CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Prospects of Industrial Revolution 4.0 in Construction Industry of Pakistan

by

Wafa Nasir

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in the

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This thesis is dedicated to:

My Father and Mother

And everyone supported me in this journey, Who have been always a symbol of Affection, Happiness, and Bliss.

CERTIFICATE OF APPROVAL

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(Wafa Nasir)

Abstract

This world is growing at a fast pace, and we are all aware of the increasing trends of digitalization in the global market. Everything has been made smart and is just one click away. These are all the manifestations of industrial revolution 4.0., which has paved the way for new advancements in technology with its unbeatable features, integrating multiple disciples like the CPS (Cyber-Physical System), IOT (Internet of Things), smart factory, artificial intelligence, cloud computing, and much more.

The rigidity of the construction industry is not really a new concept for the world. This industry has been recognized as one of the most dangerous industries and the least one to adopt new technologies. It is well known for being intricate, risk susceptible, and full of uncertainties. This research has been done to investigate the novelties provided by Industrial Revolution 4.0, especially focusing construction sector of Pakistan, using PEST analysis.

A thorough Literature review was done to find out about the major driving factors of industrial revolution 4.0. The PEST framework was used to gain an overview of the existing construction industrial setup. The extensive in-depth research laid the framework for the creation of questionnaires. The Delphi approach was used to identify the most essential components of this investigation. A questionnaire survey was used to obtain data from industry professionals. Pilot research was done, and professional feedback was obtained; afterward, changes to the questionnaire were made based on the feedback.

159 questionnaires were distributed among professionals from which 106 responses were collected, so the total response rate came out to be 63%. SPSS software was used to determine the reliability factor of received replies, ensuring data reliability. After data analysis using a normality test, a non-parametric pattern was observed. Spider web and bar charts were used to depict the results.

Results show high popularity of IR 4.0 among professions and show a positive attitude of individuals towards technological advancements. PEST framework

shows that among all other factors, the political factor is the most influential one for implementing industrial revolution 4.0 in Pakistan. It can be concluded from research that a framework with defined rules and regulations would help in a better understanding of this revolution. Among many other factors the economic risk factor of buying new technology is the biggest hindrance to its way towards adoption of IR4.0.

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Abbreviations

IOT	Internet of Things
CPS	Cyber Physical System
GDP	Gross Domestic Product
IR	Industrial Revolution
SPSS	Statistical Package for social Sciences
VR	Virtual Reality
BIM	Building Information Modeling
RFID	Radio-Frequency Identification
A&C	Architecture and Construction
CI	Construction Industry

Chapter 1

Introduction

General

This chapter explains the fundamental concept of the Fourth Industrial Revolution. How it began, and what technical breakthroughs it provides in many areas, particularly construction industry. The progress that has been accomplished so far in adopting this new revolution and the biggest obstacles to its adoption.

1.1 Background

This world has witnessed many technological revolutions with the passage of time. Invention of wheel marked the 1^{st} Industrial revolution which is also known as 1^{st} generation (1760 1840). 2^{nd} era (1870 1914) of revolution begins with the mass production (intensive use of electricity). Industries started producing things in bulk. 3^{rd} technological revolution started in 1950's, when digitalization became widespread. T.V, Laptops, mobiles, Personal computers made their way almost in every house and offices.

Now comes the 4^{th} generation in 2014; which is about the automation of manufacturing and industrial particles. 5^{th} Industrial revolution era is believing to begin at the end of this 21^{st} Century only if we excel in achieving the goals of IR 4.0.

One of the major drawbacks of industrial revolution 4.0 explained by Qazi et al. (2022) is the fear of large percentage of people that humans would be replaced by machines resulting in losing their jobs [1] . This limitation is aimed to be removed by Industrial revolution 5.0 in which machines and man will dance together, metaphorically. The theme behind industrial revolution 5 can be well expressed by the following expression "Blockchain + AI + Human = Magic", which looks quite impossible keeping in mind the current circumstances but will later give its fruit [2].

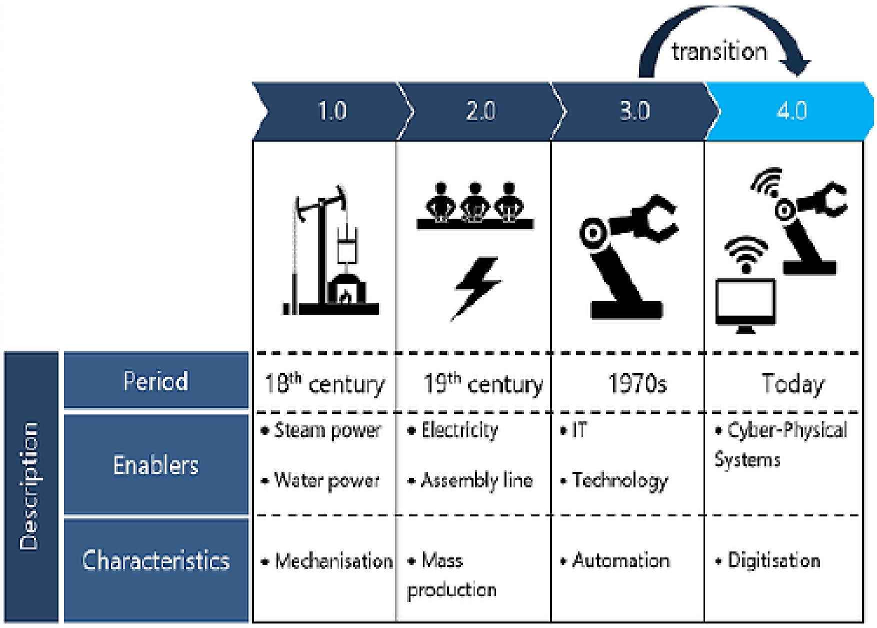

FIGURE 1.1: Concept of Industrial Revolutions [3]

Industrial Revolution (IR) 4.0 main theme is "automation and data exchange" [4]. The idea of smart homes in which everything is controlled by sensors and connected to the internet through Wi-Fi was being developed keeping in mind the motto of Industrial revolution 4.0

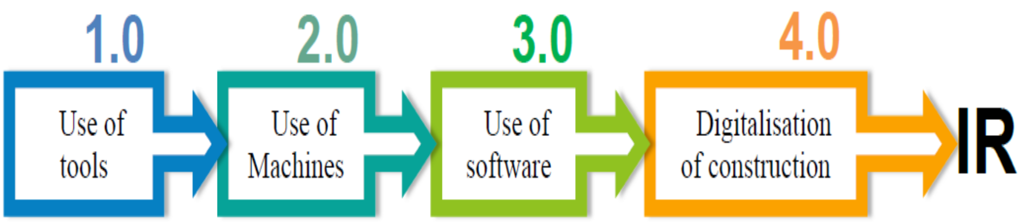

FIGURE 1.2: Industrial Revolution Process [5]

With Industrial revolution 4.0, the concept of smart, digital, and connected home/ buildings is now possible, but it involves great integration of information, process, knowledge, and people [6]. Machine learning also comes under its domain. Machine learning gives the ability to get relevant information automatically. It enables computers and systems to use the gathered data sufficiently to process their work. Industrial revolution 4.0 supports development and improvement through its proficiency limit and has an overflow effect on the design and development of this industry as the need for low-cost housing has never been this high. The changes that take place here influence society as a whole: construction costs decreases, and the environment thrives, all this is accomplished through making effective use of finite resources. It benefits the economy by narrowing the global infrastructure gap and accelerating overall economic development [2].

The major idea behind this revolution can be defined as "technical aid which supports physical work" [2]. Computing, Materials science, quantum artificial intelligence (AI), the Internet of Things (IoT), robots, self-driving cars, and 3D printing are currently developing technologies. 3D printing and many other Industry 4.0 technologies can change the dynamics of project management [7].

It has been evident for decades that the construction industry is the most reluctant among all to adopt new technologies to a point that its bizarre Industry specialists. Studies commonly indicate a generally conservative mindset in this industry. challenges that are seen as major roadblocks to innovation, such as high initial invention costs, a perceived lack of risk capital, and a long pay-back period for investments. Sustainability and different digitalization aspects have made it possible for Industry 4.0 to be adopted and not only just adopted, to become the need of the industry. The large data set it offers to store data in the cloud, the models that can be developed using BIM and many other softwares, smart homes concept, GPS locate systems, and much more are all the manifestations of this industry 4.0 which have forced this reluctant industry to adopt them and enjoy their impacts [7].

BIM, which is widely used in the construction industry, also shares some features of Industry 4.0. The introduction of BIM is a breakthrough for the construction industry. It is believed that IR4.0 will open new ways along with cyber- physical systems (drones, embedded robots, sensors , etc.) in construction but precisely the definition of Industrial revolution 4 is still unknown. A difference of opinion exists regarding its exact definition (concept).

Some people believe that it is "the use of ubiquitous connectivity for real-time decision making", while others see it as an encompassing approach that goes beyond a simple technological framework to best meet the industry's current challenges. The decentralized connection between the physical state and cyber-physical system through ubiquitous connectivity. Although BIM does provide such connection i.e. To be able to create twin models, these models are made and controlled by humans, in industry 4.0, the need for humans will also be assumed to be replaced by technology [3]. The concept of Industrial Revolution 4.0 is based on the total automation of the whole project life cycle.

1.2 Research Motivation and Problem Statement

Construction is well-known for its fragmented nature. The product is always unique and is built through a series of fragmented actions. The construction sector continues to use old labor intensive industry techniques, resulting in excessive energy consumption, environmental pollution, safety hazards, and low efficiency in project delivery.

Emerging technologies such as the big data, Internet of Things, artificial intelligence, and cloud computing have been shown to significantly contribute to industrial intelligence in terms of efficient design, performance appraisal, resource management, energy savings, risk monitoring, project delivery, and emission reduction.

- The construction industry's key challenges include its complicated nature, unique product, fragmented supply chain, social and political behavior, culture, and risks.

- Using the PEST framework, we will investigate how the Industrial Revolution.4.0 will affect the construction industry. How beneficial it will be for the stakeholders.
- How much benefit can we get using the wonderful products of this new revolution.

1.3 Overall Objective and Specific Aim

The general goal of this study is to accurately analyze the key challenges in the construction sector and how the adoption of technological transformation of IR 4.0 will help to minimize or to some extent, seldom eliminate them.

"The specific aim of this MS research work is to investigate the main issues faced by construction the industry for implementing Industrial Revolution 4.0 using the PEST framework and to investigate the opportunities presented by deploying IR 4.0."

1.4 Scope of Work and Study Limitations

Pakistan comes under the category of an underdeveloped country, and we have limited resources. The lack of integration with international organizations remains one of the major concerns. The local construction industry still operates traditionally and the application of new technologies remains limited.

However, the impact of advanced technological applications cannot be overlooked. Keeping in view the benefits for the future, the current work explores the implementation of Industrial revolution 4.0 components in the construction sector. The study was limited to 4 social and economical factors included in PEST; the rest still needs to be addressed.

1.5 Brief Methodology

Figure 1.3 briefs the graphic presentation of methodology adopted to carry out this research.

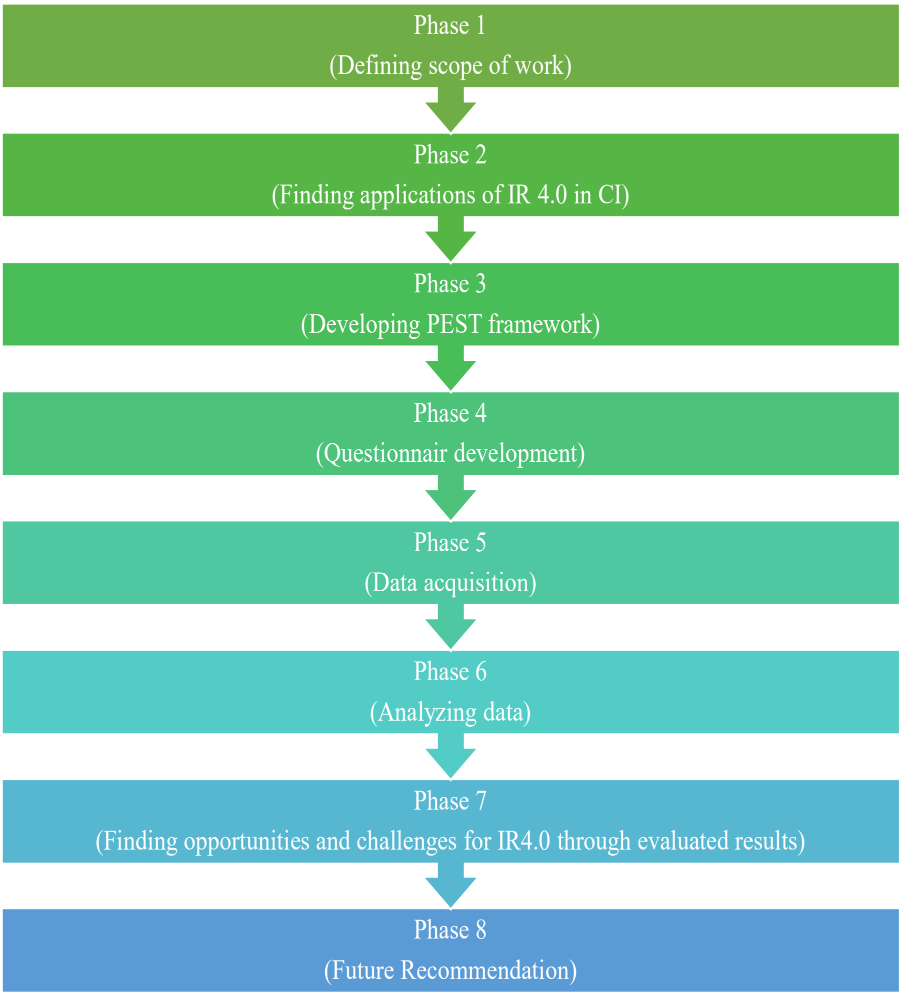

FIGURE 1.3: Methodology of Research

1.6 Thesis Outline

This research comprises of the 5 chapters.

Chapter One: Chapter one is entitled as introduction. It addresses the fundamentals of the research topic as well as the need for this study. It includes the following topics: background, research motivation and problem statement, overall objective and specific aim, the scope of work and studies limitations, brief methodology, and thesis outline.

Chapter Two: This chapter provides the summary of earlier research work, the gap it left, and the core notion underpinning the entire topic of the industrial revolution.

Chapter Three: This chapter covers the basics technique and methodology that have been adopted to complete this research work.

Chapter Four: This chapter discusses the findings and conclusions drawn from the surveyed data.

Chapter Five: This chapter is composed of conclusions supported by future recommendations.

Chapter 2

Literature Review

The focus of this chapter will be on the 4rth industrial revolution, its needs, and how beneficial it will be for the construction industry. The topics under discussion in this chapter will provide a comprehensive review of major components of Industrial revolution 4.0, Applications of IR 4.0 in all fields especially in construction, barriers towards successful implementation of IR4.0, research gap and future prospects of this new industrial revolution in construction industry of Pakistan.

2.1 Industrial Revolution Background

According to Alaloul et al. (2020), for the process of Industrial development comprising of data exchange and automation, IR 4.0 has been established as a fundamental terminology of the development, introduced previously as "Industries 4.0" in Germany. This term originated from Germany; their government backed this future vision by encouraging the automation of industrial operations. A German working group having several individuals from various backgrounds developed a strategic application work plan to boost German industrial competitiveness globally. This work plan gave the German federal government the idea for its 2020 Strong Strategy, comprising of High-Tech solution. Within the German manufacturing industries, IR 4.0 aims to develop an enactment. To improve the efficiency and less needed manpower, the IR 4.0 implementation will provide a phenomenon to interconnect every mechanized automation through subsequent technological advancements to maneuver and share information. A concept called "Smart Factory" developed by the industry comprises the idea that the data storing, and decision making is carried out by cloud computing and cognitive computing. However, IOT has proven the proficiencies of IR 4.0 manifest vision by being functional with cyber-physical systems allowing the process of monitoring humans in real-time without being physically present [8].

Today, the Internet has revolutionized the usage and subsequent opportunities provided by computers, robots, and automation even though they still existed in the past decades. To revolutionize the management decision-making process, the principle of IR 4.0 is to devise smart operations and intelligent production pathways. These operations consist of the classification of data based on clustering neural networks performing scheduling for which grounds are provided by algorithms. Increasingly affordable solutions are required to gather, evaluate, and utilize data generated from monitoring the activities, operations, and processes of materials, employees, and equipment, including products, as well as in real-time decision making.

