any time on any device;
2. Improved communication between connected devices;
3. Saving of time and money as data packets are transferred over a connected network; and
4. Less human interaction and improved quality of business's services due to more automating tasks.

1.4.3.Disadvantages of IoT

Some disadvantages of IoT include the following:

1. As the information sharing is increased by the connected devices, the possibility of hacking or stealing confidential information may occure.
2. Organizations may have to deal with huge numbers of IoT devices, and collecting and managing the data from all those devices will be challenging.

3. If there's a bug in the system, it's likely that all connected device will become corrupted or affected.
4. Since there's no international standard of compatibility for IoT, it's hard for devices to communicate with each other from different manufacturers.

1.5. Need of Study

As the enhancement of Internet of Things (IoT) networks and its vast use by various industry, it is one fear may arise that construction industry may have left behind the other industry. That is why the construction industry should start the use of applications offered by IoT to ascertain the smoothness and fast progress of the construction process. At present, developing countries like India, needs fast development of infrastructure and construction, so the better solution is to use IoT applications to boost the speed of construction. So this paper aims to check the feasibility of IoT in the construction industry and to find out the IoT applications which may help for fast and quality development of construction.

1.6. Objectives of Study

Following are the main objectives of the study work:

1. To study the current practices of IoT applications in construction industry.
2. To analyse the impact of IoT applications in construction industry through survey.
3. To recommend strategies for using different IoT applications to various key players.

1.7 Scope of Study

Scope is limited to Vadodara and Anand city of Gujarat, India. For this study, types of project which are considered are residential and commercial.

1.8 Organization of the Thesis

This thesis consists of Five chapters as follows:

Chapter Two reviews the IoT applications used in construction industry through literature and summarize major findings from literature review.

Chapter Three discuss about the current practices of IoT in construction industry.

Chapter Four covers the research methodology.

Chapter Five presents the stakeholder details, sample size calculation, data collection method and result analysis

Chapter Six provides the conclusion based on analysis and recommended strategies along with future scope are also discussed.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

This chapter documents existing literature on the subject matter, IoT applications used in construction industry. Literature published in various national, international and other online and local journals; national, international and other conferences; various reports; master and Ph.D. dissertations; books; various standards published by various authorities; etc. have been studied and their small important contents have been stated here. Then, major findings have been stated describing the most important findings of this literature review described as in tabular form.

This chapter therefore provides an extensive background to enhance understanding of the subject by looking at it in context and in content as well as put the entire research in an appropriate theoretical context.

2.2 Critical Literature Review

Review of Literature is the core of review paper. In the last few years, analysts have noted that IoT is the hot topic for research. Also the researchers found that the IoT is very useful in many ways in construction industry at different stages of construction. The major benefit of the IoT application in construction industry is ease of working and it also boost construction speed with better quality output. Some of research works done in this field are as follows:

A. Medvedev et al. (2015) stated that efficient waste collection should be considered as a fundamental service for Smart Cities and that Intelligent Transportation Systems (ITS) enable new services within Smart Cities. They explained that Internet of Things(IoT) components like, RFIDs, sensors, cameras and actuators are very useful into ITS and surveillance systems for efficient waste collection. In the research they propose an advanced Decision Support System (DSS) for efficient waste collection in Smart Cities using IoT devices. They created a model for data sharing between truck drivers on real time in order to perform waste collection and dynamic route optimization and also the same system handled the ineffective waste collection problems in inaccessible areas within the Smart City. Surveillance cameras were used for capturing the problematic areas and provide evidence to the authorities of city. Researchers also mentioned that the waste collection system aims to provide high quality of service to the citizens of a Smart City. **[3]**

A. Praba et al. (2016) explained that IoT is mainly deals with Communication and Information Technology departments but it is also useful in many ways by its applications to Civil Engineering structures. Researchers stated that there is great need to perform Bridge monitoring using IoT into practical use and there is also a great need to devise Alternate Energy Conversion Systems, for self-sufficiency in electrical power generation for consumption. They found that movement of vehicles have great impacts on Bridges, and through a suitable system, one can transfer that impact energy into electrical energy. They researched two type of sensors that is piezo sensors and Piezo generators and also they suggested to use piezo generators with IoT to create a model to perform a work which they have already discussed in their paper. **[2]** The similar concept of durability and assessment is analyzed by **W. Taffese et al. (2019)** using IoT and intelligent data analysis for corrosion monitoring and durability assessment. **[18]**

J. Xu et al. (2018) aimed to develop a closed-loop lifecycle management system which can enable a consistent flow of information for use and reuse for all stakeholders. The framework integrates the state-of-the-art smart construction using construction automation and internet of things (IoT) technologies to help practitioners to access and manage the information via a standard interface among various applications throughout the entire lifecycle. Into a closed-loop lifecycle management system for IoT based smart construction, several digital technologies such as 3D laser scanner, drone, building information modelling (BIM), augmented reality (AR), Auto-ID, global positioning system (GPS), wireless sensor network (WSN), robotics, mobile digital devices, and web-based applications are used to collect data from different stages which is then stored, shared, processed, and utilized in one unified platform for all stakeholders to support better decision-making and interaction throughout a project lifecycle. This framework will support a smart construction from top to bottom throughout the entire project life cycle. **[10]**

V. Jeevana et al. (2018) used a concept of IoT to achieve process improvement by minimization of time. Researchers followed qualitative research and found that the major cause for delay was poor site management in construction industry. After the expert opinion and the data collection researchers reached to a conclusion that monitoring day to day activity is required to minimize the delay of insufficient site

management. So the sensors to capture information are set and the real time monitoring of the sensor are done so when the material needs or possibility of delay is identified then it is immediately connected to network and sent to the site manager. So the site manager can take action regarding the issue even though the site manager is not present at the construction site. Figure 2.1 describe the framework for poor site management using IoT. **[17]**

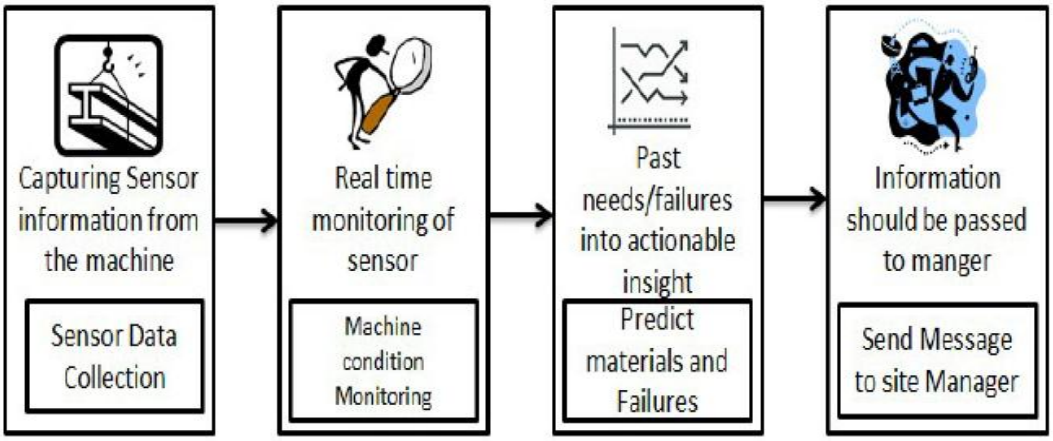

Figure 2.1: Framework using IoT for poor site management [17]

S. Mahmud et al. (2018) used the questionnaire method to identify the types of IoT applications used in construction industry of Malaysia. The questionnaire was analysed using nominal analysis. The study was conducted on construction industry players which comprising of government agencies, developers, architects, engineers, quantity surveyors and class G7 contractors covering all states in Malaysia. By this survey the concluded majorly used IoT based applications which were WhatsApp, Telegram, Facebook Messenger, email, GPRS and less used IoT based applications, which were sensor technology, Scan-Marker, Smart Watch etc. **[16]**

Bhavna et al. (2018) concluded that there are many devices that support IoT like Arduino, Raspberry PI [3], and other micro-electronic devices and IoT itself capable of using the Internet and wireless technology. So to produce a smart home automation system, IoT is to be connected with some components like, IR Sensors, LCD display, Power Supply, Capacitors, Wifi and the same concept is to be carried out by **M. Peruzzini et al. (2013) [12].** researcher established smart home information management and proposed energy efficient network usin information and communication technologies (ICT) tools and internet of things (IoT). **[4]**

A. Kumar et al. (2018) stated that the timely updates and delivery of construction material on a job site could have a significant impact on the overall duration, quality, and cost of the project. The study focused on analysing the role of Internet of things in providing a real-time update on the delivery and data for material handling in supply chain management, and review the role of IoT in the function of value addition into it. Researchers concluded that the use of IoT coupled with smart sensing devices could help in the communication and material tracking with high accuracy and free of noises such as human error, and other environmental factors. So it would help project manager in schedule updates and improve material efficiency. **[1]**

C. Cho et al. (2018) found out the solution for the collapsing scaffolding structure, researchers derived a smart prevention system using BIM, sensors, FEM analysis and IoT application to monitor and prevent the scaffolding structure collapse possibility. **[5]**

H. Reddy et al. (2019) as well as **J. Shah et al. (2016)** talked about the very critical point of construction industry that digital transformation is an ongoing challenge in the construction industry. they also mentioned that utilization of digital technologies is helpful to improve business process and IoT is one such robust system which helps to solve the above problem. So the researchers have investigated and concluded that the IoT sensors can used with various type of connection devices like Global Positioning System, Radio Frequency Identification, ZigBee Module, Wireless Sensor Network etc. and it allows objects to be sensed and controlled remotely across existing infrastructure. **[6] [8]**

Michael Urie stated that Currently, many existing building management systems (BMS) do not fully utilise the large amount of operating data being generated. IoT can help identify operational issues more easily as most building operators do not have the time to analyse historical trend data in order to identify these operational problems. Author mentioned that IoT technology has the scope to benefit projects on site during the construction phase as well as in completed buildings from a facilities management perspective. Also he listed some of the capabilities which are, Sensors Placed in Completed Buildings and Structures, Augmented Reality (AR), Power/Fuel Saving, Remote Usage and Activity Monitoring, Enables 'Just-In-Time' Provision, Tracks Tools and Equipment etc. **[13]**

L. Parra et al. (2019) decided to find out the combination of different systems aimed to monitor different aspects of the smart city such as e-health, air quality monitoring, gas, water and electricity monitoring, or emergency situations detection etc., which can be used to create a more sustainable and a securer smart city. Researchers have described the systems which will compose the future smart cities by combining different networks in charge of monitoring and controlling. Which are, IoT with WSN for e-Health and Human Well-Being Monitoring, Utilities Monitoring Systems, Emergency Situations Monitoring, Air Quality and Climate Monitoring Systems. Figure 2.2 displays Proposed architecture for smart city combining different systems. **[11]**

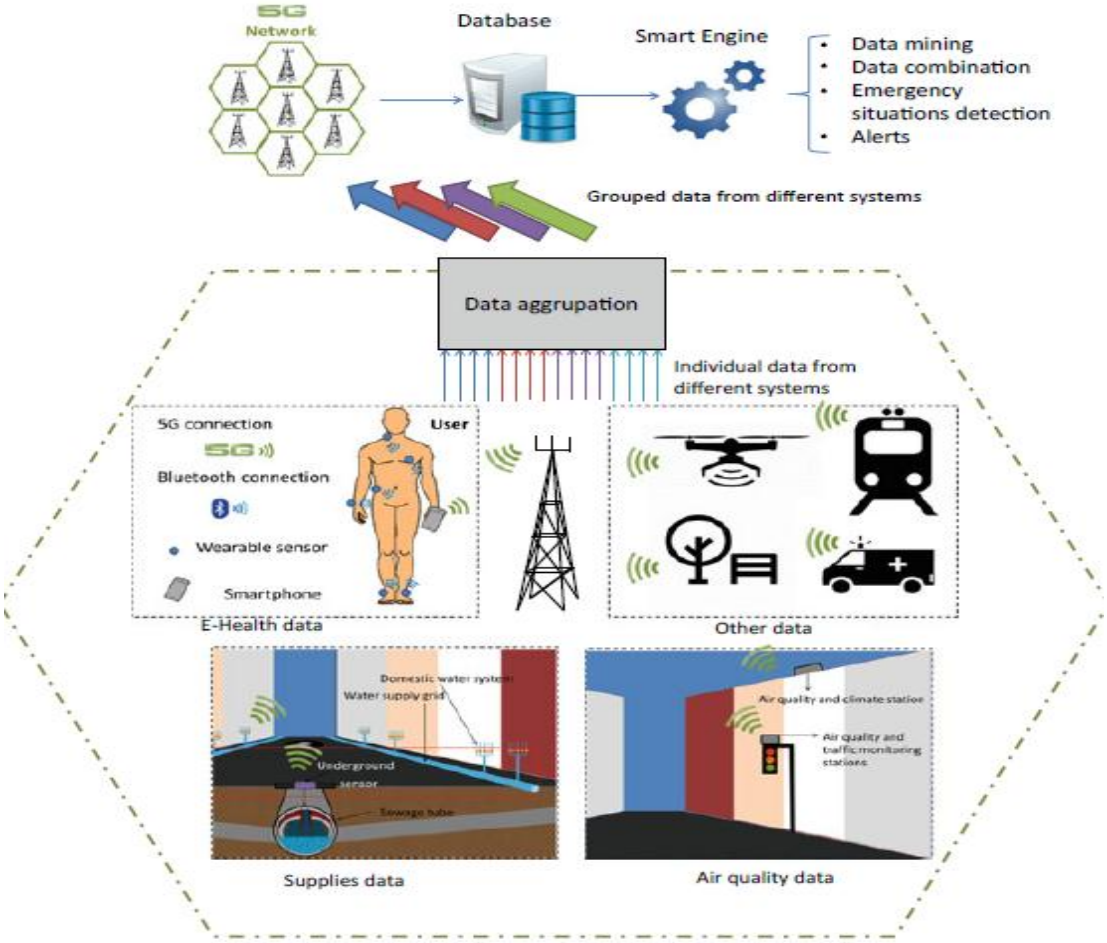

Figure 2.2: Proposed architecture for smart city combining different systems [11]

S. Okishiba et al. (2019) discussed about the use of excavator using tablet and Wi-Fi modules autonomously. Using wifi and microcontrollers an operator can use the tablet to operate the excavator as per required directions. **[15]**

2.3 Literature Summary

From the above literature review several type of IoT applications that can be used at different phases in construction industry, some of these are represented in the tabular form displayed below in table 2.1 and also the literature summary about the IoT used in construction industry as per several authors is displayed in the table 2.2 shown below,

Table 2.1: IoT applications used in different phases

Phase	IoT Appliances
a) Smart Communication	1. Social media 2. Websites 3. E tender 4. Scan marker 5. Wi-Fi
b) Remote Operation	1. Autonomous machinery 2. Drone 3. Robotics
c) Supply Replenishment	1. RFID 2. GPS tracking
d) Maintenance of Machinery	1. Sensors 2. Microcontrollers
e) Power, Fuel & Energy Savings	1. Lighting & electricity sensors 2. Fuel saving sensors 3. Microcontrollers
f) Augmented Reality (AR)	1. AR with Google Glass
g) Building Information Modeling (BIM)	1. BIM modelling 2. Sensors in building
h) Give an Efficient Way	1. GPRS 2. Google map 3. Mobile/Tablet
i) Security Control	1. RFID 2. CCTV 3. ERP

j) Managing Workers	1. ERP 2. CCTV 3. Drone
k) Worker Health	1. Smart watch 2. Drone 3. E-Health Monitoring
l) Environmental Monitoring	1. Sensors
m) Structure Health Monitoring	1. Sensors
n) Waste Management	1. Sensors 2. Micro controllers 3. Wi-Fi

Table 2.2: Literature summary of IoT in construction industry

IoT Application / Authors	RFID	Sensors	CCTV	Drone	BIM	AR	GPS	WSN	Robotics	Mobile/ Tablet/ PC	Scan Marker	Smart Watch	Wifi	CAD	Microcontroller
M. Peruzzini et al. (2013)		*	*					*		*			*		
Medvedev et al. (2015)	*	*	*												
A. Praba et al. (2016)		*													
J. Shah et al. (2016)		*						*					*		*
J. Xu et al. (2018)				*	*	*	*	*	*	*					
Jeevana et al. (2018)		*													
Mahmud et al. (2018)		*					*			*	*	*			

Bhavna et al. (2018)		*	*									*		
A. Kumar et al. (2018)		*					*							
C. Cho et al. (2018)	*	*			*								*	
Reddy et al. (2019)	*						*	*						
Michael Urie (2019)		*		*		*	*		*			*		
L. Parra et al. (2019)		*										*		
W. Taffese et al. (2019)		*						*						
S. Okishiba et al. (2019)										*			*	*

2.4 Major Findings from the Literature Review

The critical literature review based conclusions are as follows:

1. IoT is the latest technology which is capable to connect with several devises using internet. **[3][11][15]**
2. The development in this technology and the use of that in construction industry may very helpful in many ways. [**5][6][8][13]**
3. Using IoT applications find out the solutions of problems raised in construction at different stages and speed up the construction with better quality with less number of flaws. **[4][12][17]**
4. IoT is very helpful for construction industry as it can be used in pre-construction stage, construction stage as well as it is also used in post construction stage, so IoT is beneficial in construction for whole lifecycle of a project. **[2][10][18]**

CHAPTER: 3

IoT IN CONSTRUCTION INDUSTRY: CURRENT PRACTICE

3.1 Introduction

Internet of Things (IoT) is a human-designed technology conceptualized by intelligent virtual objects, which are capable of knowing all matter and permit the devices around themselves to interact automatically without human's control.