2.2 Industrial Revolution 4.0

The German government in 2011 introduced the terminology called Industry 4.0 which emerged as an advanced structure [9]. This structure uses shared data in the form of information and communication networks to automate the communication of information across processes and production. In the sense of innovation and qualitative nature, the fourth industrial revolution is taking place presently. As a matter of concern, the production process can be managed and administered through an integrated technique that shows the quantity as well as quality of the changes as it shows flexibility and combination. To accommodate the fluctuations and demands of the market and to remain competitive globally, the manufacturing firms need persistent evolution in their production system. As the industry becomes more digitalized, there is a growing interest in organizations investing in tools and developing solutions for integrating their processes, people, equipment, and products into a single integrated network. This network allows them to collect, analyze and evaluate the data that eventually leads to the company's development evaluation and upgrading of processes.

Various terminologies like the 4^{th} industrial revolution, Industry 4.0 is being used. The letter "4" describe the rise in digital technology of the industry. The attempt to create completely automated, wireless machine functions, that integrate an intricate array of digital tools, technologies, and programming languages that act in accord [10]. Information and communication technologies, mechatronics, electronics, data processing, and cyber-physical systems are being focused efficiently by Industry 4.0. The process of automation, robotization, digitalization, sensitization, and monitoring which develops the production and distribution procedure is effectively anticipated by Industry 4.0. Even though the technological methodological implications do not have to ensure clarity, some authors devised the concept and terminology for the construction sector as well called "Construction 4.0" [11]. As efficiency and effectiveness are the two main parameters in any development, industry 4.0 also focuses on its foremost purpose to improve in terms of automation and operation considering these parameters. The design, manufacture, operation, and servicing of inventions and organizations will all being affected by Industry 4.0. Artificial intelligence, big data, the Internet of things, sensor-based technologies, 3D printing, cloud computing, and advanced software such as Building Information Modelling are all part of IR 4.0.

2.3 Components of Industrial Revolution 4.0

Technology has played an important role in positively affecting human life although it has some disadvantages its positive impacts surpass the negative ones. Industrial Revolution 4.0 is believed to change the whole mechanism of the construction industry starting from design, productivity, execution, till maintenance. It is believed that it will open many new ways in the construction industry. The main vision of Industrial Revolution 4.0 is increased digitalization, automation, and the enormous use of information and communication through ubiquitous connectivity. Systems integration, simulation, additive manufacturing, augmented reality, cloud computing, cyber-security, autonomous systems, the internet of things, and big data are the nine pillars of Industry 4.0 [9].

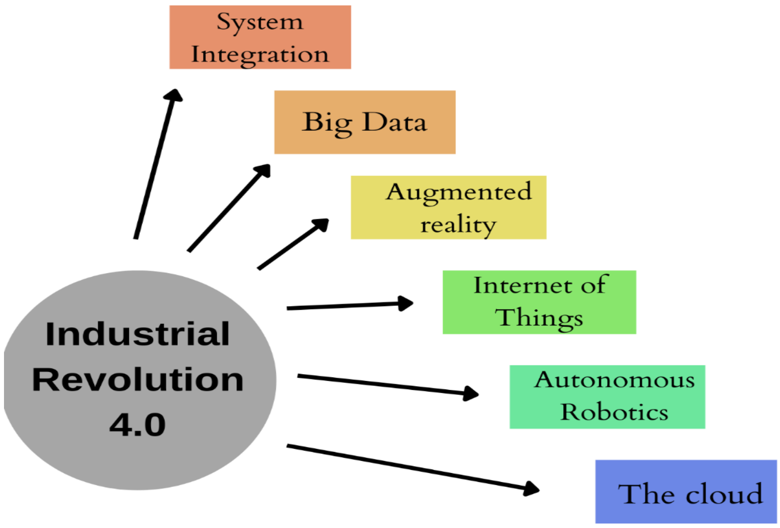

FIGURE 2.1: Major components of IR 4.0 [9]

During study, many aspects of the Industrial Revolution are encountered, such as artificial intelligence (AI), big data, cognitive computing, cloud computing, augmented reality, artificial intelligence, virtual reality, robotics, 3D construction, and so on. A variety of publications are examined to uncover the key components that constitute the foundation of IR 4.0, some of them are outlined below.

2.3.1 IOT (Internet of things):

Internet of things refer to the tool or technique that combines physical and virtual worlds with the help of different applications like sensors, cameras and many other devices. With the help of these devices one can monitor the actual progress of project throughout its life cycle. Sensors help in collecting the data and that data is transferred to the required system for analysis. The on site data generated from a construction site is used by the BIM model to supervise the construction works, thanks to the Internet of Things [12]. Internet of things (IOT) set-up, a gateway, and a data center constitute an IoT system. The sensor network is often used by IOT devices to communicate the sensor information gathered from sensors to a gateway [13].

Sensing data is sent to the cloud by gateway with the help of oblivious connectivity. Cloud analyses the sensing data, and the IoT gateway controls the actuator of the IoT device. As a result, multiple elements working together build an IoT system as a functional system. Sensors, actuators, gateways, lightweight apps, and other IoT parts are designed, deployed, and managed independently of cloud computing services that include data processing as well as storage [13]. The sensor-based method necessitates location detection, as well as human identification and authorization recognition. The use of sensor-based technologies to locate on-site individuals, machines, and workplaces is a common approach for enhancing construction safety. In terms of price and scalability, the GPS module (GPS)-based tracking technology is also used in restricted areas. Sensor-based locating devices, such as ultrasonic sensors systems, ultra wide band systems (UWB), radio frequency identification systems (RFID), and chirp spread spectrum (CSS) systems, are extensively used on dense and chaotic work sites [14].

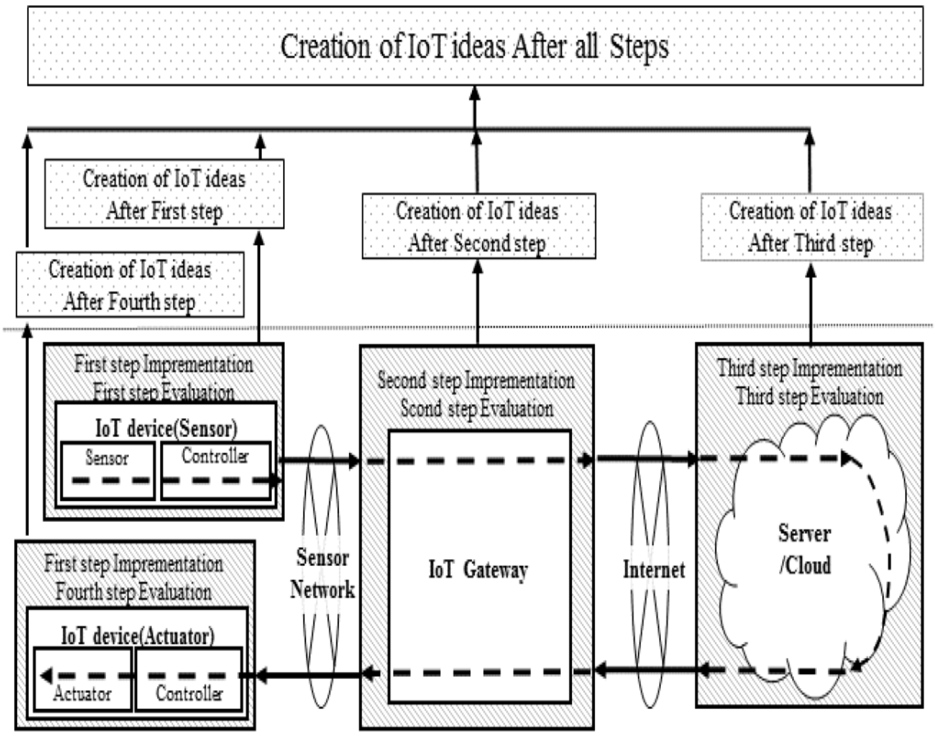

FIGURE 2.2: Describing IOT Mechanism and Working [13]

2.3.2 CPS (Cyber-Physical System):

The Cyber-Physical System (CPS) describes a broad range of intricate, physically aware, and versatile engineered systems of next generation that incorporate technologies for embedded computing (cyber components) into the physical domain. CPS is to establish a connection between the physical and cyber systems in areas where it is difficult to do so [15].

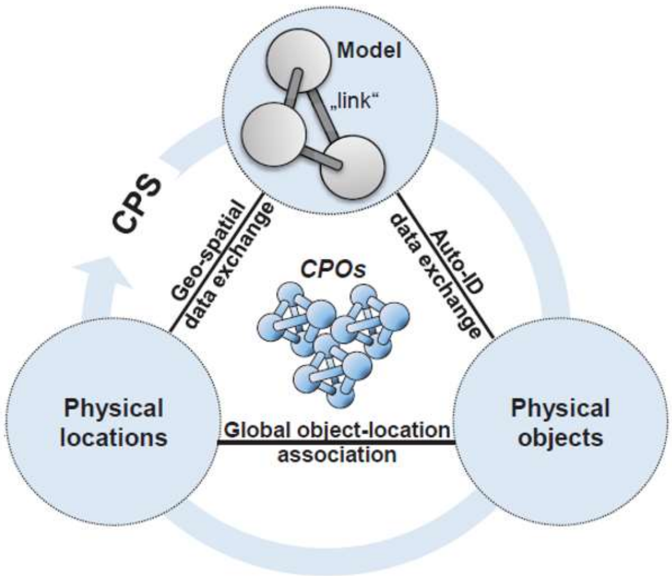

FIGURE 2.3: CPS-Concept [16]

A Cyber-Physical System (CPS) is a physical and engineered system that can control and monitor the physical environment. CPS is a wide field of engineering that supports applications through air transportation, emergency response, critical infrastructure, medicine and health care, robotics for service, intelligent transportation, and unique smart manufacturing.

CPS is revolutionizing innovative global manufacturing and allowing the transition from Industry 3.0 to Industry 4.0. In terms of cyber-physical systems, we are presently in the Industrial Fourth Revolution. Most current computing devices have embedded systems that monitor and manage physical processes like airplanes, cars, motorized highway systems, manufacturing plants, and managing air traffic, etc. [17].

2.3.3 Big data:

Big data refers to the information gathered during tendering and bidding, planning, design, construction, inspection before approval, and operation management phases of a building or structure. Big data is a type of information and communication technology [12].

A Variety of sources becomes the basis of this data generation, including the Internet of Things (for example, data streams from sensors or RFID readers), information systems (for example, BIM, PMS, and ERP), and previous project records. Big data has been created as a result of advances in digital. technology. Its importance isn't in managing large amounts of data, but in extracting the values concealed within them.

The 4Vs features of big data may be used to characterize it in general: volume, velocity, variety, and value. Big data in the construction sector applies to data created throughout the building or structure's life cycle, including phases such as planning, design, tendering and bidding, construction, project closeout, and operations management. These data originate from a variety of places including the Internet of Things (for example, data streams from sensors or RFID readers), information systems (for example, BIM, project management systems (PMS), enterprise resource planning (ERP), and previous project records and portfolios [12].

2.3.4 Virtual Reality

The graphical interaction between computers and people has been substantially enhanced because of recent improvements in computer display technology. People may now get a highly realistic perspective of buildings, infrastructure, and other graphical models by using virtual reality.

Virtual reality is an experience in which a person is encircled by a three-dimensional computer generated representation and can walk around in the virtual world and observe it from different perspectives, to reach into it, grab it, and change it [17].

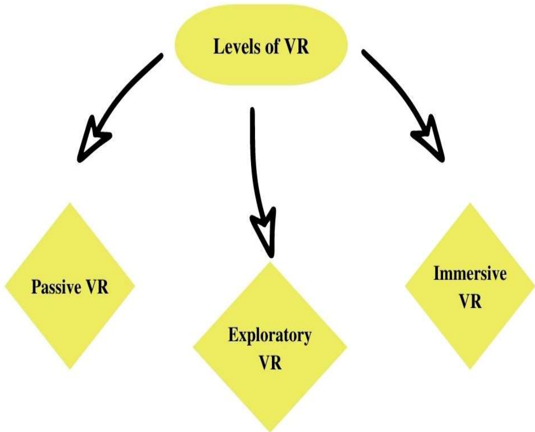

FIGURE 2.4: Levels of VR [18]

Different levels of virtual reality technologies have been defined by different authors. Passive virtual reality refers to spectator activities such as watching movies, Tv, reading books, etc. Exploratory Virtual reality involves interactively exploring a 3D environment solely through the monitor of computer. Immersive virtual reality is the one where the user can fully interact with an artificial environment, with all his senses being simulated and being able to directly affect the computer-generated environment [18].

Because of their simulation and visualization capabilities, many commercial VR technologies are now presented for the use by the Architectural Engineering and Construction sector in multiple domains and for multiple reasons, ranging from common desktop software to advanced immersive experiences. As BIM use and the availability of information-rich accurate 3d designs rises, a growing number of VR systems enable stakeholders and experts to easily access and explore a building's virtual prototype, primarily for better design communication and assessment. The application of these technologies to more specific problems, on the other hand, remains an open research subject [19]. Virtual reality in building is the next stage in generating 3D. It necessitates the creation of a detailed digital model of the project, like 3D modeling. In contrast to 3D modeling, It immerses the user in the virtual scenario, allowing them to totally immerse themselves in it. BIM According to leading AI textbooks, AI is the study of "intelligent agents," or devices that recognize their environment and take actions that enhance their chances of success.

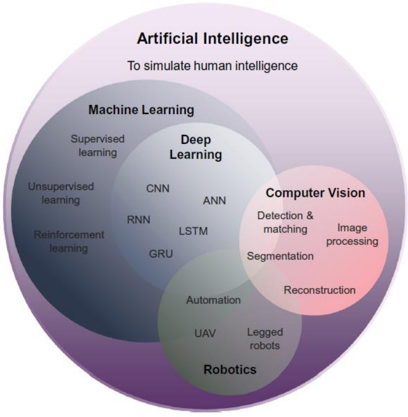

FIGURE 2.5: Illustration AI and Virtual Reality [18]

2.3.5 Cloud Computing

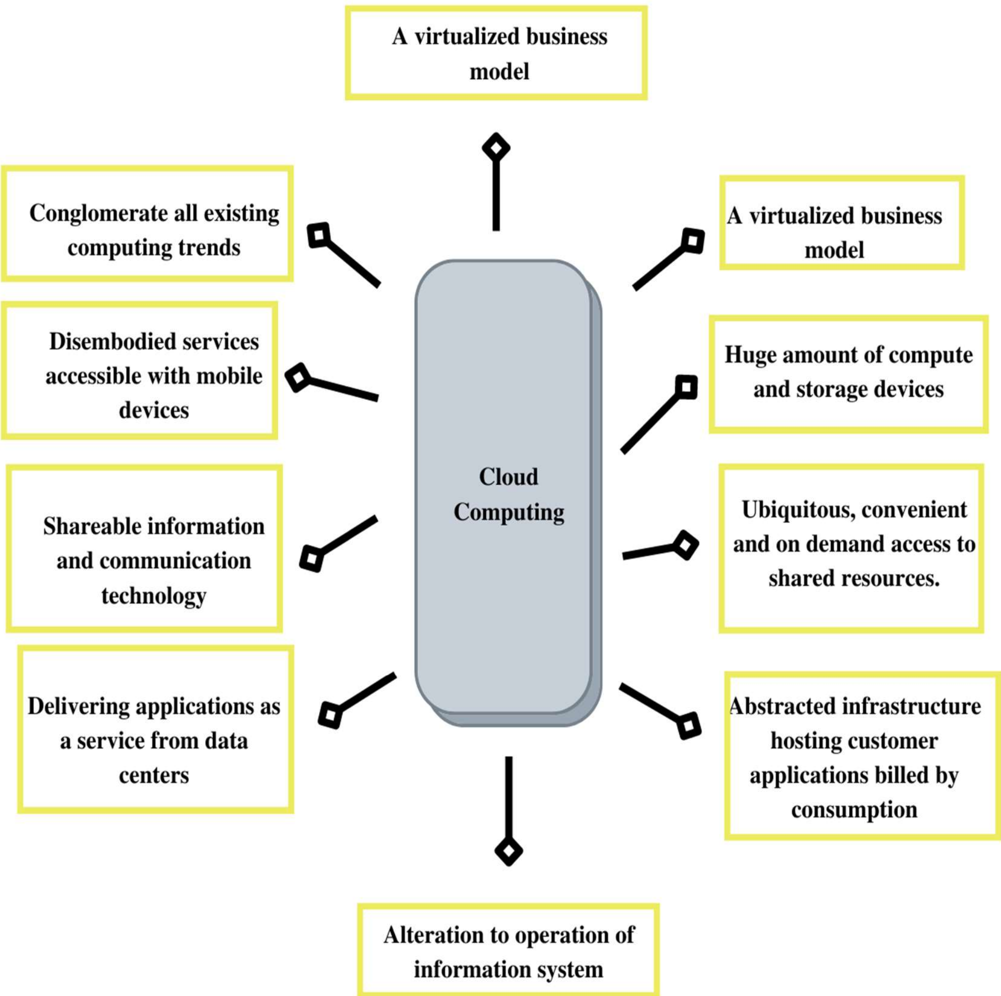

FIGURE 2.6: Cloud Computing Mechanism [20]

Cloud computing is a notion for swiftly supplying and releasing required network access to a whole pool of configurable computing resources (such as servers, networks, applications, storage, services, and applications) with minimal administrative involvement or service provider intervention.

The usage of cloud computing in the construction sector is a new domain with many opportunities. Work, time, and resource Scheduling allows cloud technology results in the reduction of execution time and enhance resource efficiency, which in turn results in cheaper resource costs and energy use.

The performance of the cloud task manager is linked well with the cloud data center; is closely related to the efficiency of the entire cloud computing services. Job scheduling takes into account job characteristics such as job length, job execution time, and so on.

Cloud computing enables a construction company to obtain IT solutions as services that are tailored to the specific demands of a building project at the appropriate moment. Construction projects generate a large amount of data, starting with the design stage, when several modelling simulations are required to merge the owner's building vision into a realistic design by the professionals.

The use of emerging technologies such as the IOT, 5D BIM, and virtual reality generates massive volumes of data in real - time. Drone photographs of a site that would consume points on a cloud service would demand hundreds of GBs on a standard PC. Construction works are carried out by several work groups, each of which has a set of business reporting models, which are kept in distinct silos. The availability of widely scattered data makes it harder for market participants to make quick and critical judgments.

This has led to cost variances, poor planning, project delivery delays, and a worse Return on Capital (ROI). A centralized library is offered by the cloud for construction statistics for an end-to-end encrypted solution that increases the effectiveness and management of the construction sector. Construction employees may participate more actively and the project team can stay organized and effectively integrated if they have access to up-to-date project data [17].

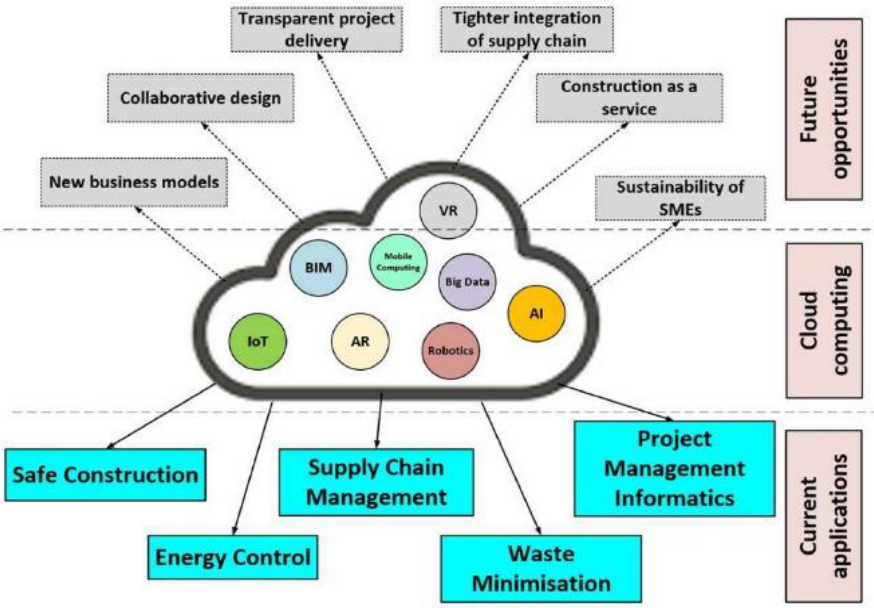

Figure 2.7: Applications of Cloud Computing [20]

2.3.6 Smart Factory

Intelligent manufacturing technologies are production systems that are extensively automated and IT-driven [21]. Manufacturing organizations should increase output and sales, enhance the stability of the manufacturing process, and reduce manual participation in the workshop in order to construct the smart factory. The smart factory may achieve adaptable manufacturing, flexible reconfiguration, and efficient production with the analysis of manufacturing data, all of which are targeted at modifying the system to changes in business model and client procurement behaviors. The Internet of Things (IoT) is used to combine the underlying equipment resources in the construction of smart factories. As a consequence, the manufacturing system includes perception, connectivity, and data integration capabilities data analysis and logical conclusions are used in smart manufacturing to achieve equipment maintenance, product quality control, and scheduling. Furthermore, the Internet of Services is being utilized to virtualize manufacturing resources by transferring them from a local database to a cloud server. In general, smart manufacturing, which is based on digital and automated production, employs information systems (such as cloud platforms and IoT) to improve industrial resource management. IT systems, digital modeling, equipment infrastructure, and data usage are all part of a smart factory [22].

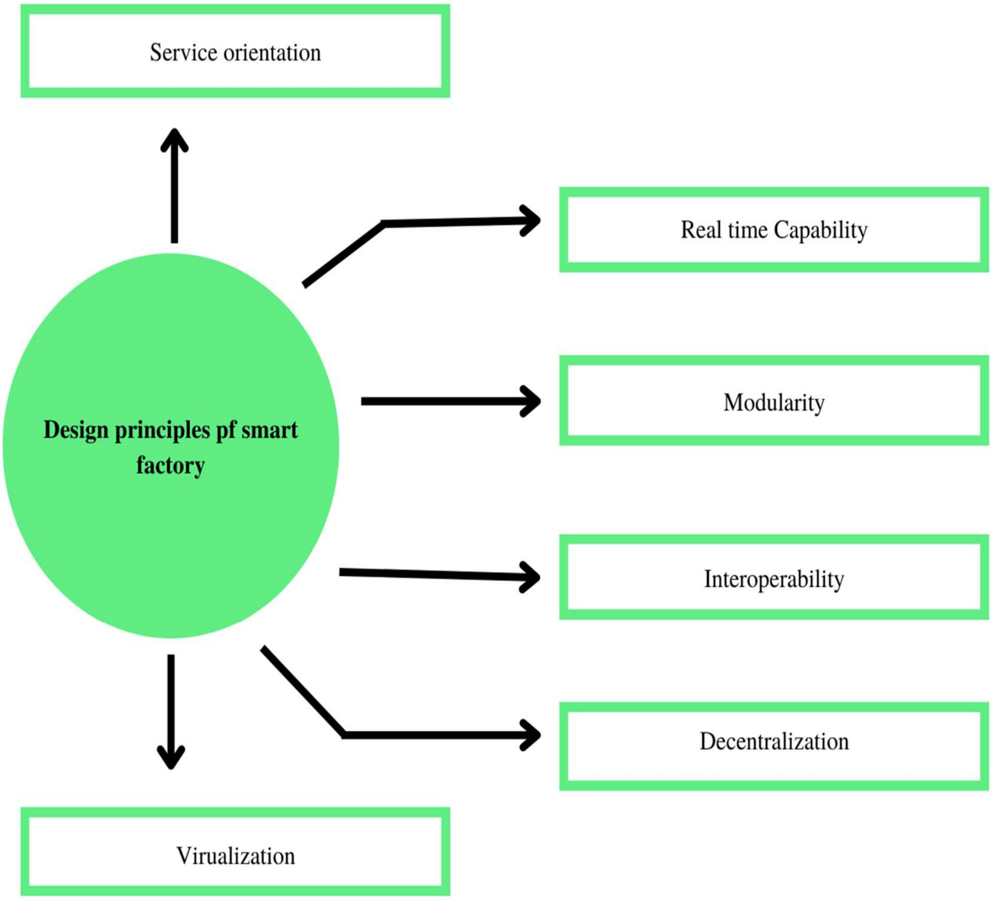

Figure 2.8: Design principles of smart factory [23]

The design factory comprises of some fundamental principles essential for the design. These principles are termed as Real Time Capability, Modularity, Interoperability, Decentralization, Virtualization, and Service Orientation. Real Time Capability is often termed as responsiveness and the name indicates; that it is considered for the systems capability to respond to alterations provided to it at specified time. These alterations might include the changes in the requirements of customers and simultaneous malfunctions and resource failures of the system. The response of the system considering all these unpredictability to internal changes and the controlling of these events along with monitoring them in real time is the main concern. As a matter of concern, the system should recover immediately after the change has been reported. Secondly, Modularity is considered as a vital approach to design of system as it efficiently is responsible for combining and separating the components of the system. Higher modularity means integrating the modules or components abruptly which should be a main component in smart factory system. Thirdly, the Interoperability as the name indicates deals with the inter connection of system components in order to share information within these components typically technical. For instance, considerably sharing information regarding business between customers and manufacturing enterprises can make the system more reliable, efficient and responsive. Additionally, the change in business situations and environments will have a colossal effect on the strategies used in a system design. The employees can decide based on these changes, the strategies to be adapted considering mundane matters timely. Virtualization is also an important design principle while structuring a smart factory and system that is responsible for engendering artificial factory environment. This environment would consider CPS much like the actual one and will effectively simulate and monitor processes involved in system design creating digital prototypes and eventually enables strategic implementations with the help of those simulations. Finally, as we are aware that the main idea of the manufacturing industries was previously focused on selling products while now it has been shifted to selling services along with products with equal contest. Using this strategy the profit margin can be achieved on a better scale making this design principle fundamental in design a system based on smart factory [23].

2.4 Commonly Occurring Issues in the Construction Industry

In compared to other manufacturing industries, the construction sector confronts several hurdles, resulting in a significant lag and setback in productivity. In fact, the construction industry is one of the least automated in the world, and most investors recognize the industry's lengthy history of reluctance to change. Managing a Project in construction sector is more complicated and time-consuming than it needs to be due to a lack of automation, digitalization, and the industry's largely manual nature [24]. Expense inefficiencies, time overruns, bad quality performance, misinformed decision-making, and poor productivity, health, and safety performance are all because of lack in proper digital skills and innovation initiatives in the construction business. The Construction industry is well known for its rigid nature. In all industries, construction is the last one to adopt new technologies and changes [20]. Pakistan comes under the category of underdeveloped countries. Although it is trying to grow rapidly and meet up with the pace of a fast-growing country thats the reason behind the reluctance to adopt technologies. Adopting new technologies is a great risk due to increased costs. This low adoption can be the result of the misalignment of incentives. Possibilities are limitless but still being a 3rd world country, it is a huge risk to adopt new and costly technologies. In some industries, underdeveloped technologies are being used but people are unaware of the immense uses of that technology. They do not explore them because the risk associated with exploring them is too high now for them. They could be imploding in different sectors, but their use is still scary. In some cases, people are using software like BIM which is the manifest of Industrial revolution 4 but unfortunately, they are in oblivion about the industrial 4th Issues connected to CI are described in the table given below:

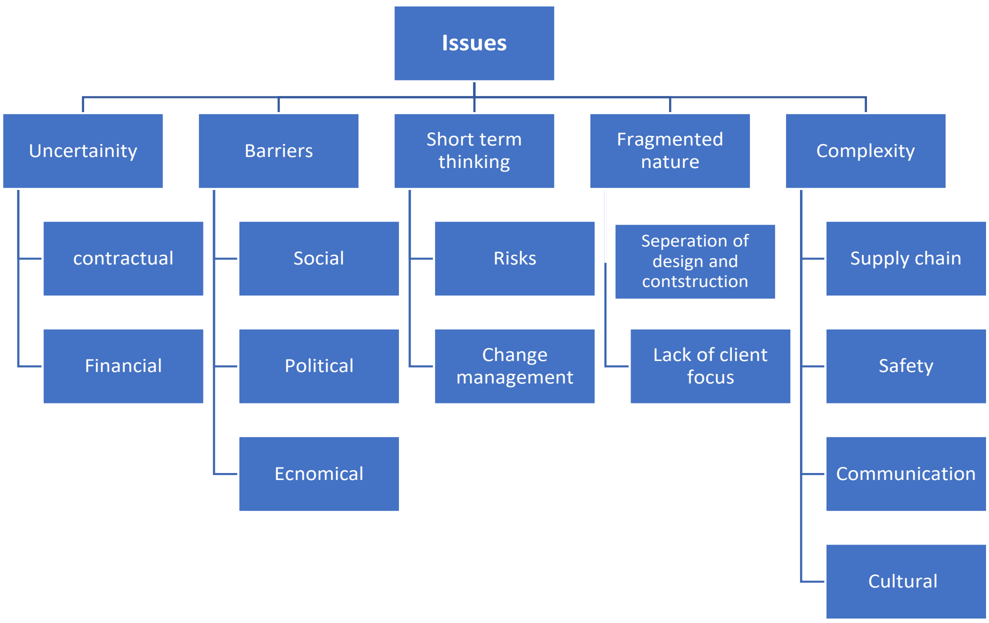

Figure 2.9: Commonly Occurring Issues in Construction Industry

Obstacles to intelligent construction are as following:

1. Uniqueness of project; as every construction project is unique. Normally in other industries you create the same product, you give the commands to the machine or technology and produces the massive amount of same product, but that can't be done in construction as every site is different, every building is designed for different purposes, different conditions and for different uses. To build an integrated intelligent system, it is better that every component is modular and reusable, although this is a challenge under the current technical conditions.

2. Discreteness: construction project are not one go projects. They are complex and involve multiple parties, contractors, and subcontractor. Activities which are linked together and often share the same resources and man power, these all factors make construction project highly complex. In most of the cases information does not flow accurately and wisely down the hierarchy.

3. Uncertainty and risks but Industrial revolution 4.0 develops a concept called smart factory, where cloud computing and cognitive computing stores data and make decisions thus increase the efficiency of work. BIM originated from computer-aided design (CAD) and has now evolved into an innovative technology that supports the whole life cycle of a construction project by providing a virtual model and relevant information about buildings. It helps in visualization of ones need and demands thus, decreasing the risk factor [25].

2.5 Applications of IR 4.0

2.5.1 In all Industries

Industrial Revolution 4.0 is built on digital uprising revolutions, with its primary feature of uniting digital technology and society under one cover [26]. The IR

4.0 is an inevitable worldwide phenomenon that will have a significant impact on governments, industries, and economies.

Technologies are meaningless unless they result in new business models, revamped business processes, services, and work systems that are tailored to the unique features of each organization or area of the economy [27]. Industry 4.0 aims for a good degree of interconnectedness across all processes and products throughout their lifespan. Humans, technology, product, and methods are all self-organizing and interconnected regarding production. This enables an integrated reaction to change as well as the incorporation of regenerating planning into management systems [28].

Industrial revolution 4.0 doing wonders in every field. how the world works is changing again for the fourth time in its history. IoT also allows tracking, and monitoring, simultaneously giving real-time geolocational data resulting in request alerts to customers. If a merchant puts their store's location into the database, virtual assistants like Google Assistant, Alexa, and Siri will notify consumers that nearby retailers have the goods they want. when the Internet of things is incorporated into an ERP (Enterprise Resource Planning) system, we can provide services to end customers such as order automation and product delivery to partner organizations, as well as data storage, retrieval, and analysis all of which fall under the purview of traditional business intelligence.

RFID is a tracking and identification technology that uses radio waves to send data from an embedded electronic, placed to an object to a reader. RFID technologies have been widely used across Europe and the United States' supply chains, proving their capacity to assure data correctness and minimize the bullwhip effect, out of storage, of shelf phenomena, and inventory turnover and restocking processes.

Big data analytics (BDA) assists businesses in illustrating customer behavior, understanding their preferences, developing appropriate marketing strategies, identifying sales transactions, and promoting a long-term commitment association. They also seek to construct a customer loyalty projection utilizing BDA to loyal consumers and enhance profitability, since a loyal client contributes an extra 25-100 percent in income. Nike is a corporation that manufactures athletic footwear, apparel and equipments, they have devised a system and utilize the tool of augmented reality to allow their customers to construct and customize their shows based on their preferences and willingness.