The sensors that have been put in everyday items such as mobile phones have now reached the construction industry. It has been used throughout the life cycle of project from pre-construction to post-construction phase. In construction industry IoT can be help in many ways as to boost the speed of construction, to improve the performance and quality of output, to manage the entire project with real time monitoring in efficient way. Not even during construction but IoT is also helping to develop smart, energy efficient buildings in context of automation, safety, security, energy saving and so many benefits. The discussion of current practices in utilization of IoT devices and applications in construction industry is forwarded.

3.2 IoT in Construction Industry: Current practice

IoT technology has the scope to benefit projects on site during the construction phase as well as in completed buildings from a facilities management perspective. There are several capabilities which are offered by the IoT applications which smoothens the speed of construction as well as it will be helpful in many more activities during different phases of construction. Some of the capabilities are summarized below:

1. **Enables 'Just-In-Time' Provision**

When it comes to material management, units of supply can be labelled with RFID tags, a system can count that units and can give real time data to the management personal. It improves the management approach of inventory management for the project, and it triggers to reduce the idle time and projects will have better chance of being completed on expected on time. Also RFID tagged machines and RFID tagged helmet holder labors can be tracked and just-in-time management can be made using this technology effectively. Figure 3.1 shows the example of RFID tagged material and manpower can be tracked at any time with real time monitoring. By using this monitoring, expert can manage the resources between the simultaneously working sites. IoT applications will significantly improve the resource management during construction phase.

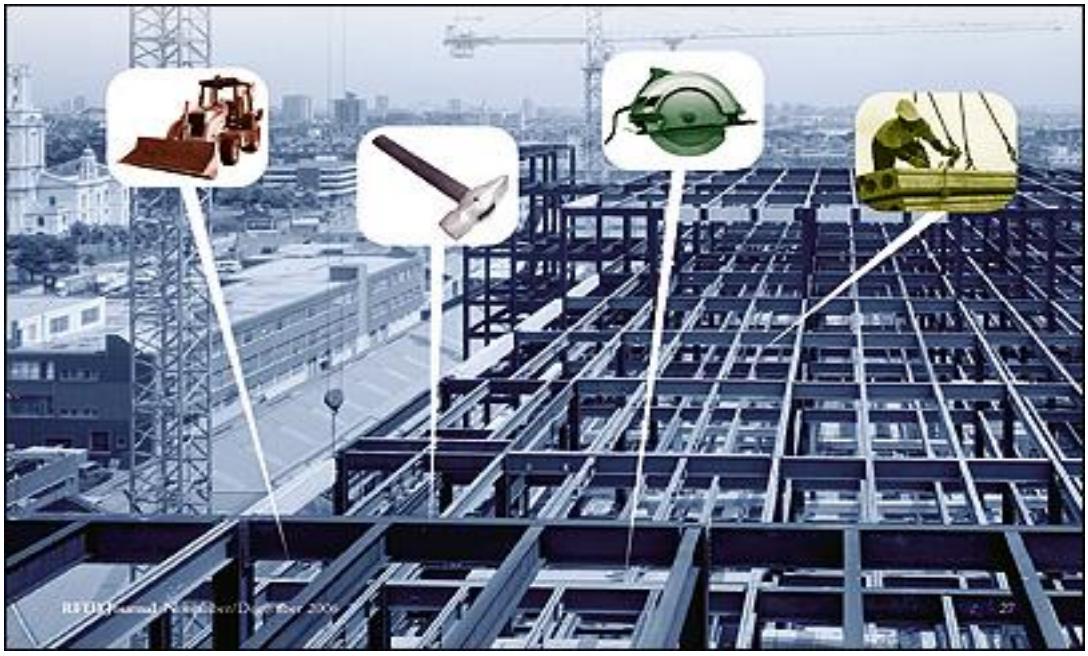

Figure 3.1: Tracking of RFID tagged resources

2. Smart Communication

For communication now-a-days, social media is increasingly popular tool. It includes some apps like Facebook messenger, WhatsApp, Telegram and so many other applications. This social media need only internet connectivity to use it as a communicating tool. E-Mail is also an effective way to communicate in a corporate world. Websites are also one example of smart communication, because the entire portfolio of your firm can be displayed to the customer or people through the websites. Figure 3.2 shows apps which are used for smart communication. Scan marker is a good example of smart communication today because, this is a digital pen which is capable of scanning any printed text and transmitting the text into any device like computer, tablets and smartphones via Bluetooth connections. This device is able to save typing time, translating around 40 languages and text scans capable of producing sound.

Figure 3.2: Tools and Apps used for Smart communication

3. Remote Usage and Activity Monitoring

IoT technology can help to provide autonomous machinery to use in hazardous places or remote places where there is a risk of worker's health as well as their safety. For Activity monitoring, drones and CCTV surveillance are best example. It provides timely updates on the site as well as the performance and productivity can also be measured and analyzed. Figure 3.3 displays how drone can be useful for site monitoring.

Figure 3.3: Drones for Site Monitoring

4. Supply Replenishment

Construction requires an adequate supply of materials to ensure the smoothness of the project. However, the late supply of materials cases often occurs at the site due to time-consuming of the delivery process. Through the Internet of Things approach, when the supply unit is labeled with a Radio Frequency Identification (RFID) tag, the system on the site can automatically count the quantity. When the count falls below a certain level, the system will provide information to the central system to place more orders. In addition, the RFID tags placed on the goods allow them to be easily accessible, knowing the suitability of the temperature of the item, handling carefully and informing if the item has damage, expiration and stocks are decreasing.

5. Maintenance of Machinery and Equipment

Heavy Construction machinery can be equipped with sensors connecting to the IoT applications. These sensors can send information to a system for any maintenance or repair requirement. Power and Fuel sensors provides the update about power consumption and fuel usage data as well send the early warning if there is need of fuel.

6. Power, Fuel and Energy Savings

Unmanaged power and fuel consumption will result in wastage that will impact the cost of the project. Through the Internet of Things approach, the site can send information about the amount of electricity used and the lighting usage after an office hour can be adjusted for energy saving. Additionally, machines and machinery can be controlled to turn them off automatically if they do not move in seconds for fuel-saving purposes. Automatics lamps with connected systems and sensors are in use at site as well as in smart buildings and cities also. Here one example of automatic lamps with sensors connectivity is shown in Figure 3.4. These type of lamps are connected with motion sensors with it.

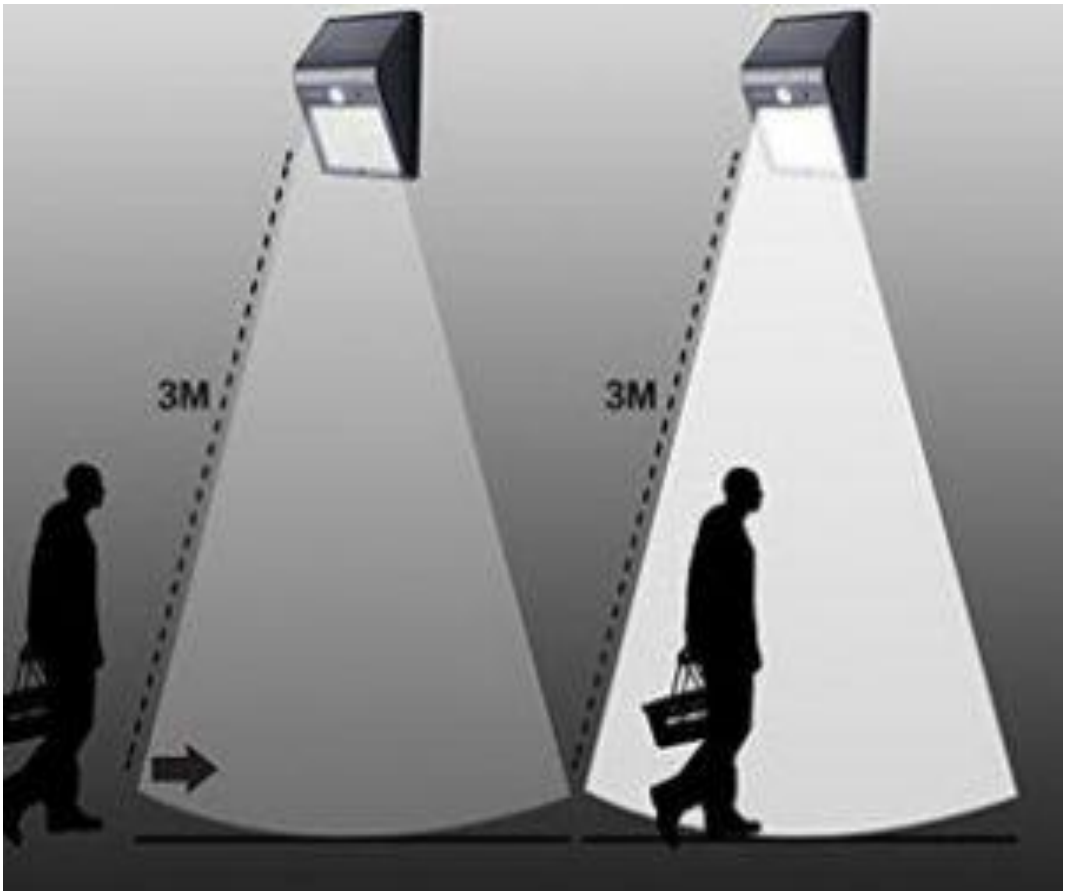

Figure 3.4: Automatic lamps connected with sensors

7. Augmented Reality (AR)

Google Glass has offered AR for a variety of usage. AR combined with the Internet of Things network to transmit information and make it visible on Google Glass. This allows employees to receive noticeable instructions on Google Glass about what to do, danger alerts, current work productivity and more. It also helps to a presenter to show and explain to the client or engineers to show what actually will be constructed. The pictures shown below are example of Augmented Reality in different ways. Figure 3.5 Shows the hologram Augmented 3D model is there and can be presented and understandable easily. While Figure 3.6 explain one example of Augmented reality. In this example the plan of the structure is there and it's digital QR code can be scanned to see the Augmented structure developed automatically which is easy to see what will be built actually there.

Figure 3.5: Augmented Reality with Google Glass/VR box

Figure 3.6: Augmented Reality using QR code

8. Building Information Modeling (BIM)

BIM is a computer model used to monitor the construction of its lifespan, and it can be achieved by placing sensors in the building that has been built. This sensor can then transmit state information on materials influenced by climate change and time circulation, providing information on possible changes in energy efficiency and structural conditions when there is an earthquake. Also the data from the Internet of Things can also be used as an information used for energy consumption patterns, temperature changes and human movement in buildings.

9. Give an Efficient Way

Inefficient transport routes may lead to extra fuel consumption and also the delay in delivery of material which is ultimately ended with project delay. Through the IoT, sensors are acting as General Packet Radio Service (GPRS) which will suggest the driver with most efficient route. Google map is also one application which provides a driver a short travel routes. Figure 3.7 shows the use of Goggle map to find out efficient shortest path for travel.

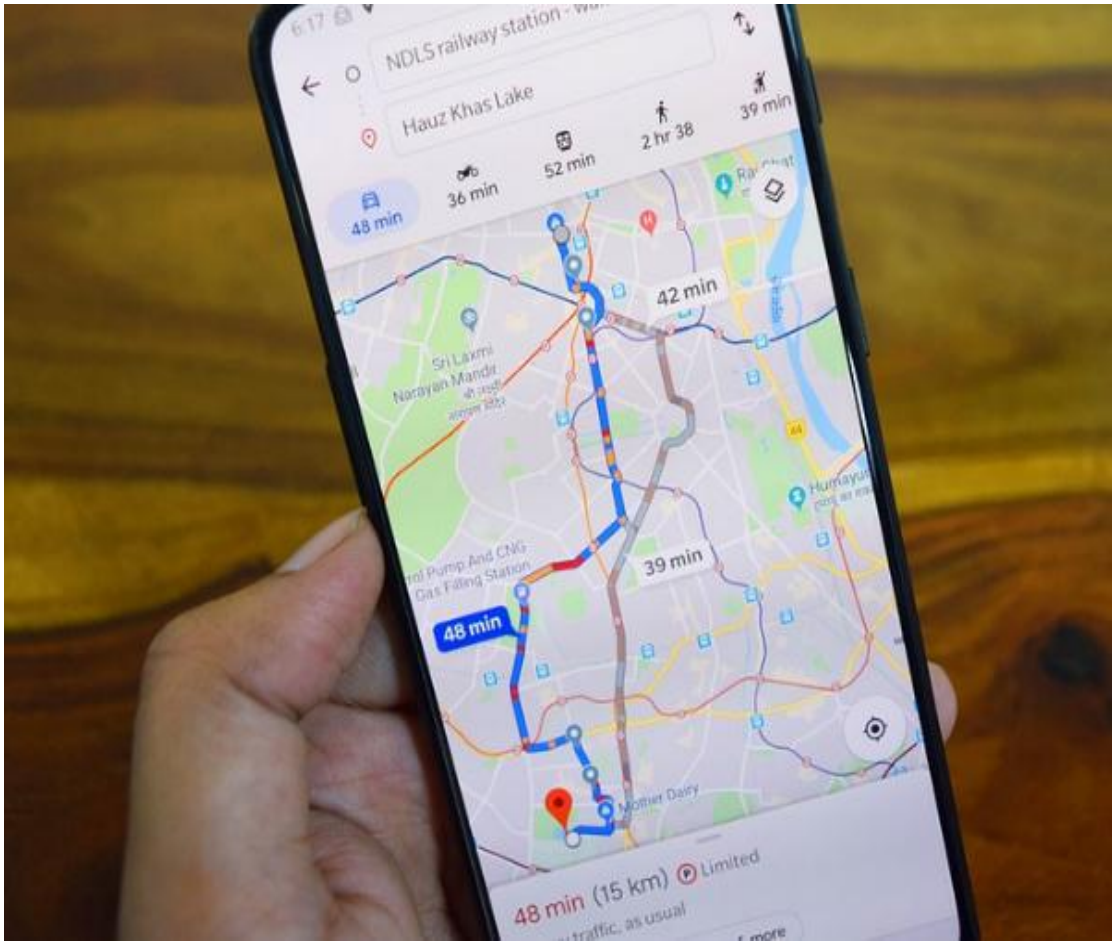

Figure 3.7: Google maps

10. Security Control

Generally main threat for construction site is theft of materials. Using of RFID tag will help to check the current location of any material or item. Also Smart lock system connected with systems and network will provide safety and security. CCTV camera attached with system as well as the owner's mobile will give live monitoring of site at any time and from anywhere.

11. Managing Workers

IoT will help effective to manage workers and also can help to determine the worker's productivity with real time monitoring. Sensor connected Id card or Badges given to the worker provide quite good information about the workers to the manager. From that manager can track them and also schedule the man power resource as per site's requirement. Worker's and employees' daily attendance connected to the server will help to make their salary payments, their efficiency etc. Entire project database connected with server through the network and system can be accessed by any responsible authority will surely reduce the time to finding required information in hardcopy documents, and the database connected to server is always been updated if any changes are there in any documents.

12. Worker Health

Working with heavy machinery and equipment for long time may cause workers to experience fatigue, which affects the productivity of the workers.

Figure 3.8: IoT wearables at construction site

A wearables connected to internet are capable of checking pulse rate, blood pressure, tracking. These wearables will provide worker's actual health conditions and manager can manage them accordingly. Figure 3.8 shows several types of IoT wearables such as smart helmet, smart glasses, smart wearables.

13. Environmental Monitoring

Some devices equipped with sensors and network are capable to monitor fire, flood threat and air quality. These devices sense these type of threats and the information is sent to the server and the remedial measure are taken accordingly.

14. Building Structure Health Monitoring

Internet of Things is used as a building health monitor where the sensor is known as the Linear Displacement Sensor placed on structures capable of detecting vibrations, cracks and conditions of building materials and civil structures such as historic bridges and monuments. Some sensors are also placed in new structures also to determine the displacement in beams and columns due to shock, vibrations or any other cause.

15. Waste Management

Through an Internet of Things approach, a smart waste management system implementation has been implemented using IR sensors, microcontrollers and Wi-Fi modules. This system guarantees the immediate cleaning of the trash when the trash reaches maximum levels. If the trash cannot be cleaned within a certain time, the record is sent to the authorities and appropriate action taken against the relevant contractor.

16. Smart Buildings and Smart Infrastructures

Now-a-days buildings and infrastructures are designed with many IoT devices connected for security and safety purpose. There are also many other facilities provided by the IoT applications. The entire information is sent to the server of building system and the required actions will be taken by the system automatically. Figure 3.9 shows the diagram of IoT enabled smart building. These applications provide many facilities that make the building energy efficient, environment friendly, secure, safe, automatic and smart.

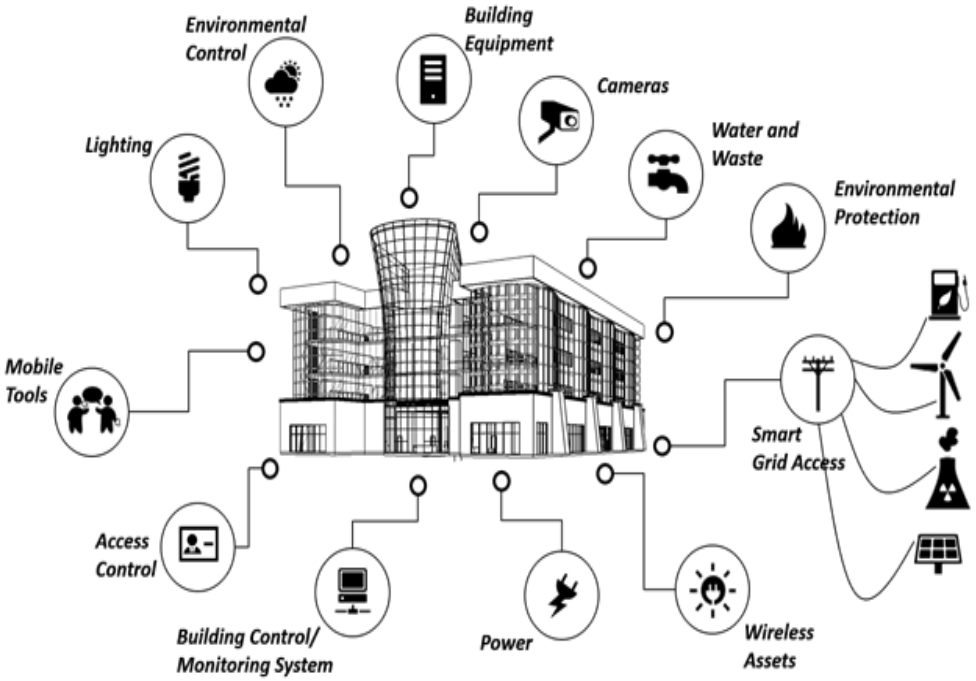

Figure 3.9: IoT enabled Smart building

CHAPTER: 4

RESEARCH METHODOLOGY

4.1 Research approach

The study aims to check the feasibility of IoT applications used by construction industry and rank their use in industry by nominal analysis after gathering data through survey. Different literatures related to this research are reviewed, and in order to see building construction practices, the following research methodology is implemented. Therefore, the actual data is collected and analyzed to find the actual practices in relation to IoT application used in construction projects at various phases and for different activities.

There are several methods of collecting data. Importance ones are: observation method, interview method, through questionnaires, through schedules. In this research, we collect data through questionnaires. This method of data collection is quite popular, particular in case of big inquiries. In this method a questionnaire is sent to persons concern with a request to answer the question and return the questionnaires. A questionnaire consists of a number of questions printed or typed in a definite order on a form or set of forms.

For this study, data was collected using both primary and secondary sources. The primary data was obtained through questionnaire directed to contractors that are involved in building projects. The secondary data was obtained from previously done different researches, internet, journals and books. The secondary data was used as a source for problem identification and was used as criteria for developing and analyzing the primary data. Questionnaire is chosen as a research instrument to gather data.

Figure 4.1 describes the methodology flow diagram for the research. First of all, the problem identification and the scope and need are decided. Then the literature review is being conducted through the national/international papers, conference, books, thesis and many more resources. Then the questionnaire survey form is designed as per guidance of guide faculty as well as the industry experts. Then the data collection is being done via survey. After collecting data from the stakeholders, the data analysis is being done. The method for analysis is nominal analysis. After the analysis, the ranking of IoT applications utilized in construction industry is being done. The below figure describes the entire methodology in a simple way.

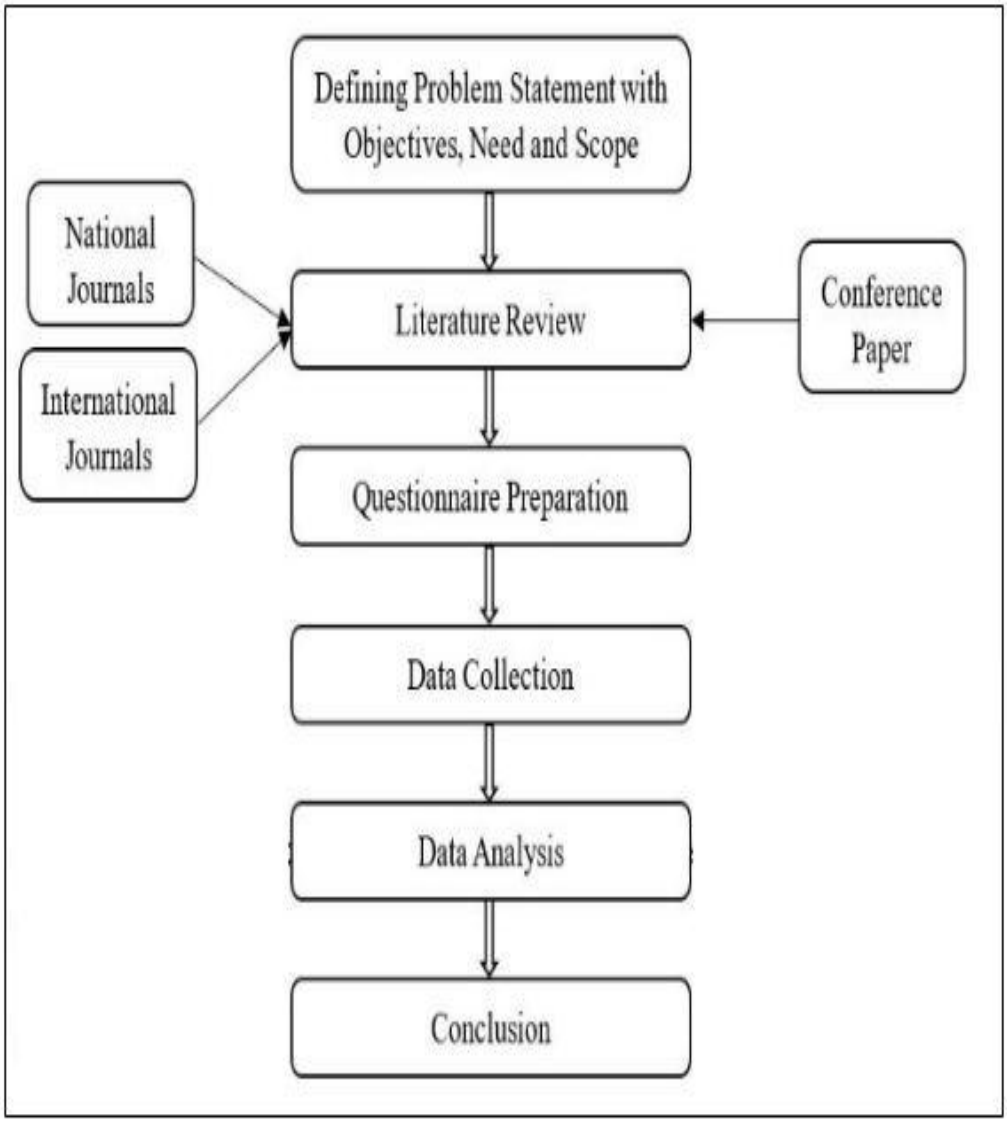

Figure 4.1: Methodology flow diagram

4.2 Survey Questionnaires

The research instrument used in this research is questionnaire which was designed in such a way that it ensures to address the objectives of the study categorized by different parts. The first part of the questionnaire is targeted to gather information about the respondents and firms profile; questions in this part were created to collect information such as job position, work experience and projects contact information. The second part of the questionnaire aims to have data about the awareness and understanding of contractors on productivity in the construction projects. The third part contains the various phases or activities in which IoT applications can be used in the construction during different stages of construction project. The questions are to be asked in the form of Yes or No form about the use of IoT applications.

The questionnaire was design based on the fact that they had to be simple, clear and understandable for the respondents and at the same time they should be able to be interpreted well by the researcher.

4.3 Research Population and Sampling

IoT applications can be utilized in both the stage, during construction and after construction, even in both residential and commercial projects as well. So the stakeholders like, contractors, architects, project managers, engineers etc. are to be covered for the survey.

Therefore, the study populations included for this research work are construction firms developing commercial as well as residential project into the Anand and Vadodara city of Gujarat State in India. Figure 4.2 shows the physical location of Vadodara and Anand city on India map.

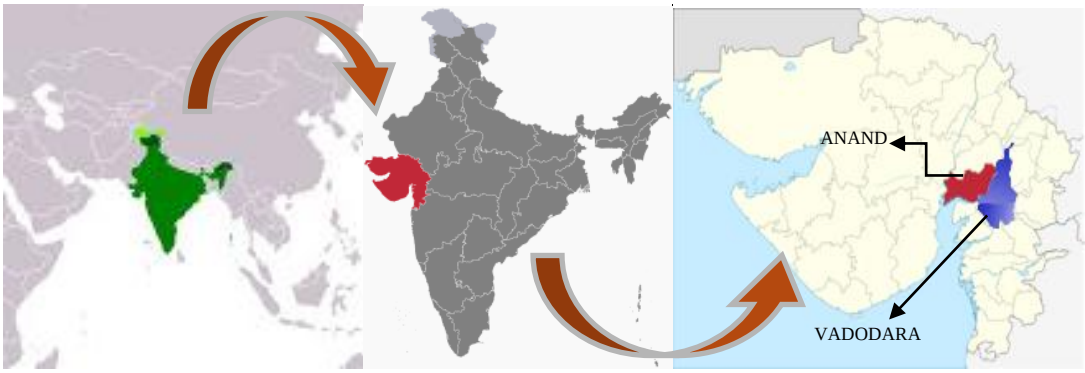

Figure 4.2: Physical Location of Vadodara and Anand on India map

4.4 Data Analysis Method

The analyses of the data obtained from questionnaires have processed which involves simple statistical approach, examining, tabulating and categorizing based on the chosen measurement scale. Most of the findings were presented in the form of tables, pie charts and bar graphs to clearly illustrate the result and to help to easily understand.

In this research, questions are designed in the form of yes or no answering. This type of collected data can be analyzed by nominal analysis.

Nominal data can be analyzed using the grouping method. The variables can be grouped together into categories, and for each category, the frequency or percentage can be calculated. The data can also be presented visually such as by using a pie chart.

The below figure shows the example of nominal data analysis.

Figure 4.3: Example of nominal data analysis

4.5 Pilot Survey and Questionnaire Revision

To improve the questionnaire section, a pilot study was accompanied. This section contained identification of different causes, collection, and conclusions of data. The application of this section benefited in better formation of questionnaire.

Mahesh Madan Gundecha (2012) conducted pilot survey and collect information. The recommendations provided from pilot survey are discussed below:

1. Questionnaire should always start with the general information of the organization
2. Some factors are not related to construction. They should be removed or modified.
3. To get more suitable and consistence meaning some factors should be rearranged.
4. Some factors should be revised with additional information.

5. Factors repeated with similar meaning should be removed.
6. Some factors should be changed to give clearer importance and understanding.

Better and accurate questionnaire related to the topic was achieved from the pilot study.

CHAPTER: 5

DATA COLLECTION

AND

ANALYSIS

5.1 Stakeholder Details

Three types of stakeholders are targeted:

1. Engineers/Supervisors
2. Project managers
3. Contractors/Builders

The cities in which survey is to be carried out are

1. Anand
2. Vadodara

5.1.1 Sample Size Calculation

To obtain statistically representative sample size of the population, following equation used:

$$n = \frac{m}{1+[\frac{m-1}{N}]} \quad \ldots(5.1)$$

Where, n, m and N represents the sample size of limited, unlimited and available population respectively. Here, m is calculated by following equation.

$$m = \frac{z^2 * p * (1-p)}{e^2} \quad \ldots(5.2)$$

where,

z = the statistic value for the confidence level used, i.e. 1.96 and 1.645 for 95% and 90% confidence level respectively;

p = the value of the population that estimated and

e = the sampling error to estimated. Because the value of p is unknown. value 0.5 used in sample size.

Population distribution among the area is as shown in Table 5.1 as follows,

Table 5.1: Population Distribution Among the Area of Study

City	Construction Firms	Source
Anand (a)	98	Road and Building Department, Gujarat
Vadodara (b)	152	Yellow Pages
Total (a+b)	250	

According to the targeted City and Stakeholders, the total no. of available population comprises of 250 construction firms which belongs to Gujarat Contractors Association and lists of registered construction firms of various government departments in construction for targeted cities.

Thus,

$$m = \frac{1.645^2 * 0.5 * (1 - 0.5)}{0.1^2}$$

$$m = 67.65$$

Here, the confidence level is taken as 90%. Now,

$$n = \frac{67.65}{1 + [\frac{67.65 - 1}{250}]}$$

$$n = 53.41$$

$$n \approx 54$$

Thus, contact with minimum 54 respondents of construction firms must be made for this study. To overcome the risk of not responding from the respondents and to reflect higher reliability and benefits for the study, the sample of 60 respondents are considered and if possible, more than these respondents shall be contacted.

5.2 Questionnaire Distribution and Collection

The questionnaire will be distributed to various stakeholders by informing them regarding the purpose of the research and asking them about their willingness to participate in the research. Once the initial willingness was shown by the respondents, a questionnaire will be given to them.

The questionnaires were distributed in hardcopy in form of Survey Form as well as soft copy in form of Google Form to different respondents in Anand and Vadodara. Around 82 respondents provided their response for this research work working throughout the different districts in Gujarat. Out of that respondents only 64 responses are to be considered for the research work, because the scope of work is limited to Anand and Vadodara City. A list of the 64 stakeholders who submit their response has

been presented in Appendix B. Table 5.2 represents the distribution of responses throughout the area of the study.

Table 5.2: Distribution of Responder

Stakeholders	City		Total
	Anand	Vadodara	
Engineers/Supervisor	13	21	34
Poject Manager	2	5	7
Contractor/Builder	9	14	23
Total	24	40	64

Figure 5.1 shows the comparison of responders between the Anand and Vadodara city. As shown in figure 62% of the respondents out of total responses are from Vadodara city and remaining 38% responses are taken from Anand city.