With client activities online or in-store, transaction data is evaluated, and businesses obtain a better knowledge of consumer behavior and preferences. With the aid of AI, vendors can easily leave storefronts unattended, saving a great deal of money on staffing expenditures [29]. Manufacturing operations, as well as procurement and logistics processes, are improved by providing services such as distant and predictive maintenance and predictive maintenance. New partners may be recruited without spending a fortune and with a lot less work [30].

Smart materials are not the talk of the town that includes UV photochromic glass, self-adhering materials, Polyurethane, Pressure-sensitive paints (PSP), Thermochromics paints and pigments, and much more. Nowadays, digital twins (DT) are used in a variety of applications and even used to forecast the structural life of an airplane [31].

The unification of physical and virtual elements improves the functionality of the project and gives competitive advantages such as higher productivity, reduced operating costs, and fewer failures. The application of digital technology enables the monitoring and tracking of items, people, equipment, and gadgets. Companies may use these technologies to obtain a significant volume and variety of data about product performance.

According to studies, a firm “ready” for DT adoption invests more than 5% of its revenue in digital technology [32]. From an agricultural point of view, studies have suggested that optical sensors might be used for examining vegetables, crops, and fruits with the aid of machine learning algorithms. Machine learning, according to studies, has yielded superior results in agricultural applications such as image identification (leaf sorting) using robotic devices and fruit detection, classification, and tallying. [33].

2.5.2 In Construction Industry

The building project task is undertaken in a highly automated workplace that depends significantly on motorized handling of materials and lifting. The industry has high reliance on cranes as the primary mode of material movement on worksites has been connected to the increasing industrialization of building processes and off-site manufacturing of (sometimes massive and heavy) modular components [34]. Immersive technology is useful in worksite safety training.

In one of the studies on prevention through design by Collinge et al. (2022), it has been recently discovered that workplace hazards can be prevented with the aid of designers, by adopting safety in design or prevention through health and safety designs. In this context, the BIM hazard identification library contributes to the provision of digital solutions for improving health and safety culture [35].

Untrained workforce at sites, lack of understanding of architects, designers, and engineers to experience a project before it is performed in actual world directly tied to the key challenges that develop in construction sector. In today's design and construction practice, a range of immersive Virtual Environment (VE) supporting devices is employed. One of the VE extensively employed in the A&C industry is HMD-based VR. HMD-based VR is utilized to create a genuinely immersive world by projecting a real 3d graphics display onto both viewers' eyes. The CAVE system, which includes a huge, stereo projection system that incorporates the use of lightweight highly polarized glasses, is another sort of immersive technology employed in the construction industry. Immersive Virtual reality is being used as a successful technique in constructing mock-ups of a project to analyze and fix concerns in design phase before the structure is constructed. In the A&C business, communication and consultation with stakeholders have historically relied primarily on visual tools such as sketches, two-dimensional (2D) drawings, and graphics. Furthermore, technological breakthroughs, such as Building Information Modelling (BIM), enabled 3D projections of designs which significantly altered this industry. A commercially developed VR system uses Immersive Technology for overhead crane operator training. Drone and Immersive Technology use in aerial surveillance for construction operations such as site surveying, progress monitoring, work inspection, logistic planning and coordination, and risk assessment has also increased. The author claims that using Immersive Technology integrated drone monitoring may increase safety managers' productivity by 50% [18].

Construction is a comparatively less technologically developed industry, and its project management is renowned for its poor performance like irregular value generation, bad quality, frequent time and budget overruns, poor safety records, and workplace conditions. Several attempts have been made throughout the years to fix this unfavorable situation, but none have been successful. The introduction of production management tools such as value engineering, value management, quality assurance, and safety management, as well as the well-known project management tool: CPM (construction project management), and several inventive cost management systems, has resulted in slight developments in the best cases. Some advantages of the IR 4.0 have also been used in construction. Most construction companies now appreciate the implementation of IR 4.0 technologies and strategies to increase their profit. Contrary to developed industries' acceptance of technology, the construction sector is infamous for its reluctance to new ideas. This apprehension stems from several factors, including perceived massive costs associated with implementing emerging technologies, training resources, the need to apply technical innovations and changes, and a reluctance to disrupt entrenched construction industry systems, processes, and procedures. Early developers are required to lead the way in the adoption of new technologies, thereby stimulating broad acceptance by top competitors and increasing the bar for productive capacity, presentation, and/or safety. Before the Industrial revolution 4.0, experts found that workers in industrialized countries are overworked, with late-night hours or being asked to take work home. Workload harms work-life balance, lowering worker productivity and endangering workplace safety. The growing attention on and appreciation for the significance of wellness in the construction industry is not matched by reality, as a lack of work-life balance is particularly terrible in the industry. In response, proponents argue that IR 4.0, as part of advanced and smart manufacturing methods, has automated the entire business, easing human managerial obligations [36].

FIGURE 2.10: Industrial Revolution 4.0 related Technologies [37]

The construction industry is among the industries that contribute to a country's Gross Domestic Product (GDP) through facilitating capital trades and appropriate management procedures. Industry 4.0 is a type of technology and concept that uses smart manufacturing, simulation/modeling, and digitalization to optimize the construction process and create new construction environments. Despite the numerous benefits offered by other industries, the construction industry has been unwilling to incorporate these concepts. Even in this complicated construction environment, the construction industry has shown hesitation to implement IR 4.0. Industry 4.0 implementation in the construction industry is estimated to boast productivity levels and profits as the industry develops. Because the area of study is still developing, there is little research on the uses of Industry 4.0 in construction engineering, which demands further analysis. Despite the apparent advantages, in many countries, particularly underdeveloped ones, construction industry is still trying to integrate IR 4.0 concepts. In the construction industry, there are a few issues that lead to conflict. Complex nature of construction projects, unpredictability, a fragmented supply chain, short-term thinking, and culture are all contributing factors. Construction projects are complicated due to the impact of numerous parties on every project. The level of complexity in a project is also determined by the project's unpredictable surroundings, which adds complexity. Building companies' fragmented supply chains and short-term thinking have hindered their capacities in areas where the brief nature of construction projects is an obstacle to advancement. Whereas the construction industry's culture is renowned for its hesitant adaptation techniques.

Construction comprises many individuals with a wide range of interests, skills, and experiences. The basic trio consists of owners, designers, and contractors, with subcontractors, material suppliers, financiers, insurance and bonding firms, attorneys, and public agency officials serving as support. This construction executive team will go through numerous stages of the project life cycle, including market research, conceptual planning, design, procurement, and construction, a startup for occupancy, operation and maintenance, and disposal. Building information modeling (BIM) has become the core of the project thanks to IR 4.0, which has brought construction digitalization. BIM is portrayed as an excellent platform for the creation of strong and creative applications for the engineering and construction (AEC) sector.

During construction works, management must make several interdependent decisions at the same time, and with the help of IR 4.0, effective and efficient decisions could be made. In the last three years, the use of digital approaches in design and construction has begun to evolve, and for many organizations, it has already become the norm.

The instantaneous handling of real-time information exchange and communication synchronization enabled by the Internet of Things increases the flow and distribution network of building materials, hence providing a higher line efficiency. As a result, manufacturing costs will be kept to a minimum, and profitability will grow as investments are properly allocated. Because investment monitoring and execution are managed through a computerized method, an automated control system aids the performance of long-term projects and so allows management choices to be less demanding and laborious. Preceding the introduction of IR 4.0, the global construction industry faced issues such as late deliveries, poor quality, and ineffective financial planning techniques; however, with the adoption of technologies, the story has changed, resulting in a satisfactory outcome and, as an outcome, making sure management's efficiency.

2.6 Barriers to Implementing IR 4.0

The main impediments are an employee and top-level management fear of losing their jobs, a lack of IT training, a bad Information Technology infrastructure, and an absence of appropriate internet availability and speed. A closed and rigid organizational hierarchy and structure with restricted knowledge exchange; an unawareness of the Industry 4.0 notion and its advantages and drawbacks; the inability to properly indicate the successful results of digital projects, for example through payback and Return on investment calculations, As a result, the company's board of directors struggles to approve budgets; and the inability to alter people's perceptions, particularly those at the strategic planning level, just so they comprehend and act on the relevance, the need to enhance people's abilities for them to grasp and apply specific digital solutions for the needs of the company, as well as reluctance among individuals at various hierarchical levels to shift their attributions and duties [28].

Retail 4.0 adoption varies by a less developed country, developing country, and developed country. Retail 4.0 is widely used in industrialized nations such as the United States, the United Kingdom, and Europe. However in LDCs with a limited internet connection, it appears that adopting these technologies will be difficult. Consumers and companies are unable to capitalize on rising e-commerce potential due to continuous obstructions and impediments such as high-cost internet services, an over-reliance on cash, a shortage of trained workers among the public, and government inattention. Governments must emphasize national digital readiness in order to allow more small businesses to engage in the digital economy as producers rather than just consumers [25]. In a few studies, trust concerns were encountered that are unwillingness to communicate data, particularly strategic data [26]. The high initial cost of this technological advancement along with the ambiguous rate of return makes it more complicated and less adaptable [27]. Collaboration with the other technical employees is required to have a deeper grasp of these technologies and to discover them thoroughly.

The road to widespread adoption of the Revolution 4.0 production idea is still lengthy. There are just a handful of Revolution 4.0 firms, largely new ones established to showcase the concept, with the construction industry still lagging far behind. The main challenges of the construction industry in the era of Revolution 4.0 are a lack of government policies, high implementation costs, unreliable broadband connectivity, low awareness of Industry 4.0 and its applications among companies, increased metal production, and concerns about losing control over your company's intellectual property [34].

2.7 Research Gap

The basis for the 4^{th} industrial revolution has been laid by the increasing integration of Internet technologies and concepts into the industrial environment. In comparison with other, IR4.0 is perhaps one of most associated with the use of the Internet of Everything in industrial organizations. However, even the idea's leading lights, the Industry 4.0 Working Group, only describe the vision, the fundamental technologies the concept aims to accomplish, and chosen scenarios, without setting a detailed definition. As a result, there has yet to be a widely agreed concept of IR 4.0, preventing an I4.0 transition.

Despite all of the advantages outlined above, there is still a research gap because no laws and regulations on the application of Industrial Revolution 4.0 have been established as of yet. Furthermore, research has been conducted on how BIM may be used to increase productivity, but no comprehensive study on its actual implementation has been conducted. It is obvious that how buildings are modelled in the virtual world differs significantly from how they function in the actual world; this disparity is known as the performance gap.

2.8 Future Prospects of IR 4.0 in Construction Sector

Industry 4.0 is a brand-new ideology that is bringing societal transformation and having an impact on everything from security to education to research to the labor market and the social structure. The managerial perspective is handled in the construction sector in a variety of ways, including strategic planning, financial advisory, and final assessment. Management optimization models at the corporate level, on the other hand, remain a research issue for the future. Modern business handles not only the issue of self-production, but also the issue of attendance and energy. At the optimization plan level, the interoperability of the separate pieces of the process should be addressed. Service can also be provided remotely. In wealthy nations, there is a manpower shortage in the building industry. An up-to-date strategy known as "age management" may be used to overcome this problem.

This management strategy looks for potential employees among the elderly. Another area for further investigation may be open communication and cultural awareness. It was stated at the 2015 "The Fourth Industrial Revolution" meeting (World Economic Forum Annual Meeting 2015) that modern technology has made globalized communication commonplace, and that openness and respect for other cultures that need to interact with one another is now one of the arrangements for technological advancement.

2.9 Summary

This chapter presents an overview of industrial revolutions, covering the major concept of Industrial Revolution 4.0. Applications for this new revolution and its developing tendencies in various industries, including construction. There are differences of opinion on its real implementation and uses; all viewpoints have been discussed in an elaborative manner to obtain a wider and more in-depth view of the scholars.

Chapter 3

Research Methodology

3.1 Introduction

This chapter describes the methodological framework adopted to complete this research. The methodology comprises of literature review done by studying Industrial revolution 4.0 and its growing trends in the construction industry, especially in Pakistan. The questionnaire has been developed by literature review and the Delphi technique has been adopted for the collection of data. This research would help in better use of Industrial Revolution 4.0 in the construction industry and especially in Pakistan. The below-mentioned sections describe the details of the methodological framework that has been adopted to carry out this research.

3.2 Research Design

A detailed literature review was carried out in order to formulate the theory of this methodological framework. A brief introduction to Industrial revolution 4.0 was studied to get the basic knowledge about it. DMAIC system was adopted, which stands for define, measure, analyze, improve, and control. Define industrial revolution 4.0 from the perspective of the construction industry. Measure the demographics of the respondents who participated in the questionnaire survey. Analyze the responses gathered about technical data. Improve by making recommendations based on your findings. Control by indicating the region that needs extra attention [7].

The PEST analysis approach is used in this article to assess the challenges and opportunities for Industrial revolution 4.0 in the construction industry of Pakistan. PEST analysis is a well known business approach for "understanding the external macro-environment in which a business works." The potential advantages of using this technique include directing strategic decision-making and establishing a competitive edge, as well as achieving positive alignment with external factors and avoiding mistakes that might undermine effective performance [35].

Commonly occurring issues in the construction industry were determined and improvements via different Industrial revolution 4.0 technologies were outlined. The Survey technique has been adopted by using questionnaires for data acquisition from clients, consultants, and contractors from both public and private sectors collectively. Delphi technique was used to shortlist the contributing factors and for the development of questionnaires. The pilot study was carried out, different responses were collected and upon those few amendments were made to the questionnaire. Data obtained was assessed by using statistical methods. Descriptive research was adopted to carry out this research for evaluating the impact of the new generations technology in the construction industry. Results and conclusions were deduced after data analysis.

3.3 Preliminary Study

To grasp the basic knowledge, new industrial revolutions and their impacts were studied thoroughly in the literature review. Basic knowledge and the innovations it offers and can offer to the construction industry, by elaborating its hardcore components; were studied in depth through a literature review. The problem statement was laid out, and the research direction was outlined.

Figure 3.1 give a detailed diagrammatical presentation of the scheme adopted to conclude.

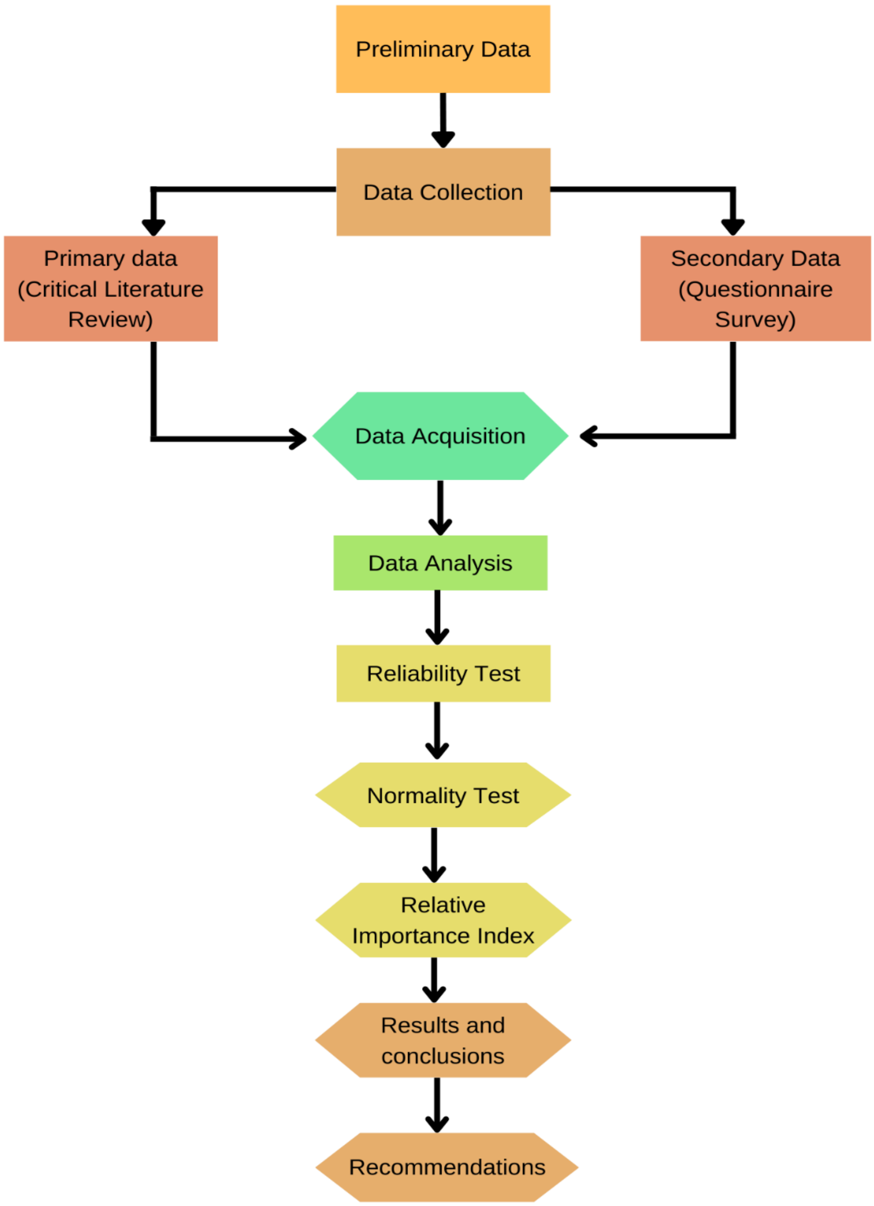

FIGURE 3.1: Research Methodology

3.4 Data Collection

After setting goals and collecting our desired data about Industrial revolution 4.0, through literature review, comes the next stage, which is data collection in which data is collected from the field, which focuses on our aim and objective of the research. Primary and secondary data have been collected to proceed with this research.

3.4.1 Primary Data

Primary data is collected with the help of a questionnaire survey by considering the goals and aims of this research endeavor against our major components of project management.

3.4.2 Secondary Data

Secondary data was collected with the help of a literature review for outlining the goal and ambitions behind this research work.

3.5 Questionnaire Development

Major influencing components of industrial revolution 4 were outlined with the help of critical literature review. Those factors were again filtered depending upon their frequency of occurrence and their impact. After finding out the major components, components were further filtered through repetition.

The questionnaire was prepared the light of the facts collected through data. Delphi technique was adopted for data collection. The data was collected from the public and private sectors, contractors, consultants, and clients. A pilot study was conducted based on the response some necessary changes were made to the questionnaire. A revised questionnaire was again sent for responses through a direct approach, online responses.

Delphi technique is one of the group decision making techniques, which help you to take information from different stakeholders, experts and helps in making a better decision. In Delphi technique, a members of panels of experts responds to questions and to each other until reaching an agreement.The theory behind Delphi technique is that you take a group of knowledgeable people and give them a numeric problem, they will work separately to come up with group consensus if given access in a series of rounds to the group's current consensus.

Delphi technique is one of the group's creativity technique. It helps in getting the responses and opinions from diverse group of experts. As the responses that are collected are anonymous, its not necessary to gather the people for physical meeting, rather it is an indirect communication that offers conservations including written inputs that is cherry on the top; helps in more extensive and feasible data collection.

3.6 Likert Scale

For gauging the responses, gathered through questionnaire survey, Likert scale was used which comprises of the flowing criteria;

Table 3.1: Likert scale [36]

Sr. No	**Description**	**Score range**
1	Strongly disagree	1
2	Disagree	2
3	Neutral	3
4	Agree	4
5	Strongly agree	5

3.7 Data Acquisition

The questionnaire was developed by using gathered data. The survey was conducted. The questionnaire was sent to different field experts, contractors, clients, and consultants, both in the public and private sectors of Pakistan. A pilot study was conducted initially and based on the responses of the professionals questionnaire was revised.

3.8 Data Analysis

A statistical package for social sciences (SPSS) was used for analyzing the data collected through surveys by professionals from all over Pakistan.

3.9 Data Analyzing Tool

For analyzing the data collected via Questionnaire survey, the SPSS system has been adopted. SPSS is the abbreviation of Statistical Packages for social sciences. It was firstly introduced in 1968 [37]. The effective features of this software include its efficiency and ease to use, which make this software accessible that can be a very good option for solving different mathematical calculations. This tool helps tackle parametric as well as non-parametric data, along with comparative and correlational arithmetic data experiments [38].

SPSS collects recorded data to produce the desired analysis. It can produce reports, charts, and descriptive figures using gathered data [39]. SPSS thoroughly understands the data and interprets it in a very well-defined manner, furthermore, it can resolve complex problems in research [40].

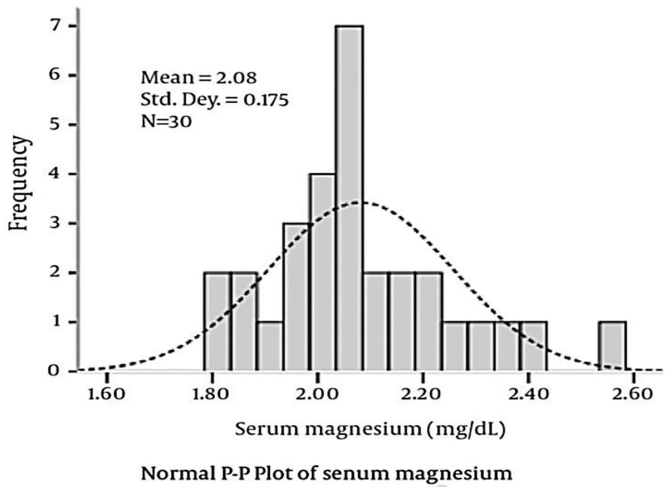

Figure 3.2: Normality plot for serum magnesium [29]

3.9.1 Reliability Test

A reliability test is used to determine the accuracy and steadiness of collected data. The reliability test is among the fundamental tests that are conducted to verify the reliability of the results. It is the test that ensures the consistency and stability of measured data. It is used in evaluating the dependability of a score used to summarize data from several items in surveys [41].

Cronbach alpha is primary for the reliability test. The more value closer to 1, the more its shows accuracy. In a statistical study, Cronbachs alpha data sets are often used. The following table shows the range of Cronbach's alpha [42].

Table 3.2: Reliability Test Range

Internal Consistency	**Description**
Excellent	$\alpha \geq 0.9$
Good	$0.9 > \alpha \geq 0.8$
Acceptable	$0.8 > \alpha \geq 0.7$
Questionable	$0.7 > \alpha \geq 0.6$
Poor	$0.6 > \alpha \geq 0.5$
Unacceptable	$0.5 > \alpha$

3.9.2 Normality Test

This is the test is used to describe the normality trend of data, whether the data is welltransformed to normally distributed. The test of normality is an important step in determining the mean and standard deviation and statistical techniques for data analysis for continuous data set. In case data has a normal distribution, parametric tests are employed to compare the groups; otherwise, nonparametric approaches are utilized [24].

3.9.3 Relative Importance Index (RII) Determination

This study adopted the relative importance index (RII) value to conclude the importance of the most significant industrial revolutions 4.0 factor in the construction industry of Pakistan. [32] It is used to explore and establish rank-wise the intensity levels of factors of IR4.0. The specific value of each factor has been evaluated by summarizing the data set given by the respondents. The intensity level was measured through the Likert scale, and that intensity level chosen by respondents was then used to evaluate the relative importance of every factor. The ranking scale which was from 1to 5, was converted into a relative importance factor for every factor to examine the rank of all selected factors. The following equation is used to measure RII:

$$RII = \Sigma W / A \times N$$

Where,

ΣW = Weightage given by respondents to each attribute.

A= Highest chosen value in factor i.e. 5 in Likert scale used.

N= Count of total Number of Respondents

Table 3.3: Relative Importance Index Range [43]

Factor	**Values**
High (H)	0.8 < RII < 1
High-Medium (H-M)	0.0.6 < RII < 0.8
Medium (M)	0.4 < RII < 0.6
Medium- Low (M-L)	0.2 < RII < 0.4
Low (L)	0 < RII < 0.2

Chapter 4

Results and Discussions Introduction

Introduction

The following information may be found in this chapter: To evaluate the level of significance or agreement of the structured questions, the data was analyzed using Statistical Packages for Social Science (SPSS) and Ms. excel. The respondents' demographic data has been discussed in this chapter. The awareness of the new revolution (IR4.0) has been evaluated. The results deduced from the questionnaire study on industrial revolution 4.0 focusing on PEST analysis have been discussed in this chapter from the perspective of the client, contractor, consultant, and others.

4.1 Section A: Survey Data Collection and General Analysis

This stage includes the collection of data. A questionnaire survey is used to obtain data. A questionnaire with three primary components was created for us. Part one contained the demographic information of the respondent. Part two was to evalaute the awareness about industrial revolution 4.0. Part 3 covered the technological aspect consisting of the PEST framework. A total of 160 questionnaire surveys were circulated to collect data out of which 106 actively responded which is greater than the minimum sample size of 96 [44]. Because there was no set frame for sampling in this investigation, a non-probability sample was employed. A response rate of 66.25% was observed. This section mainly addresses the data gathered about respondents general information, such as gender, age group, organizational type, working experience, educational background, and knowledge about industrial revolution 4.0.

4.1.1 Demographic Data and its Analysis

The gender component, which is always an important factor in society, represents gender equality. As a result, it is an important part of demography since it differentiates between male and female demographics. Demographic data help in ensuring gender equality. Figure 4.1 represents the ratio of males and females who became part of this research. Out of 106 respondents, 13% were female and 87% were male.

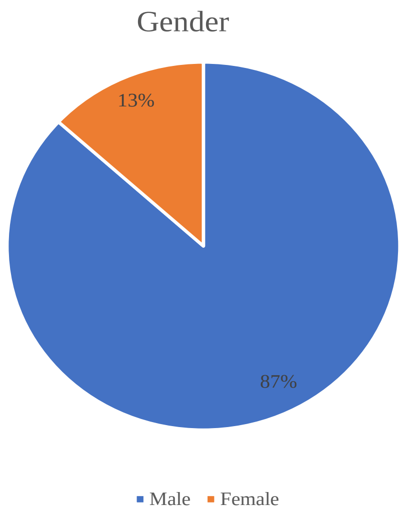

FIGURE 4.1: Ratio of Gender Response

Figure 4.2 reveals the age of the individuals who took part in the questionnaire survey. 69% were from the age group 20-30 it is quite evident from the data that mostly young and enthusiastic people became part of our research. 20% were from 30-40, 6% were 40-50, and 5% were 50 and above.

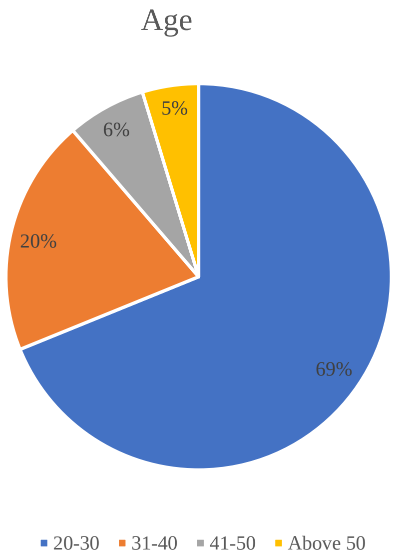

FIGURE 4.2: Age of Respondents

Figure 4.3 discloses the mix of professional positions/categories whereby the respondents belonged. 22% were working with clients, 33 were from the consultant's category, 36% belonged to the contractor's group, while 9% were from other positions that include research and development, project delivery partner, steel manufacturer, etc. The purpose of this part is to evaluate the credibility of the information that has been recorded and thus it reveals that the information that was collected has come from professional individuals.

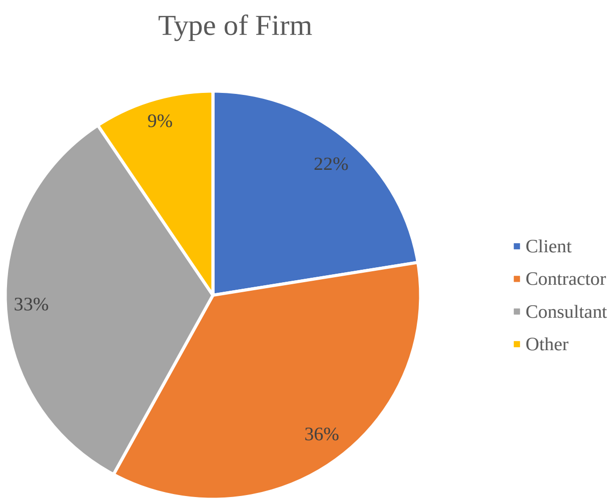

FIGURE 4.3: Type of Organization of Respondents

Education is the most important factor as it plays a vital role in ensuring a nations prosperity. Its one of the most crucial aspects of demographic data. Education opens new paths for technology and innovation. In dealing with the Industrial Revolution 4.0 our prime focus was to aim at that group of people who have some awareness about these technologies and who are currently affiliated or somehow are linked with them.

Figure 4.4 demonstrates that of the 106 people that completed the questionnaire survey, 49% had a bachelor's degree in Civil engineering, 44% had a master's degree in civil engineering, 2% had a Ph.D. in civil and 5% had a diploma.

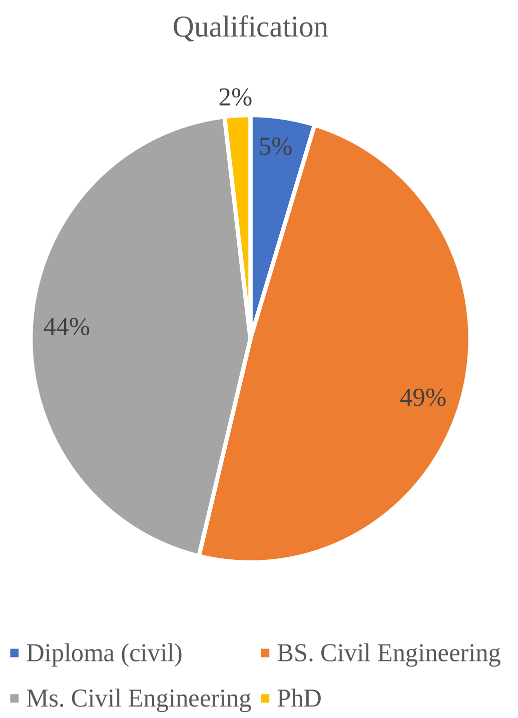

FIGURE 4.4: Qualification of Respondants

Experience is one of the most important factors in evaluating respondent's information. Figure 4.5 reveals that 62% of the respondents had 1-5 years experience, 11% had 6-10 years experience, 10% had between 11-15 years and only 17% had more than 15 years respectively.

So, in general, 38% had the experience of more than 5 years in this industry.

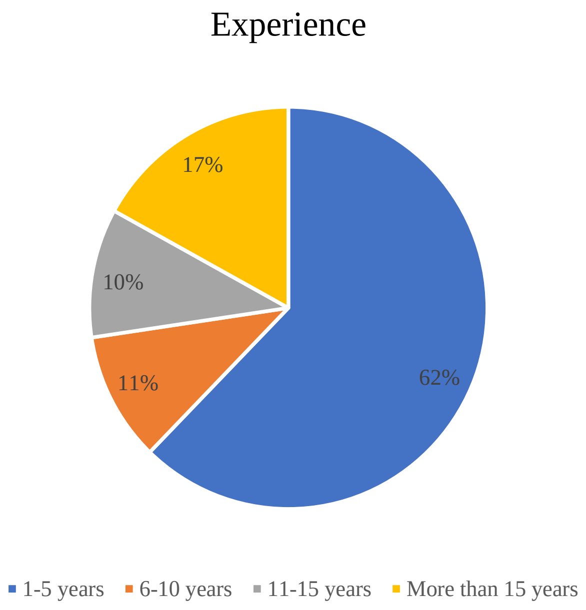

FIGURE 4.5: Experience of Respondents

4.2 Awareness of Industrial Revolution 4.0

There have been 106 responses in all. Responses were gathered through a Google form, as well as by visiting several industrial sectors. These replies were evaluated critically to make conclusions. People's comprehension of Industrial Revolution 4.0 has been assessed using many questions, and their perspectives on its future trends, worries, and significant apprehension areas have been gauged in the outcome evaluation.

At the beginning of the questionnaire survey, respondents were asked if they were familiar with the term "Industrial Revolution 4.0" and if they had heard of it. According to the findings presented in figure 4.6, 61 percent were aware of it. Among the 61% who were aware, 67% of people were between the age of 20-30.