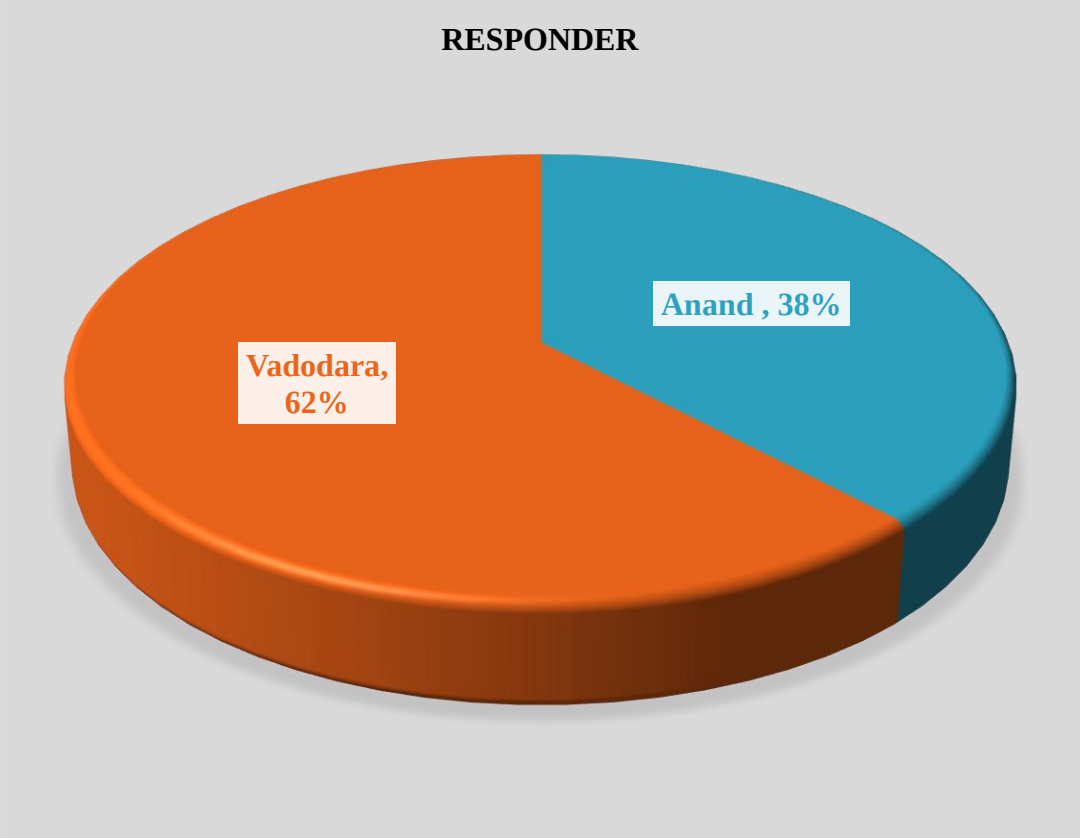

Figure 5.1: Percentage of Response Received in Anand and Vadodara

Figure 5.2 displays the comparison of stakeholders in percentage as shown in pie chart. And the city wise responses from the stakeholder analysis is given in the Figure 5.3 as graphical analysis.

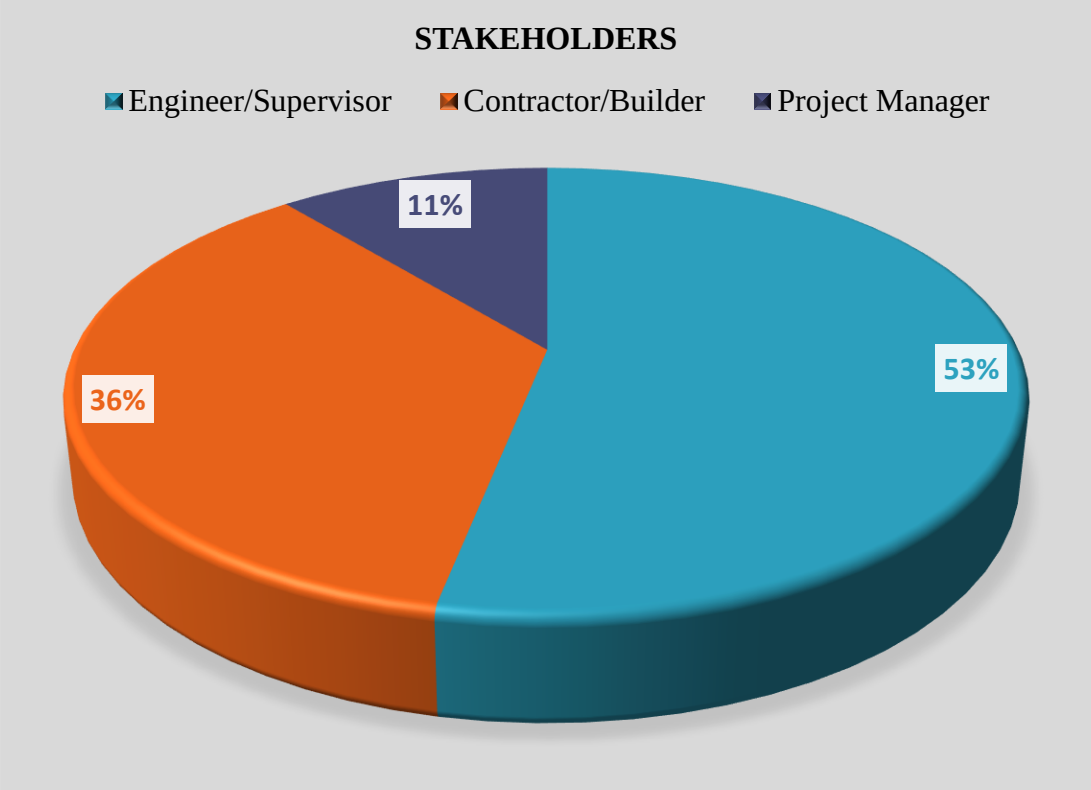

Figure 5.2: Percentage of Response Received Stakeholder Wise

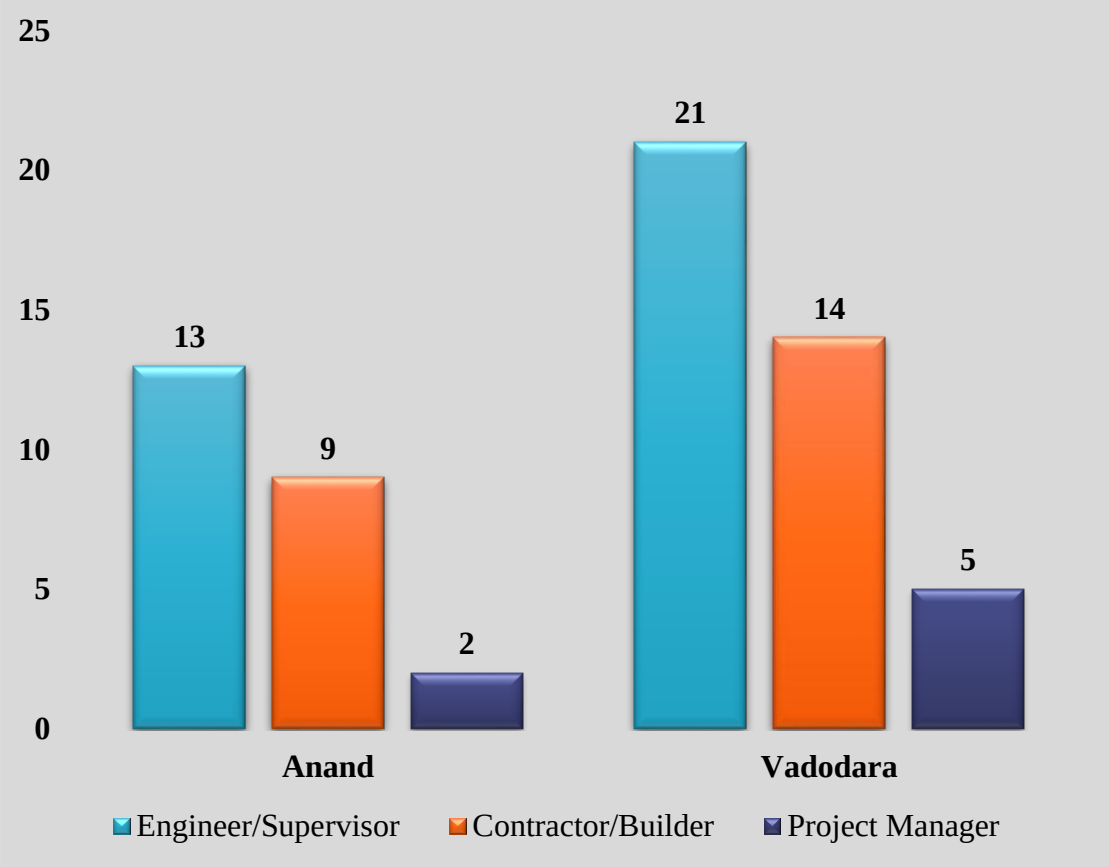

Figure 5.3: City Wise Distribution of Responders

5.3 Data Analysis

All the data of survey form gathered from responders is entered in excel for the analysis. After doing nominal analysis, the IoT applications' usage is shown in percentage value as shown in pie charts. There are different phases/activities, where IoT applications used are as shown in following figures. Figure 5.4 shows the IoT applications use for smart communication like Social Media, Website, E-mail and Scan marker. The usage of these applications is shown in pie chart.

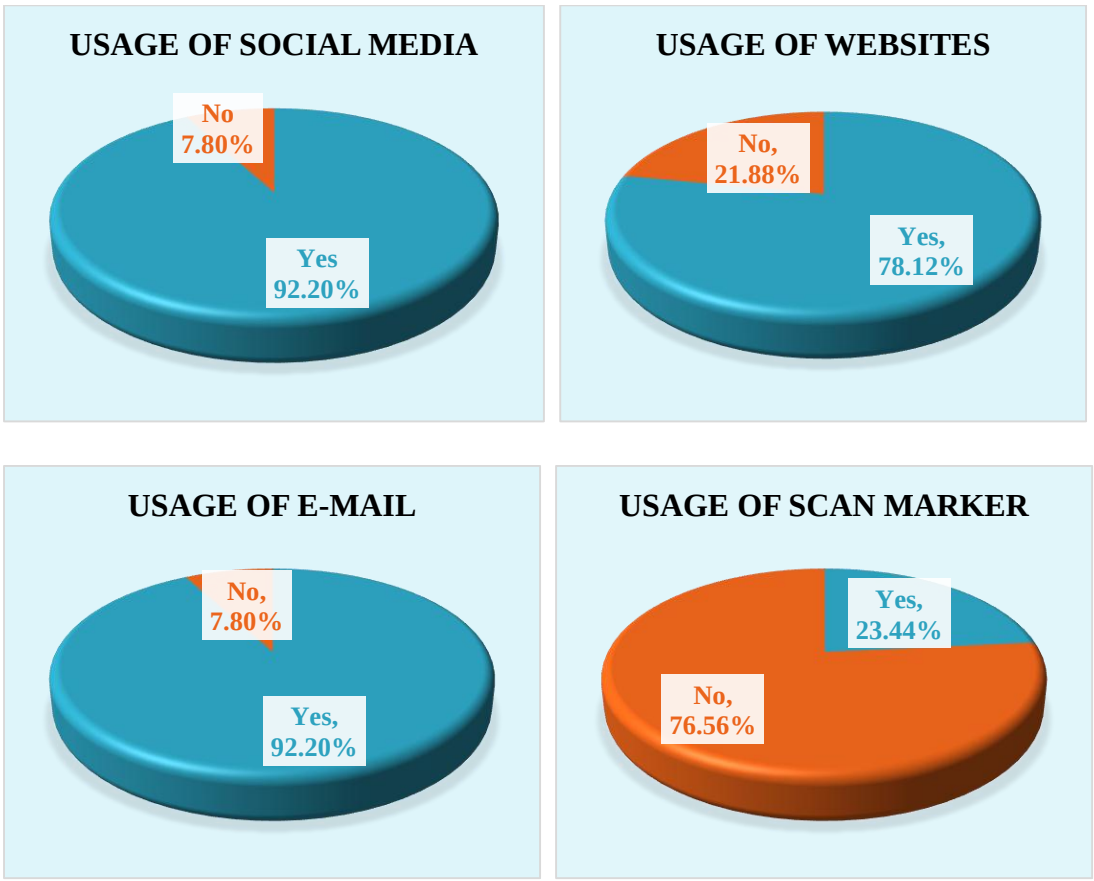

Figure 5.4: Usage of applications for Smart Communication

Figure 5.5 displays the usage of applications for meeting with client/engineers, which are AR, projector, database, BIM, AutoCAD and other software, MS project and primavera. Figure 5.6 elaborates the utilization of different applications like online ordering, online price quote, online tracking, use of GPS, google maps and use of RFID for Material order and supply activities. As per Figure 5.7 ERP system and Daily report sheet connected to system are the applications used for Attendance.