Another intriguing fact is that young individuals who are new to the sector are more aware of the technological transformation, indicating a favorable tendency toward adaption. The future is more promising for technological advancements as young enthusiastic people are more into it.

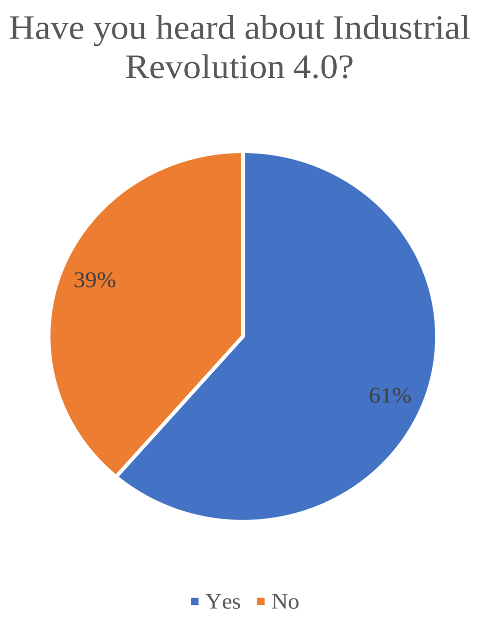

FIGURE 4.6: Respondents understanding of IR 4.0

According to the research, among different sources available when asked about what let them learn about this new industrial revolution the results are as follows shown through the pie chart i.e., figure 4.7.

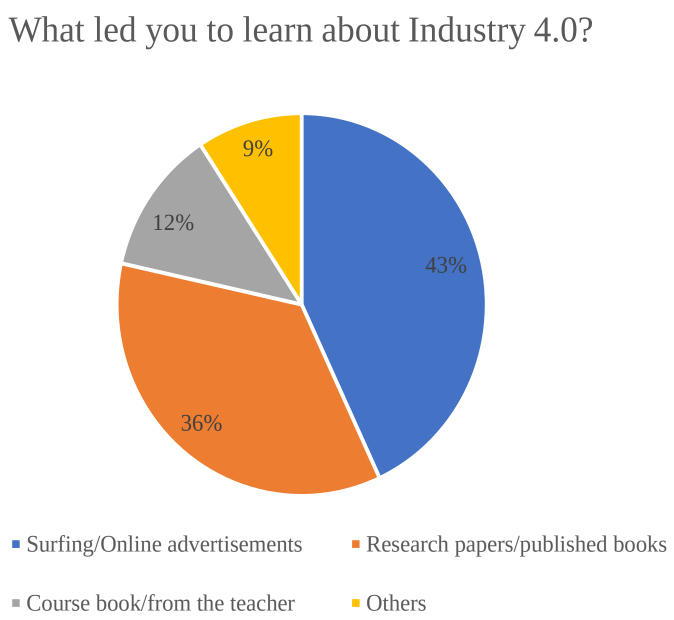

FIGURE 4.7: Profile about source of Knowledge About IR 4.0

According to the figure, most individuals (43%) learned about it through the internet and online browsing, with 36% learning about it from study papers while

12% from course books from teachers. The outcome demonstrated the influence of the internet, and web surfing is beneficial in staying current. The Internet is a never-ending source of knowledge and information, letting you learn about practically any topic or query one may have.

The need to have a more comprehensive and well-structured understanding of the fundamental principles underlying this new industrial revolution Then, this information should be refined and incorporated, with a focus on improving the curses' instructional content, particularly on technical themes. One intriguing potential is the introduction of advances in teaching and learning techniques, encouraging their digitalization and establishing intelligent interaction among the numerous actors involved [45]. Before discussing and specifying any specific IR 4.0-related technologies, the recorded answer rate was as stated above, 61 percent yes and 39 percent nay. However, when considering a handful of the several IR4.0 technologies, amazingly, all the respondents altered their minds. Which indicated that people were using the manifested technologies of Industrial Revolution 4.0 but were oblivious that these technologies belonged to IR 4.0, for example, people knew about BIM and many of them were using it, but they had no idea that BIM is a key testimony to IR 4.0's brilliance. Furthermore, respondents were asked to lint down the IR 4.0 technologies that they are presently using in their fields. This conclusion was consistent with comparable findings in other research discovered through a literature search [22]. Table 4.1 represent the summary of responses before and after a discussion on industrial revolution 4.0 related technologies.

Table 4.1: Respondent's Profile

Exposure to	**Selection**	**Total**	**Before discussion**	**After discussion**
IR 4.0	Yes	65	61%	100%
	No	41	39%	0%

Respondents were requested to indicate IR 4.0 related technologies if they are actively practicing in their sector to gain some insight into the current state or level of adoption of Industry 4.0 related technologies in Pakistan's construction industry. Figure 4.8 represents their reactions in further detail.

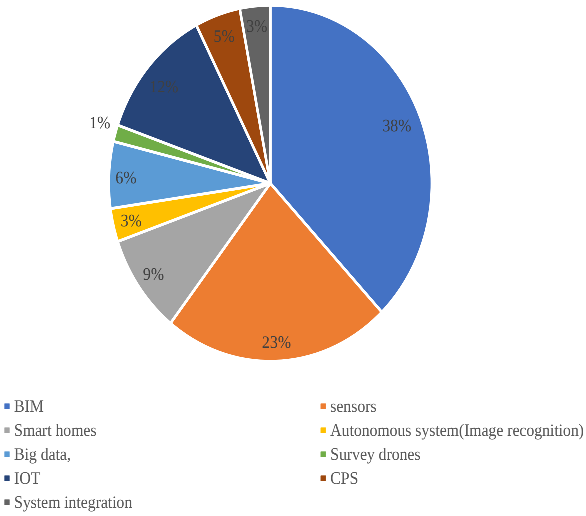

FIGURE 4.8: Technologies Currently in Use by Respondents

The figure clearly illustrates that among all technologies, BIM and sensors are the most actively and overly applied in Pakistan's current industrial structure followed by IoT, smart homes, and the list goes on.

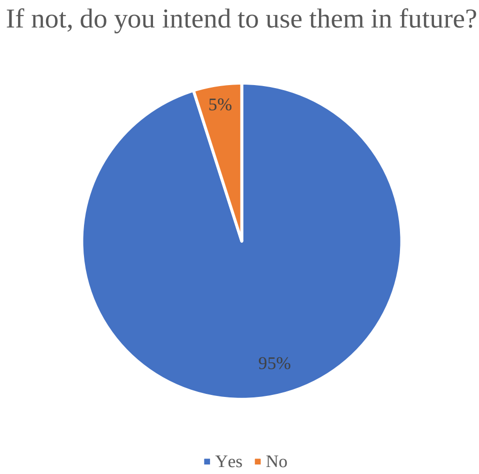

FIGURE 4.9: Trend towards adaptation of IR 4.0

For those who are not using any IR4-0 related technology in their current field, when questioned about their desire to adopt these new technologies, 95 percent replied positively, indicating a willingness to use these technologies. Only 5% expressed some uneasiness about adopting these technologies.

4.3 Section 3: Technical Data

4.3.1 Reliability Test

To evaluate the reliability of the questionnaire, the most renowned and reliable test was adopted for result evaluation which is Cronbach's Alpha test. The mechanism's reliability is defined as the consistency with which it assesses the trait it is intended to evaluate. The mechanism is more trustworthy if the variation in repeated measurements of an attribute is modest. The reliability of a measurement tool can be characterized as its stability, consistency, or dependability. Cronbach's Alpha, whose significant limit of reliability is 0 to 1, was employed for the current study's reliability test. Because it is thought that when more than 0.7 is, the scale is more reliable [46]. Consequently, the questionnaire's reliability scale across each set of project execution agencies was increased. A total of 22 questions were probed to cover all aspects of our current analysis that is PEST (political, economic, social, and technological). Reliability test for all the factors was evaluated that has been presented below in table 4.2.

Table 4.2: Respondent's Profile

Cronbach's Alpha	**No. of Item**
0.925	22

Our value came out to be 0.9 which is very much closer to 1 so it falls under the category of Excellent. It shows higher internal consistency.

4.3.2 Normality Test

To define parameters in SPSS coding of factors (Questions) has been performed. Shapiro-Wilk test is used to carry out the normality test on collected data through questionnaire survey, using SPSS statistical data analyzing tool. This tool was used in this research to clinch whether collected data tail normal distribution or not. Parametric tests are performed in the case of normal distribution data, while non-parametric tests are performed in the case when evaluated data does not follow normal distribution. P-value should be greater or equal to 0.5 in order to pass the normality hypothesis otherwise the test rejects it. Significance value of 0.00 was observed during analysis. Which shows collected data follows non-parametric trend. With sample data comprising of 100 plus responses, the normality of data does not cause much effect. In a case like this even if the data follows non-parametric trends, parametric tests can still be implied. According to central limit theorem, for data set greater than 30, shape of the data does not cause much impact and sampling distribution inclines to be following normal distribution [55].

4.3.3 Relative Importance Index (RII)

For data collection through questionnaire surveys, the Likert scale has been used. The most typical way in research for respondents to describe the level of relevance based on their experience is the Likert scale.

- describes strongly disagree,
- for disagree,
- is for neutral,
- states agree,
- states strongly agree on a five-point Likert scale.

A relative importance index is a tool that gives information about the component in terms of importance, and how significantly it is for a given factor. The Relative Importance Index (RII) is used to rank the components based on their relative importance. Its value ranges from 0 to 1. The more closely its value lies to 1, the more significant that factor carries and wise versa. Table 4.2 to Table 4.6, shows the rank and value of Relative Importance Index (RII) according to the PEST system adopted for research work. The highest value of relative importance index shows high significance of that factor.

Table 4.3: RII Calculation for Political Factor

Political Impact						
Frequency of "5" responses	**Frequency of "4" responses**	**Frequency of "3" responses**	**Frequency of "2" responses**	**Frequency of "1" responses**	**Weighted total**	**RII**
55	33	8	3	7	444	0.838
16	55	26	5	4	392	0.740
29	53	21	0	3	423	0.798
26	53	21	3	3	414	0.781
Average						**0.7892**

Table 4.4: RII Calculations for Economical Factor

Economical						
Frequency of "5" responses	**Frequency of "4" responses**	**Frequency of "3" responses**	**Frequency of "2" responses**	**Frequency of "1" responses**	**Weighted total**	**RII**
34	47	18	4	3	423	0.798
26	52	22	3	3	413	0.779
40	45	16	1	4	434	0.819
16	52	23	11	4	383	0.723
27	57	16	4	2	421	0.794
Average						**0.7826**

Table 4.5: RII Calculations for Social Factor

Social Impact						
Frequency of "5" responses	**Frequency of "4" responses**	**Frequency of "3" responses**	**Frequency of "2" responses**	**Frequency of "1" responses**	**Weighted total**	**RII**
28	47	23	5	3	410	0.774
17	63	21	1	4	406	0.766
19	46	21	13	7	375	0.708
21	46	22	11	6	383	0.723
19	34	21	22	10	348	0.657
51	40	8	4	3	450	0.849
9	28	41	17	11	325	0.613
Average						**0.7270**

Table 4.6: RII Calculations for Technical Factor

Technological Impact						
Frequency of "5" responses	**Frequency of "4" responses**	**Frequency of "3" responses**	**Frequency of "2" responses**	**Frequency of "1" responses**	**Weighted total**	**RII**
10	57	26	10	3	379	0.715
32	62	8	1	3	437	0.825
32	52	18	2	2	428	0.808
14	55	30	5	2	392	0.740
33	53	15	1	4	428	0.808
20	21	20	20	25	309	0.583
Average						**0.746**

Table 4.7: Summary of RII value

Relative Importance Index	**Value**
Political	0.79
Economical	0.78
Social	0.72
Technological	0.73

Using the obtained data, the relative relevance index value was calculated. The data reveals that all the values lie in the high-medium range, indicating their significant influence as an individual. When analyzing PEST, the political element is the most relevant and influential, with an RII of 0.79.

4.3.4 Spider Web

The statistics presented above do not follow uniformity since it does not follow circular patterns, resulting in non-uniform behavior. Political factors are the most influential among all PEST components, followed by economic factors, social factors, and technical factors. This emonstrates that the greatest impediment to its successful adaption is a political element rather than an economic factor, and so on.

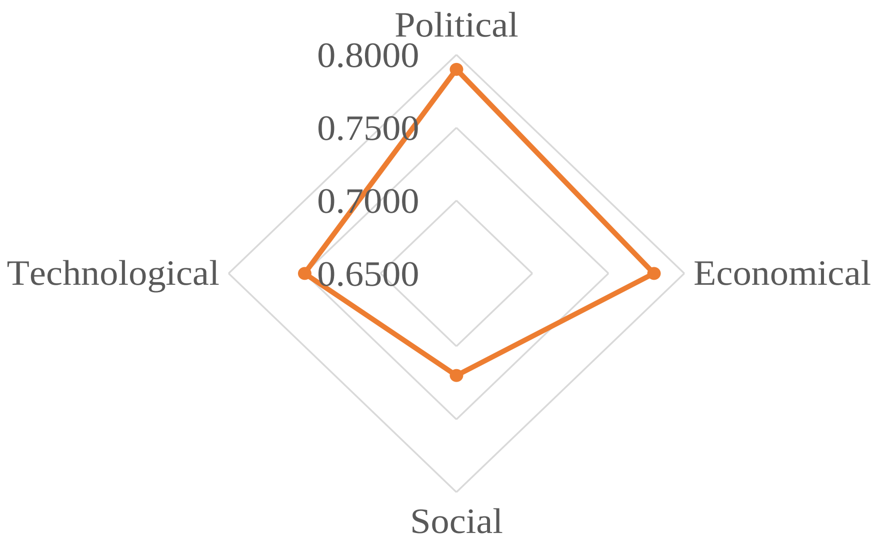

Figure 4.10: Spider Web Showing RII

Most people felt that technology such as sensors, BIM, and cloud storage may considerably assist them in making their work smarter and easier. It was also discovered that respondents agreed with the premise that these technologies may be a source of new employment creation. The main resistance and concern that was detected stemmed from a political component, namely the government's engagement in its adaption. Since it has the greatest relative significance factor of all PEST components.

4.4 Most Preferred Technology

Several Industry 4.0-related technologies were identified through a review of the literature. Respondents were asked to rate the technologies based on their level of desire for adoption on a scale of 1-5 where 1= Highest, 2= High, 3= Medium, 4= Low, and 5= Lowest.