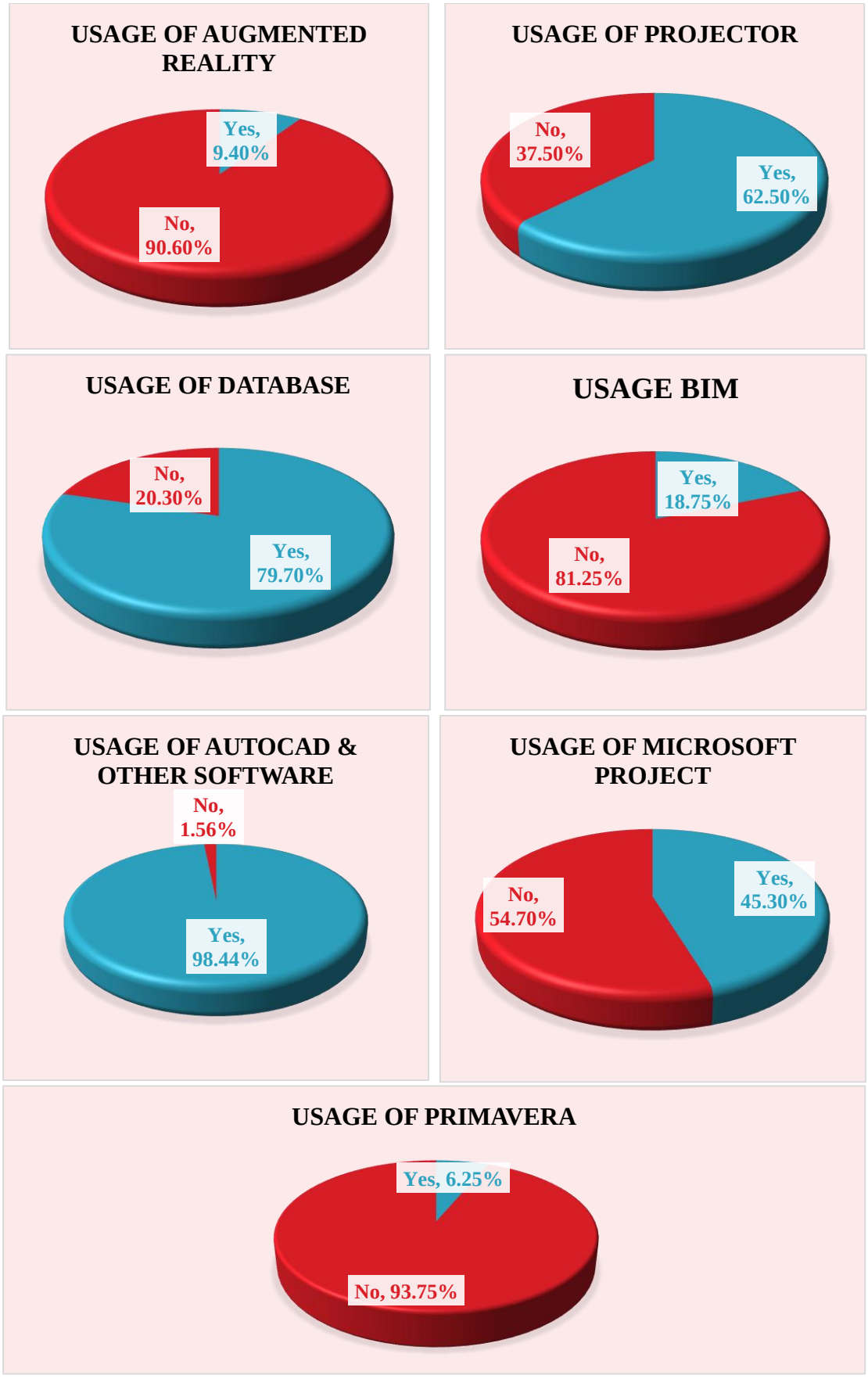

Figure 5.5: Usage of applications for Meeting with Client/Engineers

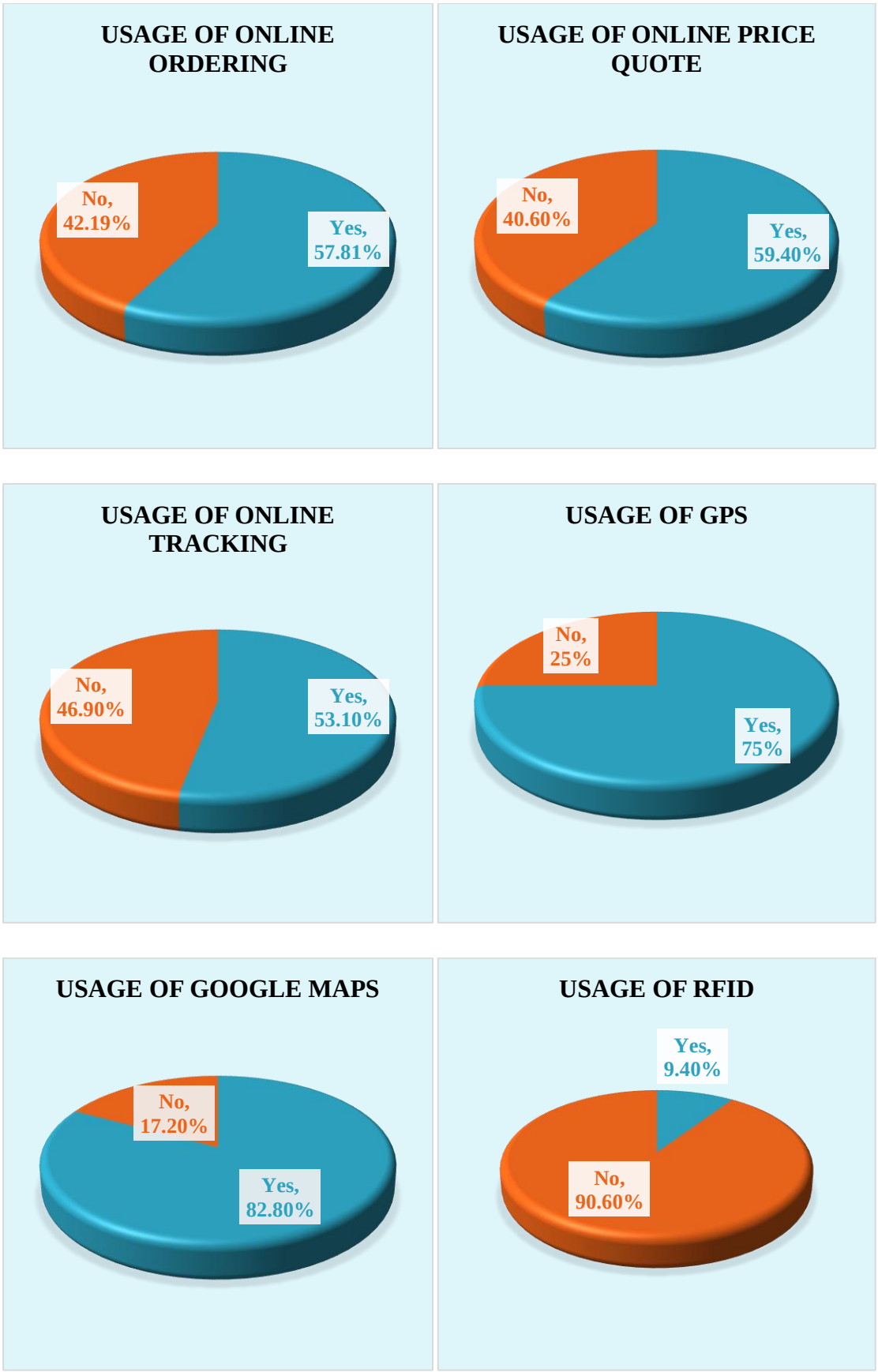

Figure 5.6: Usage of applications for Material Order & Supply

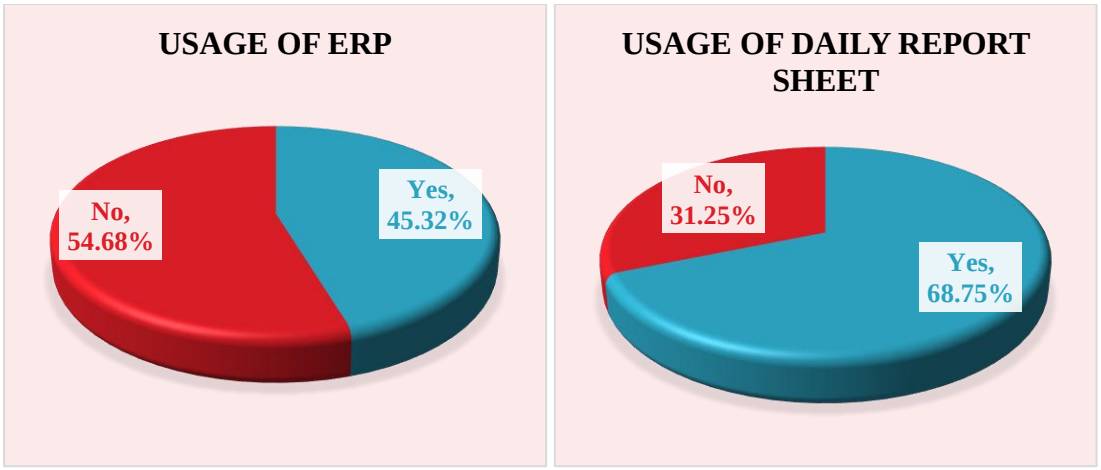

Figure 5.7: Usage of applications for Attendance of Employees

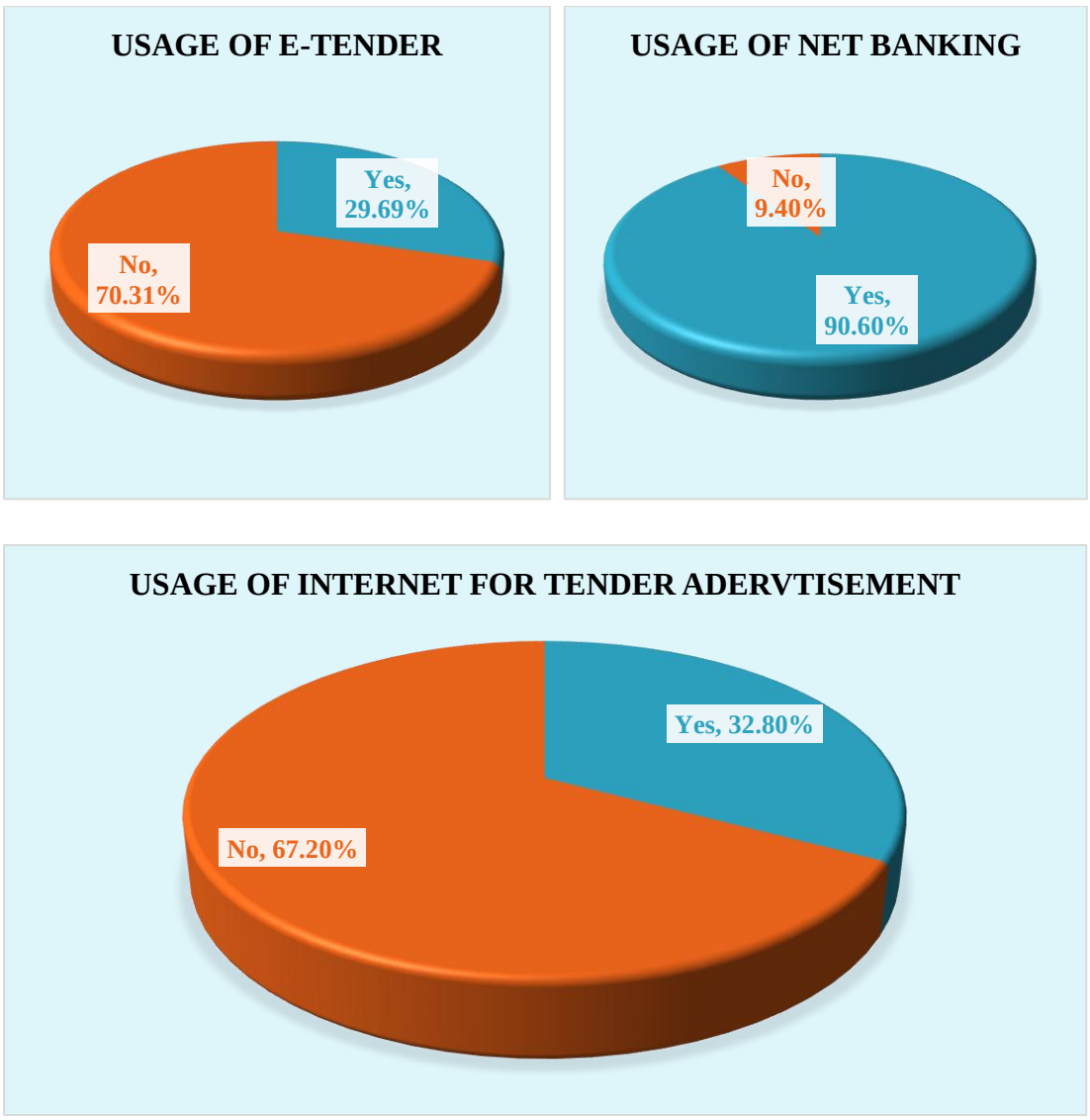

Figure 5.8: Usage of applications for Contract & Financial Management

Figure 5.8 includes applications which are used for contract and financial management, like E-tender, Net banking, Using Internet for tender advertisement. Figure 5.9 shows the usage of applications used for site supervision as well as worker health monitoring, such as use of Drone, CCTV, Smartwatch and Air quality monitoring sensors. Some applications are used for remote usage and hazardous operations, which are Robotics, Autonomous machinery and Drone. These applications are described in figure 5.10. Generally, these applications are very less used applications in Indian construction industry and mainly at where the survey was conducted.

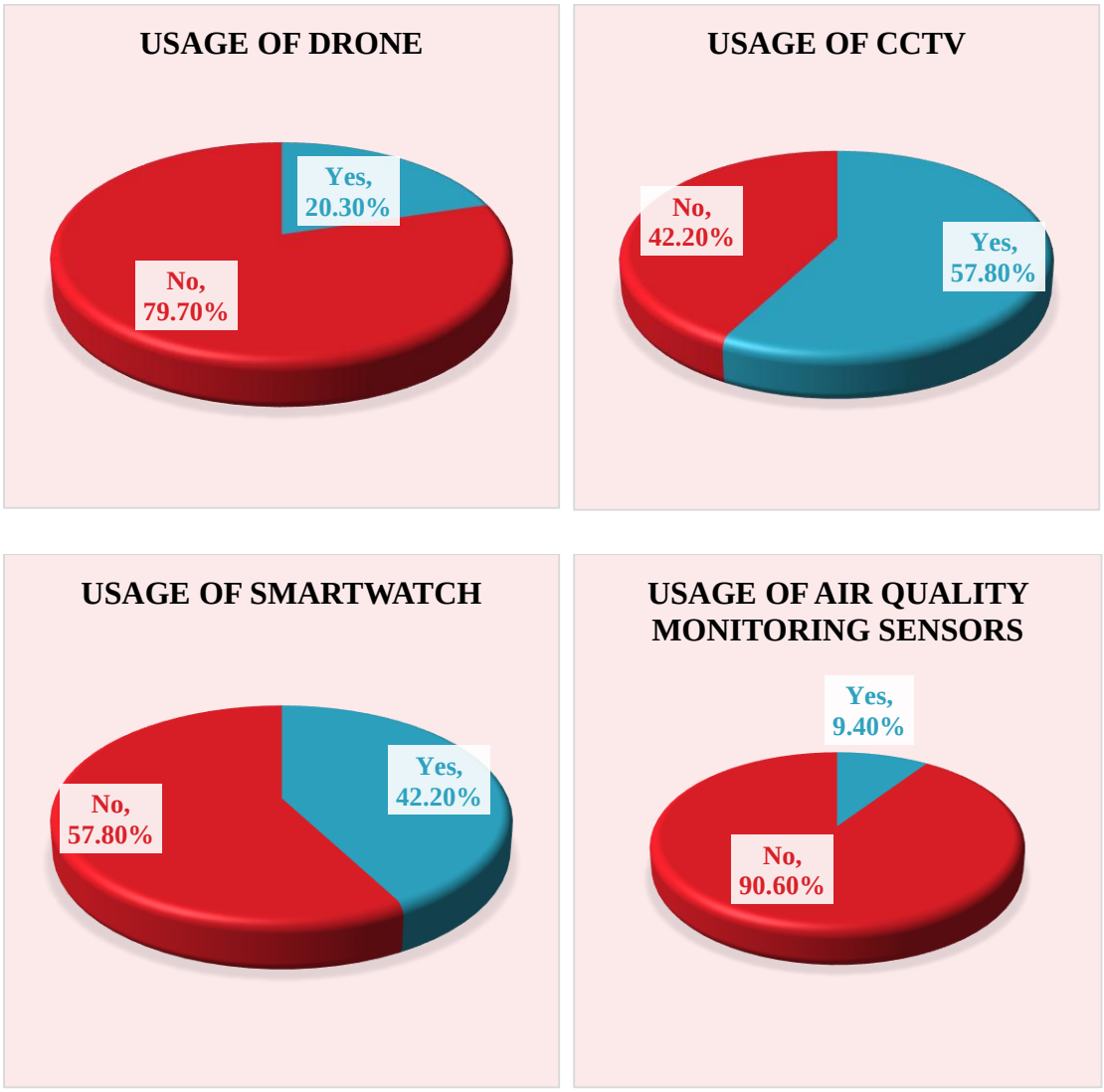

Figure 5.9: Usage of applications for Site Supervision & Worker health Monitoring

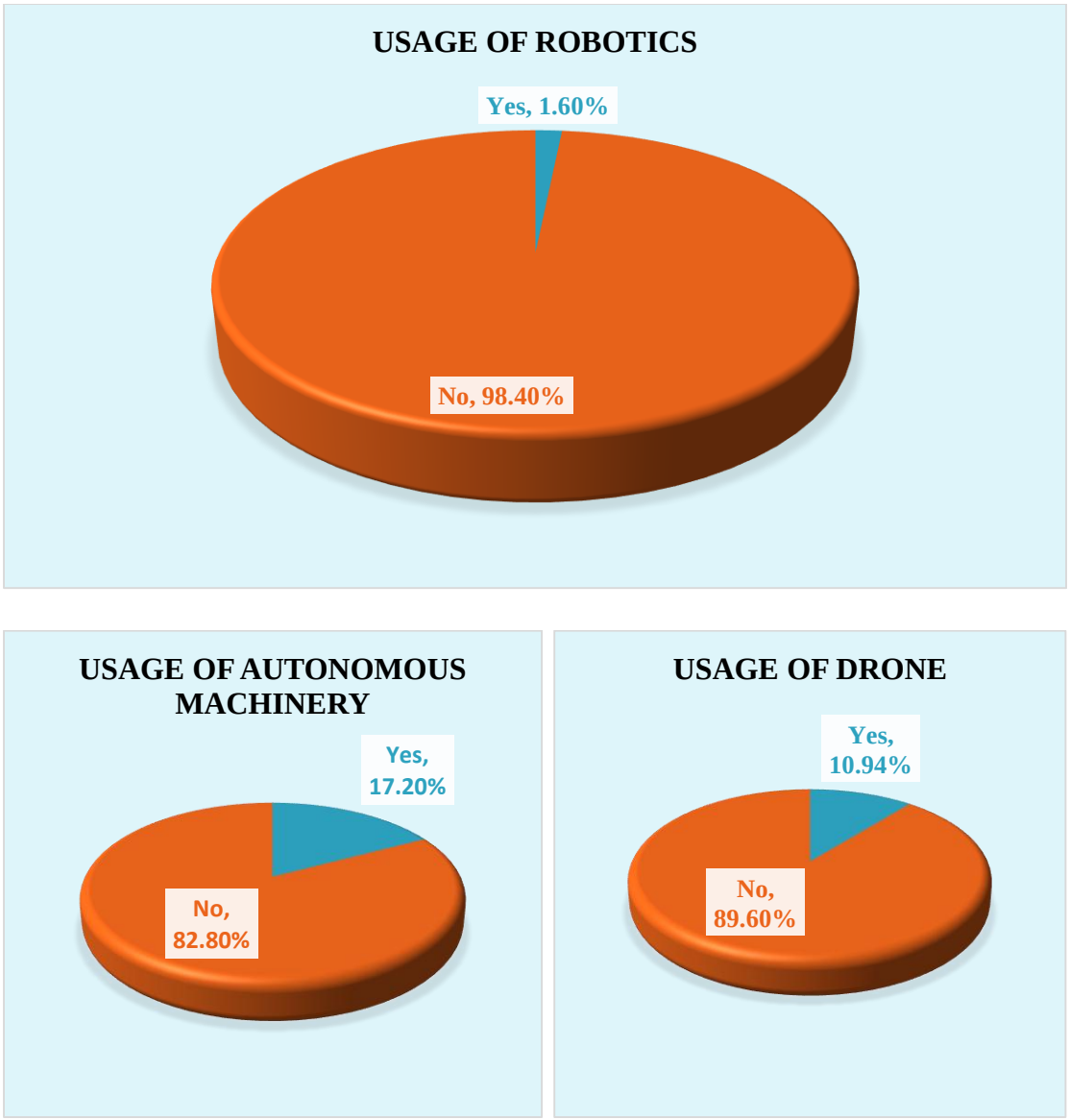

Figure 5.10: Usage of applications for Remote or Hazardous Operations

Security and safety is the main aspect for the construction site during construction phase as well as after construction phase. Because during construction, the probability of material theft may occur and after construction the security of building and the safety of users are very important. Figure 5.11 shows the usage of applications required for security and safety purpose. These applications are CCTV, Fire threatening sensors, flood threatening sensors and smart lock system for security. Figure 5.12 shows the usage of applications used for power, use and energy saving. These applications are also very less utilized applications in the construction industry where the survey was conducted. These applications are Fuel usage control sensors for heavy machinery and equipment, Maintenance activity sensors for machinery and equipment, lighting and electricity sensors as well as automatic lamps. Figure 5.13 displays the usage of

applications which are important for building structure health monitoring, these applications are BIM and Linear displacement sensors. These applications are mainly used for big project or infrastructure. The several structures which have important in context of heritage value are also equipped with linear displacement sensors to monitor the behavior of structure during its lifecycle. In last figure 5.14 shows the applications used for Waste management. The applications used for the same are Wi-Fi, Microcontroller and sensors for the waste management.

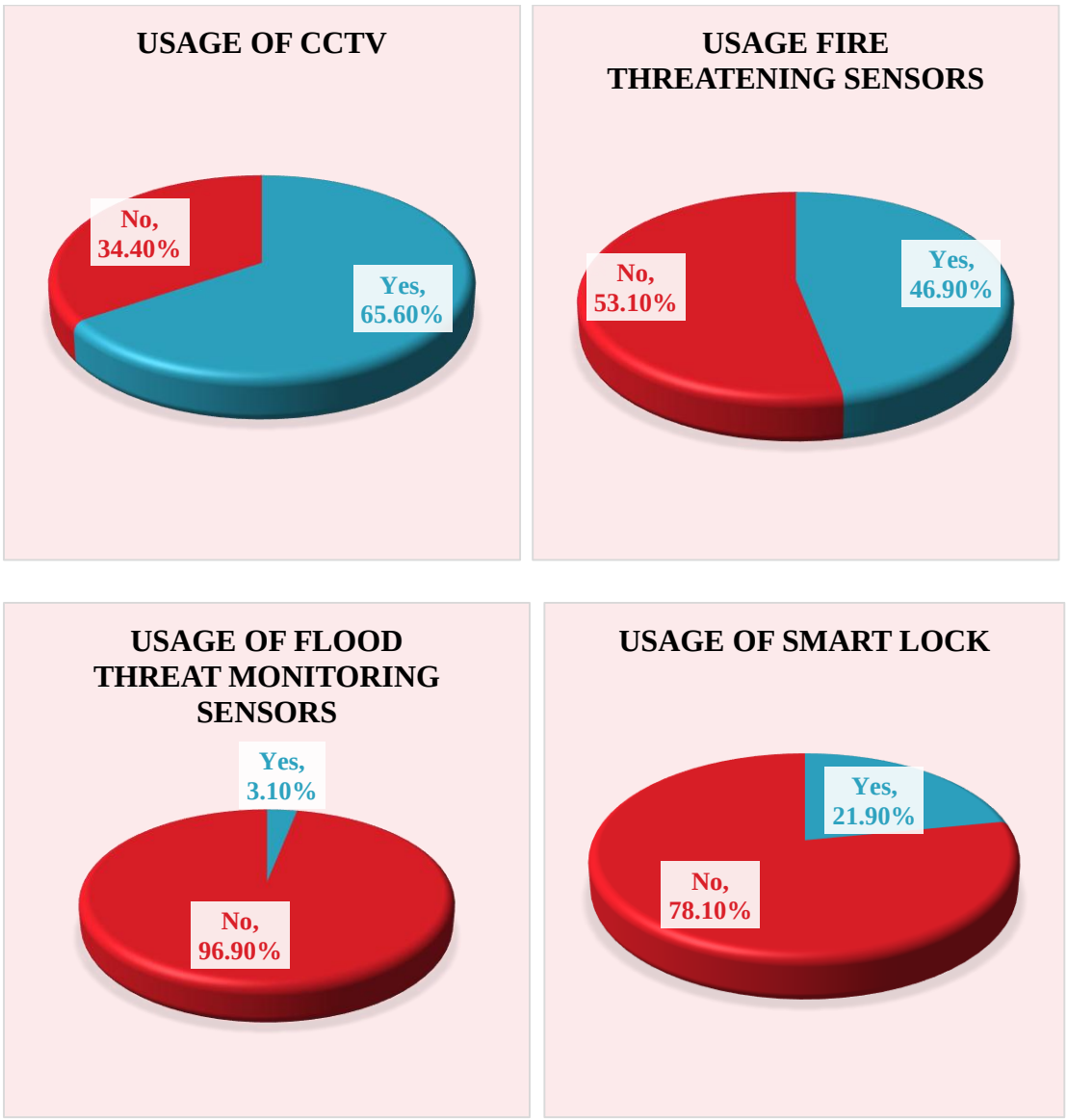

Figure 5.11: Usage of applications for Security and Safety

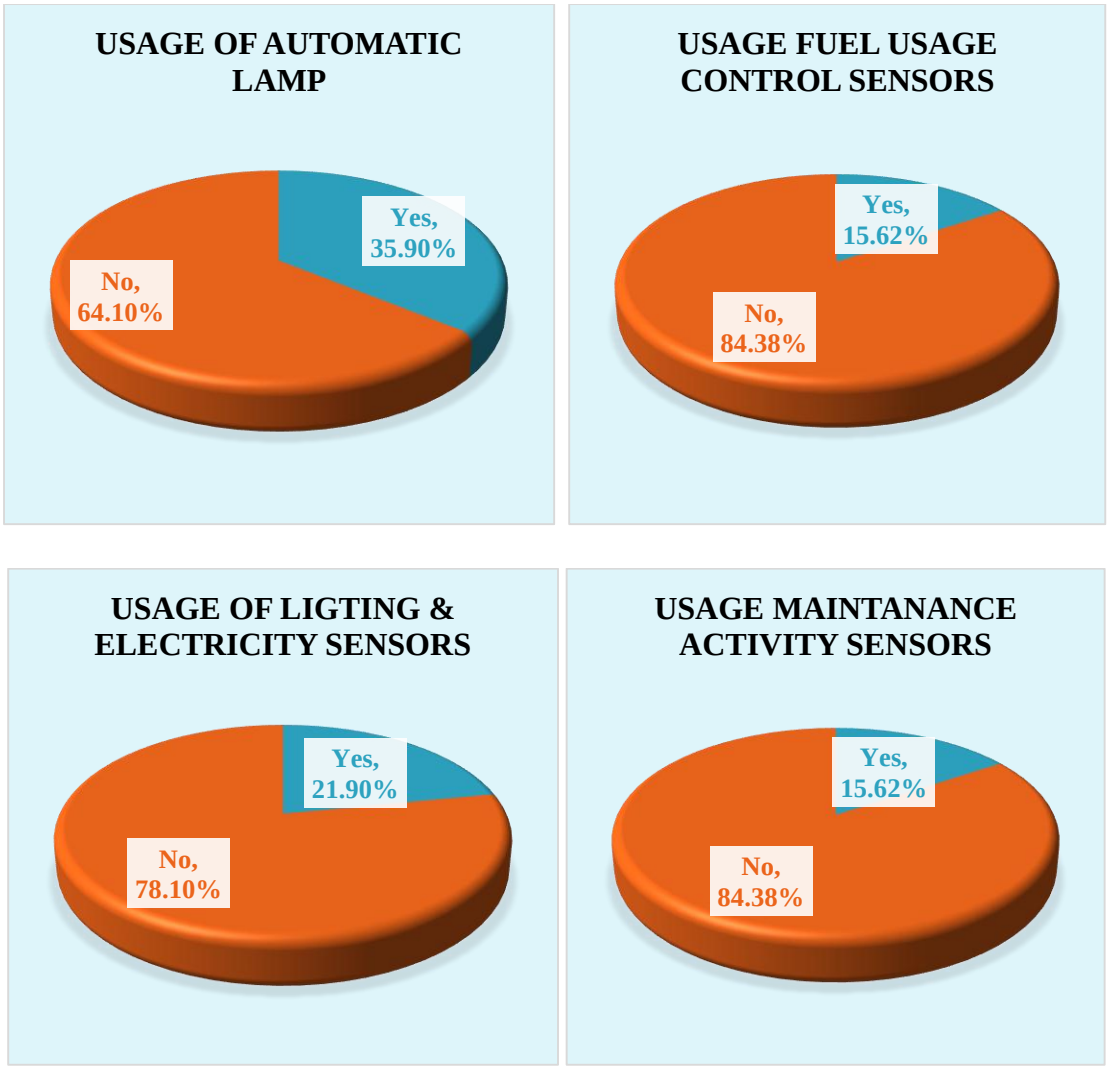

Figure 5.12: Usage of applications for Power, Fuel & Energy Saving

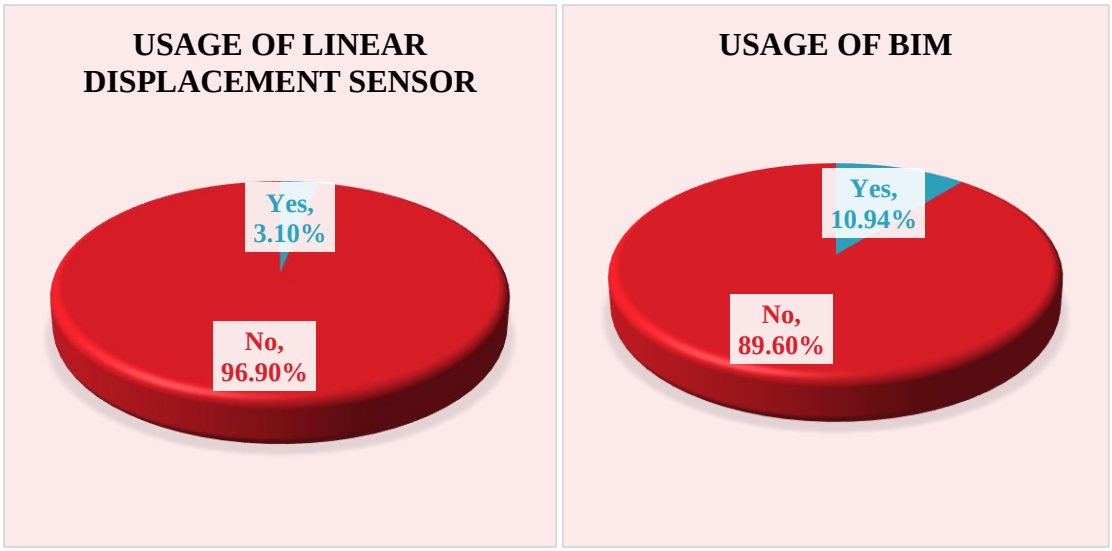

Figure 5.13: Usage of applications for Building Structure Health Monitoring

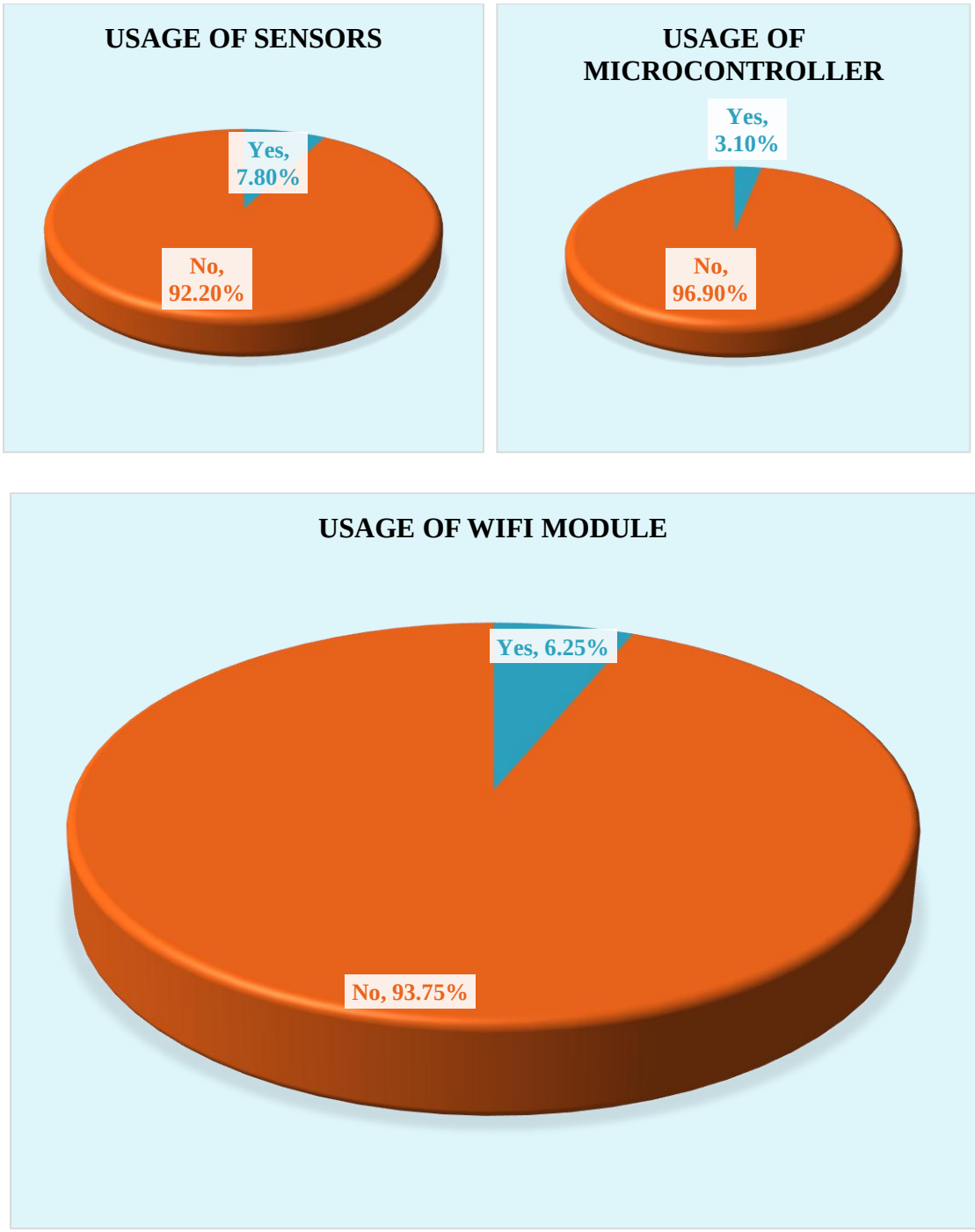

Figure 5.14: Usage of applications for Waste Management

The above said and discussed IoT applications are used during several phases and activities in construction phase as well as after construction phase. Some of the applications which are not included into the questionnaire but suggested and used at some organizations which are, Digital Boucher, Business WhatsApp, Bulk message system and Concrete strength sensors. The discussion about the ranking of the surveyed application are forwarded in the next section of the chapter.