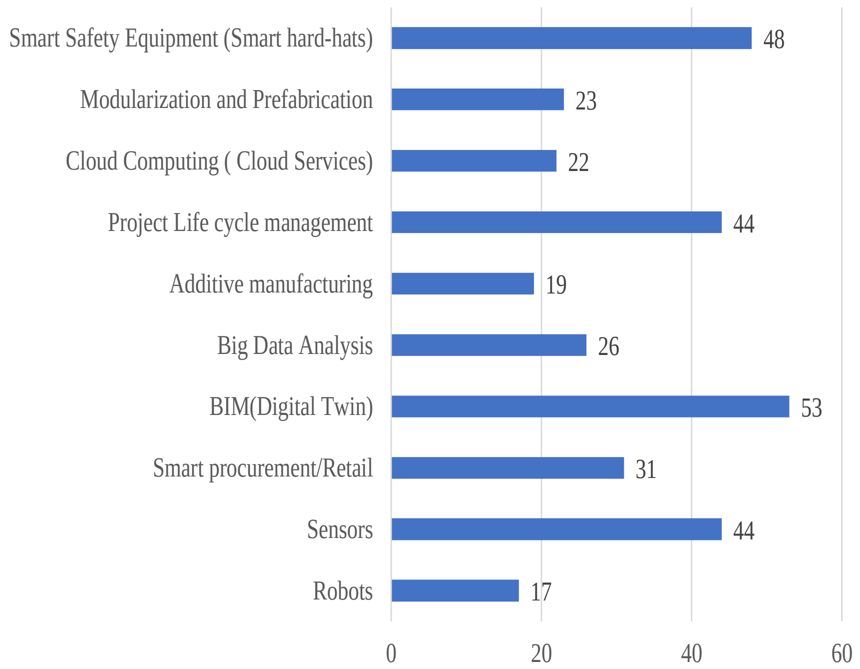

FIGURE 4.11: Highest Preferred Technological Trend for Adoption

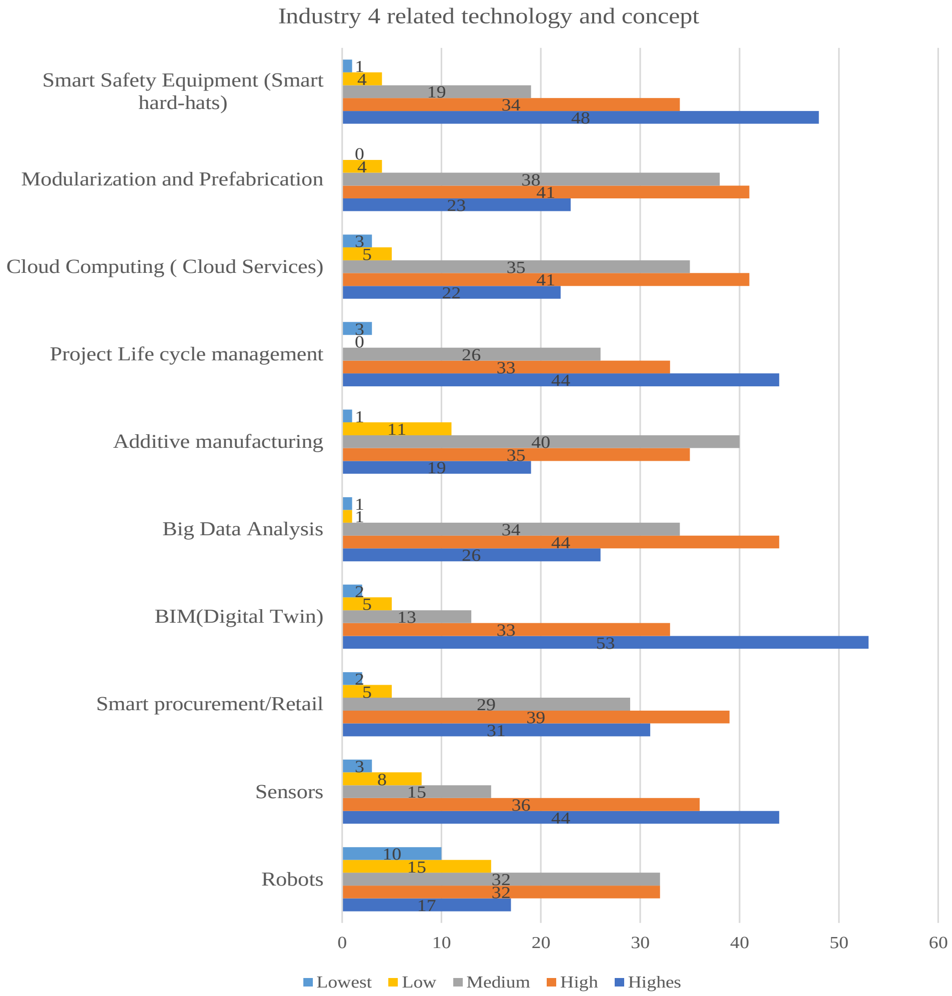

FIGURE 4.12: Industry 4.0 Related Technologies Adoption Trend

Among all technologies, BIM was chosen by 50% of respondents as the most important for adaptation, followed by Smart safety equipment, project life cycle management, and sensors, which received the third most favorable responses.

The bar graph above displays a summary of the responses received against readiness to embrace certain technologies based on their preference level. This specific question was posed to gain insight into people's attitudes regarding the realm of Industrial Revolution 4.0. According to the findings, individuals are more eager to create smart models and manage those intelligently using sensors and software.

4.5 Summary of Collected Data

Following a thorough and sharp analytical analysis of the replies obtained from the respondents, certain essential factors have been inferred. Those conclusions have been demonstrated in tables 4.3 and 4.4 in the form of opportunities and challenges offered by Industrial Revolution 4.0.

TABLE 4.8: Challenges in adoption of IR 4.0

Factors	**Challenges Summary**
Political	There was consensus that government willingness may play a key impact in the acceptance of technical advances. Furthermore, poor broadband connectivity is seen as a major impediment to its successful application in the construction sector.
Economical	A slighter consent on the fear that implementation of innovative technology is costly was perceived, moreover, the return rate of investment is ambiguous making it more complex and challenging.
Social	Every organization's leadership engagement is seen as an essential component for the effective adoption and adaptation of these technologies. Participants' indifferent reaction towards virtual solutions, such as online procurement and site visits via video/conference call, demonstrates their hesitation to adapt to virtual modes. As a result, they are wary of virtual systems.

Factors	**Challenges Summary**
Technical	Participant's reluctance towards the use of the cloud, particularly for storing sensitive information or legal data, demonstrates the prevalence of risk and safety concerns. Acceptance of artificial intelligence-related technology such as robots still needs a significant amount of time and energy.

According to Table 4.3, several aspects must be addressed effectively and swiftly to incorporate these technological improvements. First and foremost, people are unaware of the true potential of these developments. Another disadvantage and a key impediment to its successful deployment is the high initial cost and uncertain rate of return. Furthermore, there has always been apprehension about embracing new technology. Unwillingness to change also includes fear of job loss. The building industry's mostly old-school processes would also have to be confronted and corrected, as well as suitable training and education offered.

In contrast to table 4.2, which depicts the obstacles to effective Industrial 4.0 deployment, table 4.3 provides insight into the potential provided by these technological breakthroughs.

Table 4.9: Opportunities for IR 4.0

Factors	**Opportunities**
Political	An agreement was observed on the fact that funding smart and medium-size enterprises can hugely help in the flourishing Construction industry of Pakistan, thus will bring Pakistan into the race of developed counties.
Economical	The fact that respondents believe and agreed with the statement Industry 4.0 necessitates the establishment of a new industrial setup demonstrates a good response to its acceptance. A separate budget allocation for the adoption of digital technologies can hugely enhance its possibility of acceptance in society.

Factors	**Opportunities**
Social	Changing the direction of university course material and making it more technologically focused can be a significant step forward. A proactive attitude toward seeking new solution partners throughout the world may be a significant step forward.
Technical	A high agreement on the characteristic of big data that it may assist in reducing labor hours and be more efficient in risk assessment is an indication of a favorable attitude, furthermore, real-time data can help in good, effective, and on-time decision making.

Table 4.4 highlights the existing potential in Pakistan's construction industry. Industry 4.0 has the potential to create new jobs, improve labor efficiency, increase mass production, accommodate rapid change in order demand, and much more. Through video conferences, easy and remote access to faraway areas may become a source of energy and fuel-saving.

4.6 Summary

This chapter contains a summary of the data obtained, which is provided in the form of tables and charts. PEST analysis was utilized to get a macroscopic perspective of the environmental elements influencing the effective adoption of Industry 4.0. The questionnaire survey findings have been represented in the form of challenges and opportunities associated with this new revolution. The biggest impediment to successful implementation is considered to be the political factor. The involvement of governance bodies and organizational leaders may be a powerful source of the implementation of new technologies. National-level seminars must be held to raise awareness and teach people new methods to use technology. Because only then will Pakistan be able to join the ranks of the developed world. In comparison to other aspects, there was a preference for sensors and virtual models therefore, the possibilities available in these sectors must be discovered and capitalized on to maximize the industry's potential.

Chapter 5

Conclusion and Recommendations

5.1 General

This chapter comprehensively deals with the conclusions based on evaluated results and gives direction for future work, furthermore, it offers a summary of the results, mitigating methods, future recommendations, and apprehensions that will help in evaluating the most influencing factors of Industrial Revolution 4.0. The industrial revolution can have a significant effect on the construction industry of Pakistan as they both go side by side in terms of development. As a matter of concern, this developmental up-gradation is extremely beneficial for efficient and economical construction growth, considered requisite for advancement in the global market. To remain in the league of competitive and progressive fields of expertise, the construction industry must also adapt to advanced technological revolutions to cater to its construction demand and stimulate industrial growth.

5.2 Conclusion of Research

This study has investigated the impacts of industrial revolution 4.0 in the construction industry of Pakistan, looking into the extent to which Industrial revolution

4 technologies have been used in the construction industry. Different research papers using multiple modes like google scholar, science direct are primarily used to define the goals and then look for the components that play a significant role in the adaptation of Industry 4.0 technology.

This study has shown that Industry 4.0 is a fast-growing technology all around the world including Pakistan as well and there is much more to explore and adopt. It is accompanied by many emerging technologies and many opportunities are there. This study has shown clearly that IOT, cloud computing, CPS, 3D printing, and much more technologies associated with Industry 4.0 have a huge scope, it can entirely change the mechanism and map of the construction industry which has always used labor-intensive practices.

The most important elements influencing the effective adoption of IR 4.0 in the construction sector have been highlighted and connected with the data examined. The survey questionnaires were delivered to several professionals to get the opinion of industry specialists. The surveys were sent out through email and hard The surveys were sent out through email and hard copy, yielding 106 valid replies out of 160 total, which was statistically assessed.

Conclusions are summarized below:

1. Demographic data of the respondents can be summarized as follows:

    - Total out of 160 questionnaires that were handed over to people, 106 responded, indicating a response rate of 66%. Thirteen percent of the 106 persons were female, while 87 percent were male. 69 percent were between the ages of 20 and 30, with the remaining being over 30. While investigating the sort of firm, a fair average was noticed, with contractors, clients, and consulted. Involvement from all sectors attempted to be equal.
    - Talking about the experience of participants, 38% of people had the experience of more than 5 years which includes 17% of people who had an experience of 15 years and above. So, both young people and

experienced professionals were addressed to know to get a clear picture of the current circumstances of the construction industry in Pakistan.

- The generic questions concerning knowledge of Industrial Revolution 4.0 yielded startling findings, revealing that individuals were employing Industrial Revolution 4.0-related technologies but were unaware that those technologies were manifestations of IR4.0.61% percent responded in yes when asked about their exposure to IR 4.0 but 39% who responded no changed their view to yes upon mentioning technologies like BIM, modularization/prefabrication, etc.
- The most used technologies are BIM, Smart homes, big data, IoT, sensors Autonomous systems, etc.
- 100% response rate was observed in the case when asked if they intend to use IR.4.0 technologies in the future which shows a very positive attitude towards the adoption of new technologies, and they will hasten to adapt if given favorable circumstances.

2. Reliability test was performed using the statistics of the reliability test, which came out to be 0.925. The performed test depicts that our values lie under the 'Excellent' reliability category that specifically varies within the subsequent range of $1.0 > \alpha \geq 0.9$.

3. Relative Importance Index was used to study the relative importance between components, whose average resulted in the values as follows; 0.79 for the political aspect, 0.78 for economic impact, 0.72 for Social, and 0.75 for the technological side. Their major values lie in the high medium range which shows a significant impact of all selected components of Industrial revolution 4.0. on PEST.

4. Spider web developed whose results showed uneven distribution among factors that indicated non-uniformity.

5. Although Industry 4.0-related technologies have been in the construction industry for quite some time, their adoption is still in the fancy stage. Technologies such as BIM, Cloud Computing, and Modularization have advanced

greatly, while others such as Augmented, Virtual, and Mixed Reality are still being improved and may have an impact on industry sustainability. Despite the availability of these technologies, the adoption of IR 4.0 in the construction industry is severely insufficient.

6. The political factor has been observed as one of the most critical and influential ones among all others but there is a need to understand that all the other factors that are Economical, social, and technological factors also need to be addressed simultaneously.

5.3 Recommendations

The industrial revolution has 4.0 has been incorporated into the construction sector for some time, but full adoption and adaption remain a long way off, particularly in Pakistan. The construction sector is severely weak in this area, even though many of the technologies are widely available and are employed in some capacity within the industry.

1. This study has covered meticulous knowledge about the industrial revolution, its impact, and its implementation in the construction industry. It greatly helped in paving the way for further technological advancement by defining the main perimeter to conduct market research against major components of macro-environmental factors (PEST) required to be considered.

2. The current study has considered the PEST framework that covers the Political, Economical, Social, and Technological Aspects, a further study with other components and other frameworks like PESTELS, PESTLE, etc. can result in a better and comprehensive understanding of the current situation of the construction industry.

3. Reliability test and relative importance index have been evaluated, however many different approaches and tests like AHP can be adopted to develop a comprehensive framework.

4. Local construction industry lacks implementation and adoption of new technology, furthermore, proper guidance about rules and regulations related to its technologies still needs to be addressed.

5. The opportunities identified here should be prioritized to reap the greatest value.

6. To effectively executes this new industrial revolution and join the ranks of the industrialized world; the stated problems and challenges must be properly addressed.

7. A further study addressing the challenges in a more comprehensive and elaborated way must be done to properly address and eventually eradicate them.

8. A further study on how it should be implemented in the construction industry must be done for getting an extensive overview.

Bibliography

[1] A. M. Qazi, S. H. Mahmood, A. Haleem, S. Bahl, M. Javaid, and K. Gopal, "The impact of smart materials, digital twins (DTs) and Internet of things (IoT) in an industry 4.0 integrated automation industry," *Materials Today: Proceedings,* 2022, doi: 10.1016/j.matpr.2022.01.387.

[2] J. V. E. P Gauri, "What the Fifth Industrial Revolution is and why it matters," *The European Sting,* May 16, 2019.

[3] J. P. Piotr Nowotarski, "Industry 4.0 Concept Introduction into Construction SMEs," *IOP Conference Series: Materials Science and Engineering,* Nov. 2017, vol. 245, no. 5. doi: 10.1088/1757-899X/245/5/052043.

[4] H. Lasi, P. Fettke, H. G. Kemper, T. Feld, and M. Hoffmann, "Industry 4.0," *business and information systems engineering,* vol. 6, no. 4, pp. 239242, Aug. 2014, doi: 10.1007/s12599-014-0334-4.

[5] S. E. N. Lau et al., "Review: Identification of roadmap of fourth construction industrial revolution," in *IOP Conference Series: Materials Science and Engineering,* Oct. 2019, vol. 615, no. 1. doi: 10.1088/1757-899X/615/1/012029.

[6] C. Boton and D. Forgues, "Construction 4.0: The next revolution in the construction industry." [Online]. Available: https://www.canbim.com/articles/construction-4-0

[7] N. O. E. Olsson, E. Arica, R. Woods, and J. A. Madrid, "Industry 4.0 in a project context: Introducing 3D printing in construction projects," *Project Leadership and Society,* vol. 2, p. 100033, Dec. 2021, doi: 10.1016/j.plas.2021.100033.

[8] W. S. Alaloul, M. S. Liew, N. A. W. A. Zawawi, and I. B. Kennedy, "Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders," *Ain Shams Engineering Journal,* vol. 11, no. 1, pp. 225230, Mar. 2020, doi: 10.1016/j.asej.2019.08.010.

[9] C. Newman, D. Edwards, I. Martek, J. Lai, W. D. Thwala, and I. Rillie, "Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study," *Smart and Sustainable Built Environment,* vol. 10, no. 4, pp. 557580, Nov. 2021, doi: 10.1108/SASBE-02-2020-0016.

[10] F. Muoz-La Rivera, J. Mora-Serrano, I. Valero, and E. Oate, "Methodological-Technological Framework for Construction 4.0," *Archives of Computational Methods in Engineering*, vol. 28, no. 2, pp. 689711, Mar. 2021, doi: 10.1007/s11831-020-09455-9.

[11] D. A. Adeitan, C. O. Aigbavboa, E. Emem-Obong Agbenyeku, and O. S. Bamisaye, "Industry 4.0 and Construction Supply Chain Management," 2019, pp. 368375. doi: 10.3311/ccc2019-053.

[12] Z. You and L. Feng, "Integration of Industry 4.0 Related Technologies in Construction Industry: A Framework of Cyber-Physical System," *IEEE Access,* vol. 8, pp. 122908122922, 2020, doi: 10.1109/ACCESS.2020.3007206.

[13] K. Akiyama, M. Ishihara, N. Ohe, and M. Inoue, "An education curriculum of IoT prototype construction system," in 2017 *IEEE 6th Global Conference on Consumer Electronics (GCCE),* Oct. 2017, pp. 15. doi: 10.1109/GCCE.2017.8229221.

[14] R. Jin, H. Zhang, D. Liu, and X. Yan, "IoT-based detecting, locating and alarming of unauthorized intrusion on construction sites," *Automation in Construction,* vol. 118, Oct. 2020, doi: 10.1016/j.autcon.2020.103278.