5.4 Ranking of Applications

The Questionnaire form is distributed to the different stakeholders like Contractors, Builders, Site Supervisors, Engineers and Project Engineers/Managers among the construction sites in Vadodara and Anand city. After gathering the data from all responses collected from the stakeholders, the nominal analysis is to be done in Microsoft excel. After analysis of percentage values the highest used applications and lowest used applications are ranked and top 3 majorly used and top 3 least used applications are displayed in a tabular form as shown in table 5.3 and table 5.4.

Table 5.3: Highest ranking and percentage of usage on types of Internet of Things applications

Types of Internet of Things Applications	Highest Ranking	Percentage
Use of AutoCAD & other software	1	98.44
Use of Social media & Use of Email	2	92.20
Use of Net Banking	3	90.60

Based on Table 5.3, the use of AutoCAD & other software is an application that is majorly used by respondents with a maximum percentage of 98.44%. The use of social media and e-mail is the second highest application used by 92.20% of respondents. The third application that many respondents use is the use of Net Banking by 90.60%.

Table 5.4: Lowest ranking and percentage of usage on types of Internet of Things applications

Types of Internet of Things Applications	Lowest Ranking	Percentage
Use of Robotics	1	1.60
Use of Primavera	2	6.25
Use of Sensors for Waste management	3	7.80

Based on Table 5.4, the use of Robotics is an application which is less used by respondents with a percentage of only 1.60%. The use of Primavera is also the second application which is less used by respondents with a percentage of 6.25%. Then, the

use of Sensors for Waste management is the lowest third application that is also less used by respondents with a percentage of 7.80%.

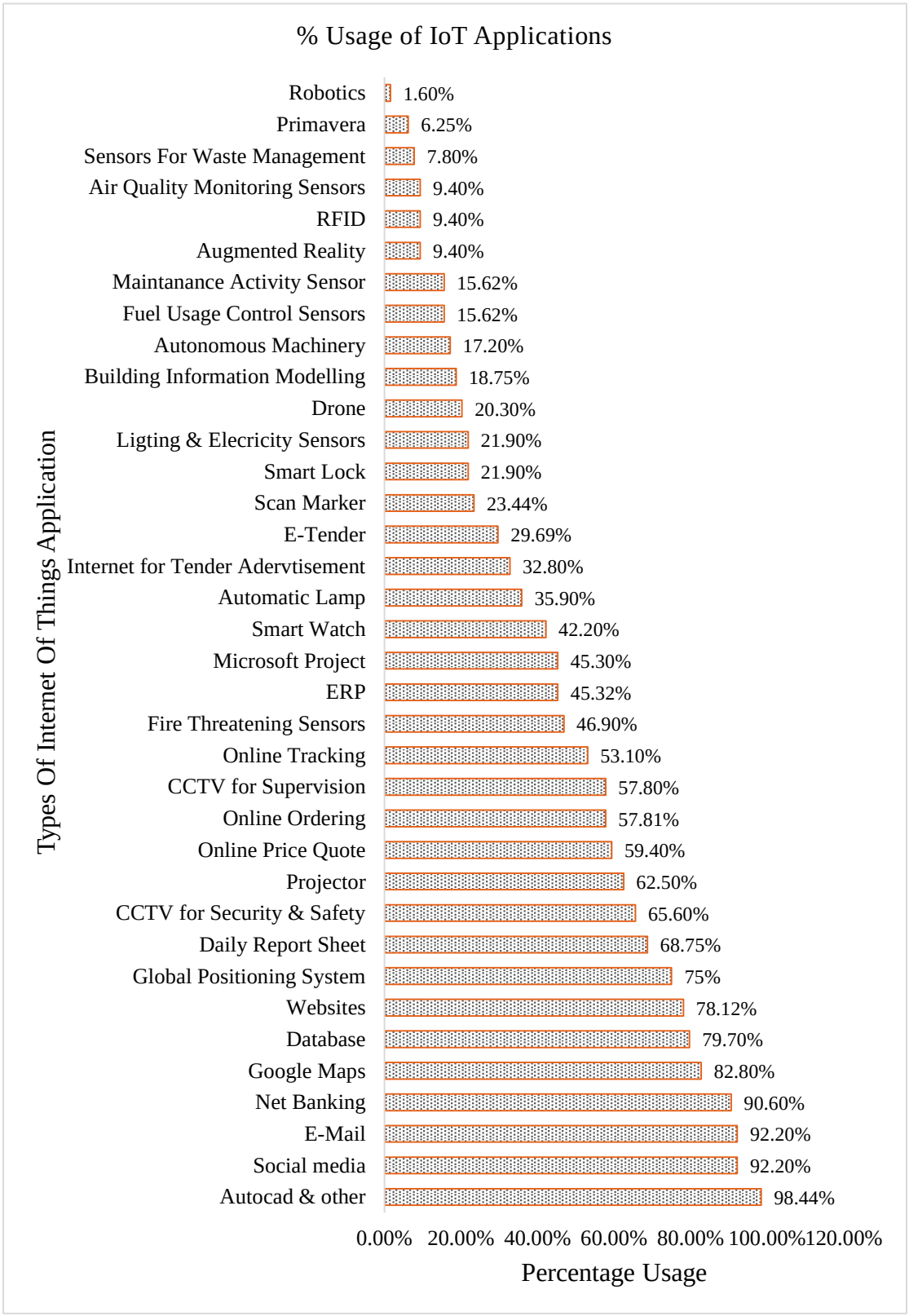

Figure 5.15: Summary of percentages of usage on Internet of Things application

The usage of IoT applications is analyzed in percentage values and presented graphically in tabular chart as shown in figure 5.15. The figure shows 36 types of Internet of Things applications that have been carried out for survey. 4 types of Internet of Things applications that get the highest percentage of users which are AutoCAD & Other software, Social medial and email, Net banking which represent 98.44%, 92.20% and 90.60% respectively. A total of 10 applications also have a satisfactory rate of usage where the percentage of usage is within 50% to 90%. 3 types of Internet of Things applications that earn the lowest percentage of usage which are Robotics, Primavera and Sensor technology for waste management which account for 1.60%, 6.25% and 7.80% respectively. Next, up to 19 types of applications are also in the percentage of the lowest usage rate within 15% to 49% only.

CHAPTER: 6

CONCLUSION

6.1 Conclusion

The results of the questionnaire survey and analysis are presented in the previous section. Conclusion resulting from the research findings are made and the relevant recommendations & future scope are forwarded.

1. There are four types of Internet of Things applications occupy the highest percentage of usage. The use of AutoCAD and other software is the type of application which is use by many of the construction industry players for design purpose as well as analysis purpose of the structure.
2. The second highest used IoT applications is social media such as WhatsApp, Telegram and Facebook Messenger. Then followed by the use of email that serves as an exchange of information between players of this industry. Both applications get the most and the same response where each respondent used it.
3. The next third highest application is the use of the Net banking as the source of financial management. Any project cannot run without money; Money is one of the important pillar in the construction industry. In India, after the demonetization phase the cashless concept is being accepted by all of the industries. That is why the Net banking is the most used IoT application for the financial activities.
4. There are three types of Internet of Things applications that have the lowest usage percentage compared to other applications. The least-used application is the use of robotics in construction industry. this happens because of the complexity of project and due to that the repetition of work is less. The another reason is that, if robotics is used then the threat of job security to labors and engineers may occur.
5. Second less used application is Primavera for project management purpose. This happens because of lack of knowledge about the software and the alternative software Microsoft Project is easy to use, so the Primavera is not adopted by most of the firms.
6. The third application is the use of sensor technology to manage the waste. Waste management is the main thing to take care but unfortunately there is less awareness and adaptive steps are taken to look into it.
7. However, the findings show that the use of Internet of Things applications is still under-utilized in the construction industry. This is because there are only 14 types of applications that are higher in usage rates than those that do not use them, and 22 applications are less used.

8. The evaluation of the respondents' knowledge of the Internet of Things application found that the majority of respondents had known each type of Internet of Things application. This proves that the construction industry players are aware of the presence of this application although its usage is still less because of lack of skills to use, lack of interest in change, lack of budget to purchase and install new technologies.
9. To increase the use of Internet of things application in construction industry, implementation and encouragement should be provided to each players in construction industry.

6.2 Recommendation

From this research study following recommendation can be suggested to the stakeholders of the survey,

1. Some of the stakeholders are not even using basic social media like whatsapp, e-mail. They must use these applications for the smart communication. The other IoT applications should be adopt for the smart communication.
2. Online financial transactions are better than other methods due to demonetization. So industry players should adopt online methods for financial management.
3. Many industry players deny to accept new technology just because of the nature to not accept changes, orthodox mentality and other reasons. They should understand the current scenario of the new era of technology and they should accept the new technologies to remain stable in this competitive world.
4. As of now robotics and autonomous machinery are not used in Indian construction industry, so the recommendation is to adapt these technologies to use in construction industry to increase the productivity as well as quality of the work.
5. For waste management there are no steps are taken for it, It would be suggested that the construction industry players should be seriously take some firm and sound steps for the waste management using IoT applications.
6. IoT applications are being a part of our life as the enhancement of technologies and internet. Almost every industry is adopting the IoT technology for better results. Construction industry should also take initiatives to adopt this technology for the betterment of the industry and economy connected to the industry.

6.3 Future Scope

For this dissertation work researcher has surveyed some of the most important applications of IoT with focus on construction industry, however, future research may be conducted on implementation of the internet of things concept in building projects and the case study may be conducted to make the concept of IoT feasible.

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APPENDIX A:

SURVEY QUESTIONNAIRE

Questionnaire

M.Tech.
Construction Engineering and management
(Civil Engineering Department),
BVM Engineering College,
(An Autonomous Institution),
Vallabh Vidyanagar - 388120, Dist. Anand,
Gujarat

To, _____

Respected Sir/Madam,

Subject: Survey work for "feasibility study of Internet of Things (IoT) in Construction Industry".

With reference to the above stated subject, our student **Rupamkumar Vrajlal Maru (ID NO. 18CM813)** has prepared **questionnaire for the Feasibility Study of Internet of Things (IoT) In Construction Industry** for of his dissertation work, which is required for completion of his Master of Technology program in Construction Engineering and Management.

The scope (area) of our work is Vadodara and Anand. Your response about utility of Internet based applications for building construction is very important for us. Therefore, I have selected you as the prime respondent for this survey work.

I kindly request you to help him carry out the survey work and share your perception about the stated subject. In addition to this, I ensure you about that your filled data will be used only for this academic purpose only.

Yours Faithfully,

Dr. Jayeshkumar Pitroda
Associate Professor
PG Coordinator of Construction
Engineering and Management
Civil Engineering Department,
BVM Engineering College (An Autonomous Institution),
Vallabh Vidhyanagar-388120, Gujarat

SECTION I: RESOPNDENT'S DETAIL

Name:		
Contact Number:		
Email ID:		
Type of profession:		
Experience in construction industry:		
Location, City:		
Project name:		
Project Contractor:		
Type of project:	**Residential**	**Commercial**
Status of project:	**In Construction Stage**	**Completed**

SECTION II: MAIN QUESTIONNAIRE

- Please answer the following questions listed below in Yes or No form. If you are using the IoT application at the given phase or activity described below, then put a right tick mark **(√)** in the **YES** column and if not using put a right tick mark on **NO** column.

No.	Phase/Activity	Usage of IoT Application	
		YES	NO
A.	**Smart Communication**		
A1	Social media (WhatsApp, Facebook, Telegram)		
A2	Websites		
A3	Email		
A4	Scan Marker		
B.	**Meeting with Client/Engineers**		
B1	AR (Augmented Reality)		
B2	Projector		
B3	Database		
B4	BIM (Building Information Modelling)		
B5	AutoCAD & Other Designing Software		
B6	Microsoft Project		
B7	Primavera		
C.	**Material Order & Supply**		
C1	Online Ordering		
C2	Online price quotes		
C3	Online Tracking		
C4	GPS (Global Positioning System)		
C5	Google Maps		
C6	RFID (Radio-Frequency Identification)		

No.	Phase/Activity	Usage of IoT Application	
		YES	NO
D.	**Attendance of Employees**		
D1	ERP (Enterprise Resource Planning)		
D2	Daily Report Sheet		
E.	**Contract & Financial Management**		
E1	E-Tender		
E2	Internet for tender Advertisement		
E3	Net banking		
F.	**Site Supervision & Worker health Monitoring**		
F1	Drone		
F2	CCTV surveillance at site		
F3	Smart Watch		
F4	Air Quality Monitoring Sensors		
G.	**Remote or Hazardous Operations**		
G1	Robotics		
G2	Autonomous Machinery		
G3	Drone for inspection		
H.	**Security and Safety**		
H1	CCTV surveillance		
H2	Fire Threatening Sensors		
H3	Flood threat monitoring sensors		
H4	Smart Lock		
I.	**Power, Fuel & Energy Saving**		
I1	Automatic lamp		
I2	Fuel usage control sensors		
I3	Lighting & Electricity Sensors		
I4	Maintenance activity sensors		

No.	Phase/Activity	Usage of IoT Application	
		YES	NO
J.	**Building Structure Health Monitoring**		
J1	Linear Displacement Sensor		
J2	BIM		
K.	**Waste Management**		
K1	Sensors		
K2	Microcontrollers		
K3	Wi-Fi Modules		
	Others (please specify)		
1.			
2.			
3.			
4.			
5.			

Thank you for sparing your valuable time. Your feedback will be used to analyze the feasibility of IoT applications used in construction industry using the above criteria for study from students' point of view. Write any additional remarks or any IoT based application which you may feel necessary to be included, but not covered in this study.