[15] A. Humayed, J. Lin, F. Li, and B. Luo, "Cyber-Physical Systems Security - A Survey," *IEEE Internet of Things Journal,* vol. 4, no. 6, pp. 18021831, Dec. 2017, doi: 10.1109/JIOT.2017.2703172.

[16] J. I. Messner, S. C. M. Yerrapathruni, A. J. Baratta, and V. E. Whisker, "Session 1121 Using Virtual Reality to Improve Construction Engineering Education," 2003.

[17] V. Getuli, P. Capone, A. Bruttini, and S. Isaac, "BIM-based immersive Virtual Reality for construction workspace planning: A safety-oriented approach," *Automation in Construction,* vol. 114, Jun. 2020, doi: 10.1016/j.autcon.2020.103160.

[18] S. A. Bello et al., "Cloud computing in construction industry: Use cases, benefits and challenges," *Automation in Construction,* vol. 122. Elsevier B.V., Feb. 01, 2021. doi: 10.1016/j.autcon.2020.103441.

[19] K. Jung, S. S. Choi, B. Kulvatunyou, H. Cho, and K. C. Morris, "A reference activity model for smart factory design and improvement," *Production Planning and Control,* vol. 28, no. 2, pp. 108122, Jan. 2017, doi: 10.1080/09537287.2016.1237686.

[20] S. R. Hamidi, A. A. Aziz, S. M. Shuhidan, A. A. Aziz, and M. Mokhsin, "SMEs maturity model assessment of IR4.0 digital transformation," in *Advances in Intelligent Systems and Computing,* 2018, vol. 739, pp. 721732. doi: 10.1007/978-981-10-8612-075.

[21] S. O. Abioye et al., "Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges," *Journal of Building Engineering,* vol. 44. Elsevier Ltd, Dec. 01, 2021. doi: 10.1016/j.jobe.2021.103299.

[22] W. S. Alaloul, M. S. Liew, N. A. W. A. Zawawi, and B. S. Mohammed, "Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry," in *MATEC Web of Conferences,* Sep. 2018, vol. 203. doi: 10.1051/matecconf/201820302010.

[23] M. Hammad Ghazanfar Baig, M. Mutasim Billah Tufail, and M. Jawad Ghazanfar Baig, "Industrial Revolution (IR) 4.0 in the Construction Sector: Exploring the Possibilities in Pakistan." [Online]. Available: www.ijicc.net

[24] J. Barata, “The fourth industrial revolution of supply chains: A tertiary study,” *Journal of Engineering and Technology Management* - JET-M, vol. 60, Apr. 2021, doi: 10.1016/j.jengtecman.2021.101624.

[25] N. Davis, A. Companiwala, B. Muschard, and N. Petrusch, “4th Industrial Revolution Design Through Lean Foundation,” in *Procedia CIRP,* 2020, vol. 91, pp. 306311. doi: 10.1016/j.procir.2020.03.102.

[26] L. L. Har, U. K. Rashid, L. te Chuan, S. C. Sen, and L. Y. Xia, “Revolution of Retail Industry: From Perspective of Retail 1.0 to 4.0,” *Procedia Computer Science,* vol. 200, pp. 16151625, 2022, doi: 10.1016/j.procs.2022.01.362.

[27] J. W. Veile, M. C. Schmidt, and K. I. Voigt, “Toward a new era of cooperation: How industrial digital platforms transform business models in Industry 4.0,” *Journal of Business Research,* vol. 143, pp. 387405, Apr. 2022, doi: 10.1016/j.jbusres.2021.11.062.

[28] A. M. Qazi, S. H. Mahmood, A. Haleem, S. Bahl, M. Javaid, and K. Gopal, “The impact of smart materials, digital twins (DTs) and Internet of things (IoT) in an industry 4.0 integrated automation industry,” *Materials Today: Proceedings,* Feb. 2022, doi: 10.1016/j.matpr.2022.01.387.

[29] C. F. Rocha, C. O. Quandt, F. Deschamps, and S. Philbin, “R&D collaboration strategies for industry 4.0 implementation: A case study in Brazil,” *Journal of Engineering and Technology Management,* vol. 63, p. 101675, Jan. 2022, doi: 10.1016/j.jengtecman.2022.101675.

[30] T. Y. Melesse, M. Bollo, V. di Pasquale, F. Centro, and S. Riemma, “Machine Learning-Based Digital Twin for Monitoring Fruit Quality Evolution,” *Procedia Computer Science,* vol. 200, pp. 1320, 2022, doi: 10.1016/j.procs.2022.01.200.

[31] H. Lingard, T. Cooke, G. Zelic, and J. Harley, “A qualitative analysis of crane safety incident causation in the Australian construction industry,” *Safety Science,* vol. 133, Jan. 2021, doi: 10.1016/j.ssci.2020.105028.

[32] W. H. Collinge, K. Farghaly, M. H. Mosleh, P. Manu, C. M. Cheung, and C. A. Osorio-Sandoval, "BIM-based construction safety risk library," *Automation in Construction,* vol. 141, p. 104391, Sep. 2022, doi: 10.1016/j.autcon.2022.104391.

[33] A. Prabhakaran, A.-M. Mahamadu, and L. Mahdjoubi, "Understanding the challenges of immersive technology use in the architecture and construction industry: A systematic review," *Automation in Construction,* vol. 137, p. 104228, May 2022, doi: 10.1016/j.autcon.2022.104228.

[34] C. Newman, D. Edwards, I. Martek, J. Lai, W. D. Thwala, and I. Rillie, "Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study," *Smart and Sustainable Built Environment,* vol. 10, no. 4, pp. 557580, Nov. 2021, doi: 10.1108/SASBE-02-2020-0016.

[35] S. E. N. Lau et al., "Revolutionizing the future of the construction industry: Strategizing and redefining challenges," in *WIT Transactions on the Built Environment,* 2019, vol. 192, pp. 105115. doi: 10.2495/BIM190101.

[36] J. Cox, "The higher education environment driving academic library strategy: A political, economic, social and technological (PEST) analysis," *Journal of Academic Librarianship,* vol. 47, no. 1, Jan. 2021, doi: 10.1016/j.acalib.2020.102219.

[37] T. Sammut-Bonnici and D. Galea, "PEST analysis," in *Wiley Encyclopedia of Management,* Chichester, UK: John Wiley & Sons, Ltd, 2015, pp. 11. doi: 10.1002/9781118785317.weom120113.

[38] S. Alanzi, "PESTEL ANALYSIS."

[39] G. Chao, A. Peng, and M. B. Nunes, "Using PEST Analysis as a Tool for Refining and Focusing Contexts for Information Systems Research." [Online]. Available: http://ssrn.com/abstract=1417274

[40] G. M. Sullivan and A. R. Artino, "Analyzing and Interpreting Data From Likert-Type Scales," *Journal of Graduate Medical Education,* vol. 5, no. 4, pp. 541542, Dec. 2013, doi: 10.4300/JGME-5-4-18.

[41] M. Hanafi Azman Ong, F. Puteh, U. Teknologi MARA, and S. Alam Selangor, "Quantitative Data Analysis: Choosing Between SPSS, PLS and AMOS in Social Science Research," *International Interdisciplinary Journal of Scientific Research,* [Online]. Available: www.iijsr.org

[42] C. Ozgur, M. Kleckner, and Y. Li, "Selection of Statistical Software for Solving Big Data Problems," *SAGE Open,* vol. 5, no. 2, p. 215824401558437, Apr. 2015, doi: 10.1177/2158244015584379.

[43] Uldana Baizyldayeva, "Decision Making Procedure: Applications of IBM SPSS Cluster Analysis and Decision Tree.," *World Applied Sciences Journal,* Feb. 2013.

[44] A. Ghasemi and S. Zahediasl, "Normality Tests for Statistical Analysis: A Guide for Non-Statisticians," *International Journal of Endocrinology and Metabolism,* vol. 10, no. 2, pp. 486489, Dec. 2012, doi: 10.5812/ijem.3505.

[45] A. Christmann and S. van Aelst, "Robust estimation of Cronbachs alpha," *Journal of Multivariate Analysis,* vol. 97, no. 7, pp. 16601674, Aug. 2006, doi: 10.1016/j.jmva.2005.05.012.

[46] Dr. Sandhya Jain, "USE OF CRONBACHS ALPHA IN DENTAL RESEARCH," *Dr. Vijeta Angural,* vol. 4, no. 03, pp. 285291, 2017.

[47] A. E. Oke, A. F. Kineber, I. Albukhari, I. Othman, and C. Kingsley, "Assessment of cloud computing success factors for sustainable construction industry: The case of Nigeria," *Buildings,* vol. 11, no. 2, pp. 115, Feb. 2021, doi: 10.3390/buildings11020036.

[48] M. Bilal, K. I. A. Khan, M. J. Thaheem, and A. R. Nasir, "Current state and barriers to the circular economy in the building sector: Towards a mitigation framework," *Journal of Cleaner Production,* vol. 276, Dec. 2020, doi: 10.1016/j.jclepro.2020.123250.

[49] N. Javed, M. J. Thaheem, B. Bakhtawar, A. R. Nasir, K. I. A. Khan, and H. F. Gabriel, "Managing risk in green building projects: toward a dedicated framework," *Smart and Sustainable Built Environment,* vol. 9, no. 2, pp. 156173, May 2020, doi: 10.1108/SASBE-11-2018-0060.

[50] B. Motyl, G. Baronio, S. Uberti, D. Speranza, and S. Filippi, "How will Change the Future Engineers Skills in the Industry 4.0 Framework? A Questionnaire Survey," *Procedia Manufacturing,* vol. 11, pp. 15011509, Jan. 2017, doi: 10.1016/j.promfg.2017.07.282.

[51] M. Bilal, K. I. A. Khan, M. J. Thaheem, and A. R. Nasir, "Current state and barriers to the circular economy in the building sector: Towards a mitigation framework," *Journal of Cleaner Production,* vol. 276, Dec. 2020, doi: 10.1016/j.jclepro.2020.123250.

[52] N. Javed, M. J. Thaheem, B. Bakhtawar, A. R. Nasir, K. I. A. Khan, and H. F. Gabriel, "Managing risk in green building projects: toward a dedicated framework," *Smart and Sustainable Built Environment,* vol. 9, no. 2, pp. 156173, May 2020, doi: 10.1108/SASBE-11-2018-0060.

[53] B. Motyl, G. Baronio, S. Uberti, D. Speranza, and S. Filippi, "How will Change the Future Engineers Skills in the Industry 4.0 Framework? A Questionnaire Survey," Procedia Manufacturing, vol. 11, pp. 15011509, Jan. 2017, doi: 10.1016/j.promfg.2017.07.282.

[54] W. S. Alaloul, M. S. Liew, N. A. W. A. Zawawi, and I. B. Kennedy, "Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders," Ain Shams Engineering Journal, vol. 11, no. 1, pp. 225230, Mar. 2020, doi: 10.1016/j.asej.2019.08.010.

[55] A. Ghasemi and S. Zahediasl, Normality Tests for Statistical Analysis: A Guide for Non-Statisticians, International Journal of Endocrinology and Metabolism, vol. 10, no. 2, pp. 486489, Dec. 2012, doi: 10.5812/ijem.3505.

Now begin the Appendices, including them as separate files

Appendix A

Issuance No: _______

CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Department of Civil Engineering

Dear respondents,

Greetings!

My name is Wafa Nasir, student in department of Civil Engineering at Capital University of Science and Technology (CUST). I am conducting Ms. Thesis research work, entitled **"Prospects of Industrial Revolution 4.0 (IR 4.0) in Construction Industry of Pakistan"**. The purpose of this research is to evaluate the role of IR 4.0 in construction industry and how it can open up the horizons of automation in construction projects. Industrial Revolution (IR) 4.0 is all about automation and data exchange. The main vision of IR 4.0 is to boost the use of big data available in cloud (i.e. shared digital environment), the enormous use of artificial intelligence and automation. BIM follows some aspects of Industrial revolution 4.0 by creating twin models, which give details about project's sustainability and profitability options. BIM, IOT (Internet of things) along with CPS (sensors, drones, embedded robots etc.) enable us to monitor progress of project throughout its life cycle.

In connection with this, I would like to ask your help to provide necessary data for my study, please feel free to answer the questionnaire.

I would like to appreciate your assistance and support in this particular research endeavor.

Thank you very much for your cooperation.

Part 1:

Demographic data and general information:

Generic:

1. Gender
   - o Male
   - o Female
2. Age
   - o 20-30
   - o 30-40
   - o 40-50
   - o Above 50
3. Qualification
   - o Diploma (Civil)
   - o BS. Civil Engineering
   - o Masters
   - o PhD
4. Type of firm
   - o Consultant
   - o Contractor
   - o Sub-contractor
   - o Client
   - o Others
5. Working experience
   - o 1-5 years
   - o 6-10 years
   - o 11-15 years
   - o More than 15 years

Part 2:

Awareness about Industrial Revolution 4.0

a) Have you heard about Industrial Revolution 4.0?
   - o Yes
   - o No

b) What led you to learn about Industry 4.0?
   - o Surfing/Online advertisements
   - o Research papers/published books
   - o Course book/from the teacher
   - o Others

c) Have you heard about the following terms?

Sensors	o Yes	o No
Smart homes	o Yes	o No
BIM	o Yes	o No
Big Data	o Yes	o No
Autonomous System	o Yes	o No
System Integration	o Yes	o No
Internet of things	o Yes	o No
Cyber physical System	o Yes	o No

d) Are you currently using any of above mentioned technologies?
   - o Yes
   - o No

If yes to (d) please mention ________
If not to (d), do you intend to use them in future?

- o Yes
- o No

e) Have you ever attended a conference or workshop on IR 4.0 applications?

- o Yes
- o No

Part 3:

Technical Data

Please rate the following according to the scale given:

(1) Strongly disagree **(2)** Disagree **(3)** Neutral **(4)** Agree **(5)** Strongly agree

Sr.	Code	Factors	1	2	3	4	5
1.	P1	Government willingness (or agreement) can play a significant role in promoting technological advancements.					
2.	P2	Unreliable broadband connectivity is a hindrance towards IR4.0 successful implementation.					
3.	P3	Adopting IR 4.0 will bring Pakistan in the race of developed countries.					
4.	P4	Governing bodies/authorities should support SMEs by providing funds to implement IR 4.0.					
5.	E1	Industrial Revolution 4.0 will help to boost economy by bringing international investments.					
6.	E2	Industry 4.0 call for new industry set-up (autonomous system).					
7.	E3	Industry 4.0 can become the source for new job creations (e.g. BIM experts).					
8.	E4	Implementation of innovative technology is costly.					
9.	E5	Organizations should set aside separate budget for the adoption of digital technologies.					
10.	S1	Leadership in your organization encourages technological transformations.					
11.	S2	Solution partners (for collaborative work) can be a great source of assistance with digital innovations.					
12.	S3	Virtual site visit (through WhatsApp videos/zoom and/or other means) is an appealing alternative that should be adopted.					
13.	S4	Customized procurement through online means (e.g. Alibaba, aliexpress) at national level shall be promoted.					

14.	S5	There exists a fear that too much technology can 'eliminate' the need of human.					
15.	S6	Course content in universities should be revised and more technical courses aiming new revolutions should be focused.					
16.	S7	"Cloud storage" is safe enough for sharing confidential project information (keeping hacking in mind).					
17.	T1	"Cloud" is great platform for sharing daily on site report and other legal documents among all engaged parties (stakeholders).					
18.	T2	Real time data can actually help in good decision making.					
19.	T3	Availability of Big Data can help in better risk assessments.					
20.	T4	Digital twins (3D models) can actually behave in real world the way they are designed.					
21.	T5	The innovation of BIM in managing computational data can result in improving construction efficiency and economy.					
22.	T6	The use of robots for carrying out work (e.g. bridge inspection) can result in better project deliverance.					

If you are given a chance to implement technologies, rate out of five according to your priority level of adoptions towards these technologies:

(1) Highest, **(2)** High, **(3)** Medium, **(4)** Low, **(5)** Lowest

Sr.	**Factors**	**1**	**2**	**3**	**4**	**5**
1.	Robots					
2.	Sensors					
3.	Smart procurement/Retail					
4.	BIM(Digital Twin)					
5.	Big Data Analysis					
6.	Additive manufacturing					
7.	Project Life cycle management					
8.	Cloud Computing (Cloud Services)					
9.	Modularization and Prefabrication					
10.	Smart Safety Equipment (Smart hard-hats)					