Your suggestions:

_____

_____

_____

_____

_____

_____

Signature of the Respondent

From:

Rupamkumar V. Maru
M.Tech. Construction Engineering & Management,
Birla Vishvakarma Mahavidyalaya

Vallabh Vidyanagar - 388120,
Dist. Anand, Gujarat. INDIA.
Phone: +91-9662513398
E-mail: marurupam2013@gmail.com

APPENDIX B:

LIST OF

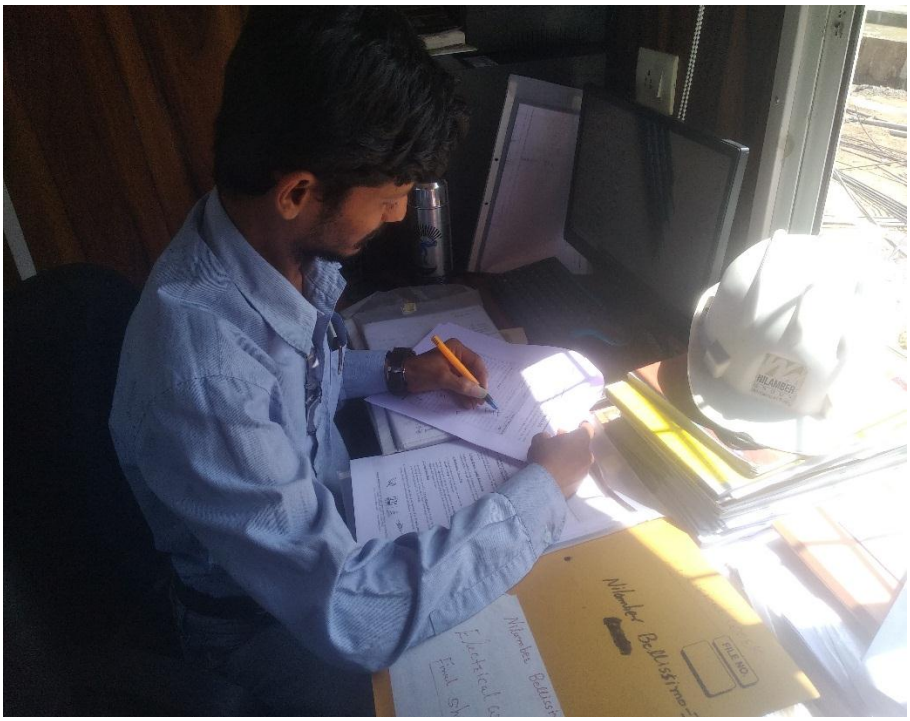
RESPONDENTS

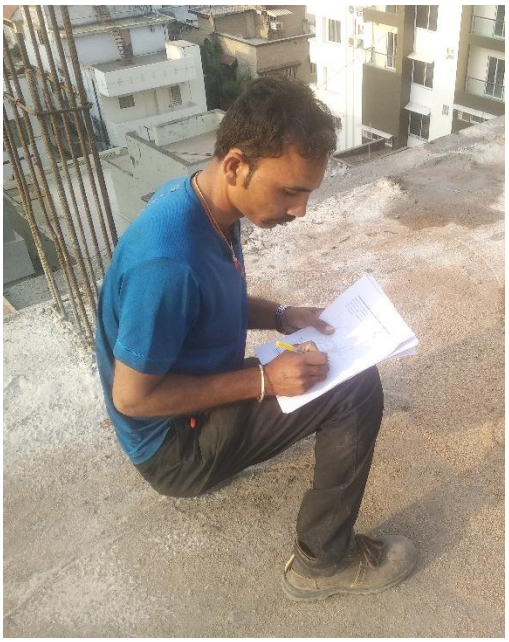
List of Respondents

Sr No.	Name	Profession	City
1	Dhaval Vadhavana	Engineer/Supervisor	Vadodara
2	Jigar Shah		
3	Shankar Patel		
4	Hiren Parmar		
5	Hardik Parmar		
6	Sunil Parmar		
7	Neel Patel		
8	Hardik Kapadiya		
9	Krunal Rana		
10	Nagarbhai Darji		
11	Mitesh Patel		
12	Amin Khan		
13	Jayesh Lalvani		
14	Sureshbhai Patel		
15	Harsh Patel		
16	Kashyap Gondaliya		
17	Piyush Patel		
18	Hiren Patel		
19	Sudhir Patel		
20	Mayur Patel		
21	Paresh Gadhiya		
22	Paresh Parmar	Builder/Contractor	Vadodara
23	Jayantibhai Parmar		
24	Maganbhai Parmar		
25	Hiren Prajapati		
26	Sagar Mandlik		
27	Arvind L. Mistry		
28	Atman A. Mistry		
29	Shrinivas Kasturi		
30	Alpesh Sukhadia		
31	Saroj Yadav		
32	Naishil Shah		
33	Irfan Shaikh		
34	Pravinbhai S. Shah		
35	Manoj		
36	Pankaj Patel	Project Manager	Vadodara
37	Manoj Bhatt		
38	Hitesh Trivedi		
39	Pareshbhai M. Parmar		
40	Pratik Patel		

41	Nirav Prajapati	Engineer/Supervisor	Anand
42	Meet Dalwadi		
43	Tushar Prajapati		
44	Dipakkumar Gandhi		
45	Vhora Fardin M.		
46	Akash A. Prajapati		
47	Kishan N. Prajapati		
48	Raj D. Gandhi		
49	Rajat Gupta		
50	Tej Gandhi		
51	Govind Limbani		
52	Chaurjit Sharma		
53	Naresh Yadav		
54	M/S Ashok & Sons	Builder/Contractor	Anand
55	M/S Jagdish & Co.		
56	Ashok J. Prajapati		
57	Manoj Patel		
58	Mitesh Patel		
59	Hemin Patel 1		
60	Hemin Patel 2		
61	Hemin Patel 3		
62	Infra Build Tech		
63	Jaydeep Chavda	Project Manager	Anand
64	Paresh Patel		

APPENDIX C: SURVEY WORK-PHOTO GALLERY



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APPENDIX D: ACHIEVEMENTS

Paper Published

1. Rupamkumar Maru, Dr. Jayeshkumar Pitroda, Prof. Amitkumar D. Raval (2020), "**Feasibility Study of Internet of Things (IoT) In Construction Industry: A Review**", Studies in Indian Place Names (UGC Care Journal), ISSN: 2394-3114, Volume 40, Issue-50, PP: 4948-4958

EDUINDEX

PUBLICATION CERTIFICATE

This publication certificate has been issued to

Rupamkumar Maru, Dr. Jayeshkumar Pitroda, Prof. Amitkumar D. Raval

For publication of research paper titled

Feasibility Study of Internet of Things (IoT) In Construction Industry: A Review

Published in *Studies in Indian Place Names (SIPN) with ISSN 2394-3114*

Vol. *40* **Issue** *50* **Month** *March* **Year** *2020*

Impact Factor *6.30*

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2. Rupamkumar V. Maru, Dr. Jayeshkumar R. Pitroda, Prof. Amitkumar D. Raval (2020), **"Feasibility Study of Internet of Things (IoT) In Construction Industry"**, ISSN-2349-5162, Volume 7, Issue 5, PP: 447-452

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In recognition of the publication of the paper entitled

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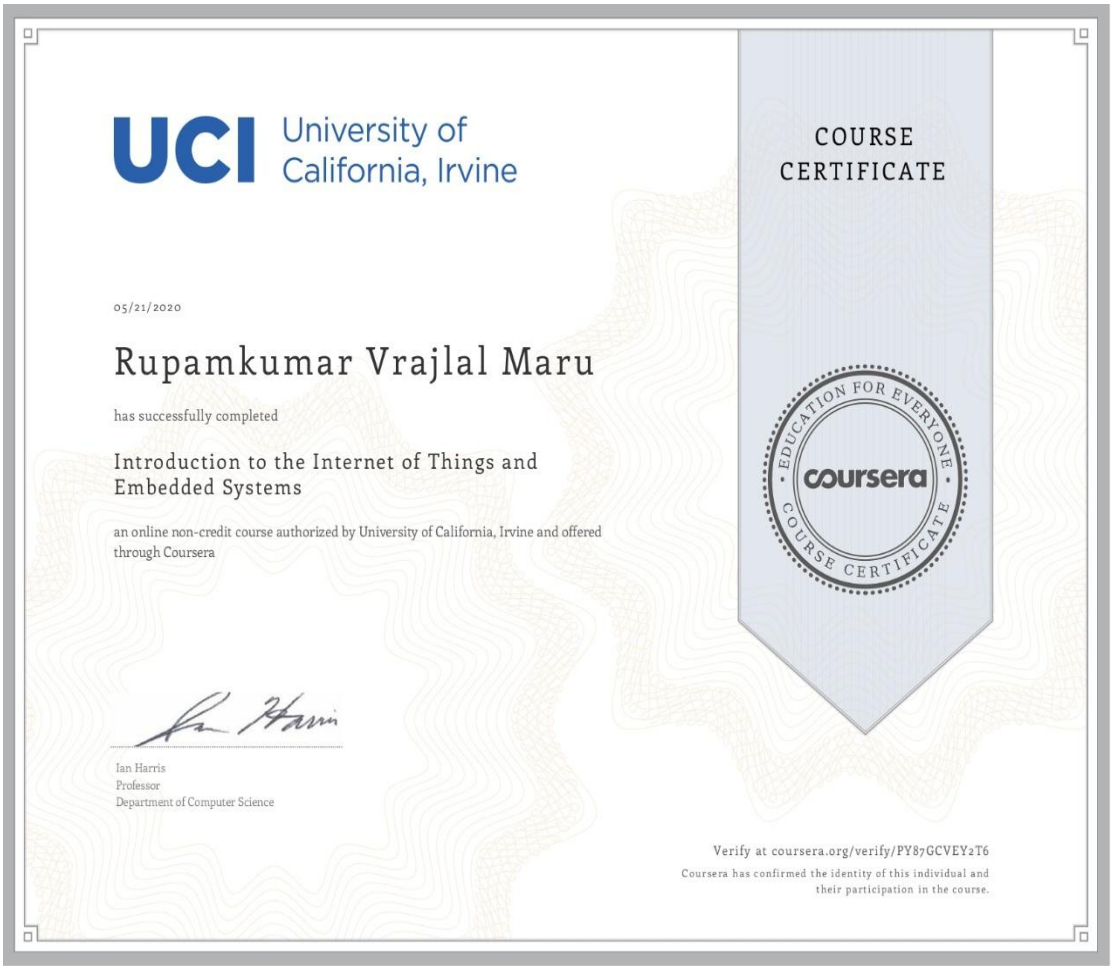
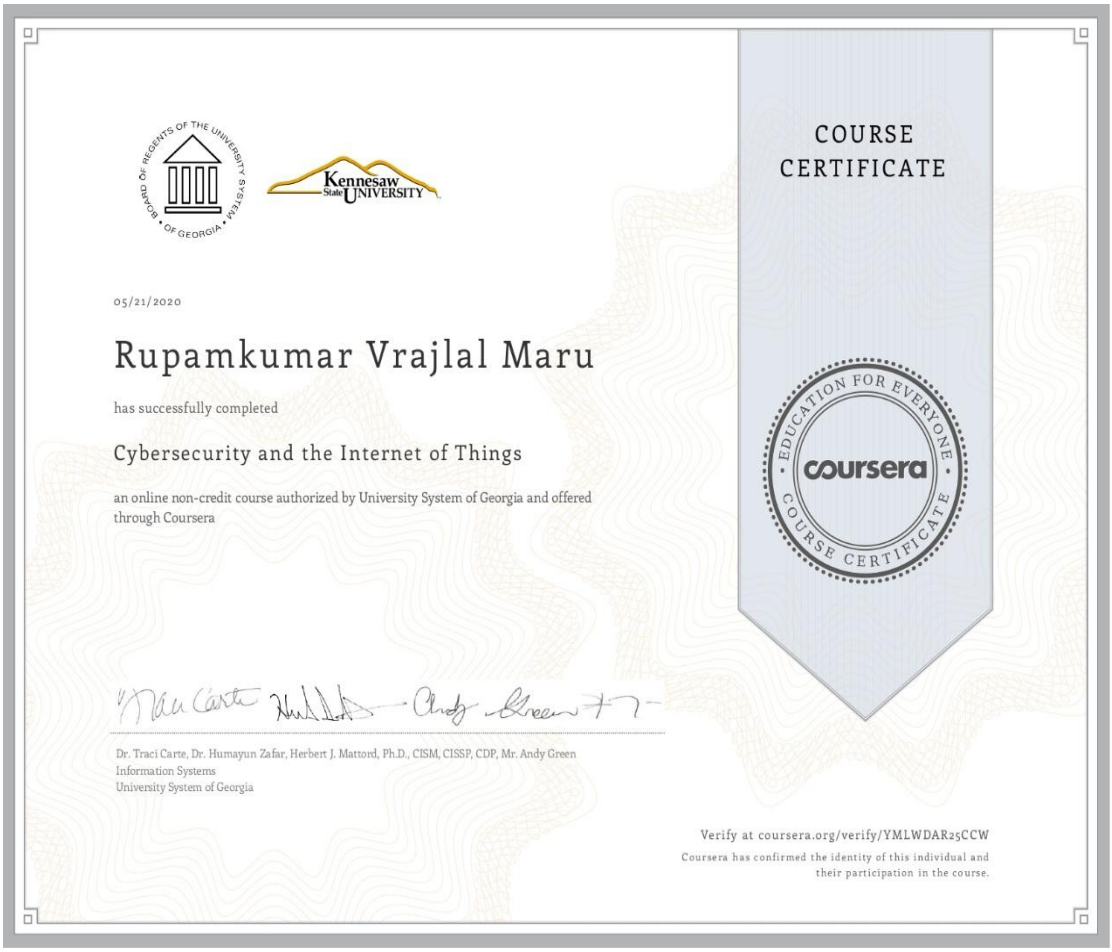
Other Course Achievement

3. Rupamkumar Vrajlal Maru has successfully completed **"Introduction to the Internet of Things and Embedded Systems"** an online non-credit course authorized by **University of California, Irvine** and offered through **Coursera**, 21/05/2020



4. Rupamkumar Vrajlal Maru has successfully completed **"Cybersecurity and the Internet of Things"** an online non-credit course authorized by **University System of Georgia** and offered through **Coursera**, 21/05/2020



5. Rupamkumar Vrajlal Maru has awarded with a national award **"Research Exellence award 2020"** by institute of scholars (InSc) for his research paper on ***Feasibility study of Internet of Things (IoT) in Construction Industry*** in July 2020.

6. Rupamkumar Vrajlal Maru has awarded with a national award **"Young Achiever award 2020"** by institute of scholars (InSc) for his research paper on ***Feasibility study of Internet of Things (IoT) in Construction Industry*** in July 2020.

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Award For : Research Excellence Award

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Award For : Young Achiever Award

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FEASIBILITY STUDY OF INTERNET OF THINGS (IoT) IN CONSTRUCTION INDUSTRY By ID NO: 18CM813: RUPAMKUMAR VRAJLAL MARU Dr. Jayeshkumar R. Pitroda Associate Professor Civil Engineering Department BVM Engineering College Vallabh Vidyanagar, Gujarat _ Prof. Amitkumar D. Raval Lecturer Civil Engineering Department B.B.I.T.
Vallabh Vidyanagar, Gujarat
A Dissertation phase-2 (CM612) Submitted to Birla Vishvakarma Mahavidyalaya (Engineering College), An Autonomous Institution affiliated to Gujarat Technological University in Partial Fulfillment of the Requirements for The Master of Technology (Civil Engineering) Specialization in Construction Engineering & Management June, 2020 BIRLA VISHVAKARMA MAHAVIDYALAYA (ENGINEERING COLLEGE) AN AUTONOMOUS INSTITUTION Vallabh Vidyanagar – 388120 GUJARAT, INDIA COMPLIANCE CERTIFICATE This is to certify that research work embodied in this dissertation entitled "Feasibility Study of Internet of Things (IoT) in Construction Industry" was carried out by ID.

No:18CM813: Rupamkumar Vrajlal Maru at Birla Vishvakarma Mahavidyalaya (Engineering College) An Autonomous Institution for partial fulfillment of Master of Technology (Civil Engineering) with Specialization in Construction Engineering and Management degree to be awarded by Gujarat Technological University. He has complied to the comments given by the Dissertation phase – I as well as Mid Semester Dissertation Reviewer to our satisfaction. Date: Place: (Rupamkumar V. Maru) _ _ _ _(Dr. Jayeshkumar R. Pitroda) _ _(Prof. Amitkumar D. Raval) _ _Head, Civil Engineering (Dr. L. B. Zala) _ _Principal (Dr. I. N. Patel) _ _ BIRLA VISHVAKARMA MAHAVIDYALAY (ENGINEERING COLLEGE) AN AUTONOMOUS INSTITUTION Vallabh Vidyanagar – 388120 GUJARAT, INDIA
This is to certify that research work embodied in this dissertation entitled "Feasibility Study of Internet of Things (IoT) in Construction Industry" was carried out by ID.

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Amitkumar D. Raval) _ _Head, Civil Engineering (Dr. L. B. Zala) _ _Principal (Dr. I. N. Patel) _ _ BIRLA VISHVAKARMA MAHAVIDYALAYA (ENGINEERING COLLEGE) AN AUTONOMOUS INSTITUTION Vallabh Vidyanagar – 388120 GUJARAT, INDIA

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DECLARATION OF ORIGINALITY I hereby certify that I am the sole author of this dissertation and that neither any part of this dissertation nor the whole of the dissertation has been submitted for a degree to any other University or Institution.

I certify that, to the best of my knowledge, my dissertation does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations or any other material from the work of other people included in my dissertation, published or otherwise, are fully acknowledged in accordance with the standard referencing practices.
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