QATAR UNIVERSITY

COLLEGE OF ENGINEERING

A STUDY ON EVALUATING THE READINESS LEVEL FOR QATAR COMPANIE TO ADOPT INDUSTY 4.0

BY

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ABSTRACT

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Title: A Study on Evaluating the Readiness Level for Qatar Companies to Adopt Industry 4.0

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In today's competitive environment, it is obligatory to maintain all business activities in all situations, even under crisis. The recent example of COVID-19, which forced most of the business entities to reduce manpower on-sites to a minimum, is a wakeup call for business entities that rely on physical manpower. Relatively less impact could have resulted if processes, systems and facilities are smart and self-dependent objects. There is, therefore, a strong need to convert processes and facilities into smart and self-dependent objects. In this thesis, an evaluative approach is used to assess and evaluate the readiness level of Qatari industries for digital transformation. Digitalization is an unavoidable industrial revolution that needs planning, preparation and changing the mindset of how companies run their operations. While digitalization opens up new business opportunities, past industrial revolutions have been disruptive, and Industry 4.0 is no exception. Therefore, a major transformation in key business areas cannot be ignored. Industry 4.0 has been trigged by both evolutionary and revolutionary innovations, inventions, and technology. In order to cope up with these changes it is necessary for organizations to undergo transformations that position them on a path towards digital transformation and digitalization of production systems. In line with this concept, this thesis investigates the challenges, barriers and success factors that companies should consider when transiting to Industry 4.0. An assessment guide for evaluating business processes of companies and their readiness level for digitalization is outlined. In addition to that, full production cycle for a cement company was evaluated in details. The results show that companies in Qatar should give more credit to transformation towards industry 4.0. Finally, business process change cycle for transforming operations to industry 4.0 is developed. The usefulness of it is to guarantee covering full business cycle and ensure continuous development.

DEDICATION

To my parents and siblings, who supported me in this journey.

To the one who encouraged me and believed in my success.

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CHAPTER 1: INTRODUCTION

The integration of advanced technologies into production systems has created new methods for business operations. Through digitization, processing time have significantly shortened, and ways that businesses formulate their strategies have been changed. Furthermore, increased digitization has enhanced machine lease time, facilitated customized production, hastened machine communication, and automated services. However, the current accelerating pace of development is due to the amount of data available to companies. (Khajavi & Holmstrom 2015) argue that digitization is driving companies to formulate new operational strategies, which puts pressure on internal systems and the identity of the business. It is imperative that in the current age of rapidly changing technologies, companies must align operating processes with their business models, organizational structure, and innovations. (Bouwman, Nikou, Molina-Castillo & de Reuver 2018) also noted that companies require significant investments to fund the formulation of cost-effective plans for the business. In this context, digitization affects business operations heavily by influencing their business model, design, and product innovation. At process level the 4th industrial revolution is about the digital connection between the products and machines in the factories using new innovative technologies (PWC, 2019).

A number of awareness camphains and the need to transit to industry 4.0 have been broadcast world wide. While some parts of the world have embarced the benefits of Industry 4.0, other parts are still laging behind. This thesis will study the readiness level of Qatari companies to digitize production cycles and move toward the fourth industrial revolution.

1.1 Background

The fourth industrial revolution is the expression to describe the digitization in the industrial field. The term digitization was first developed in German where digitization was primarily used to control the entire life cycle of the industrial process using new technologies (Vaidya al. 2018). Figure 1 shows a pyramid depicting the stages of industrial revolutions.

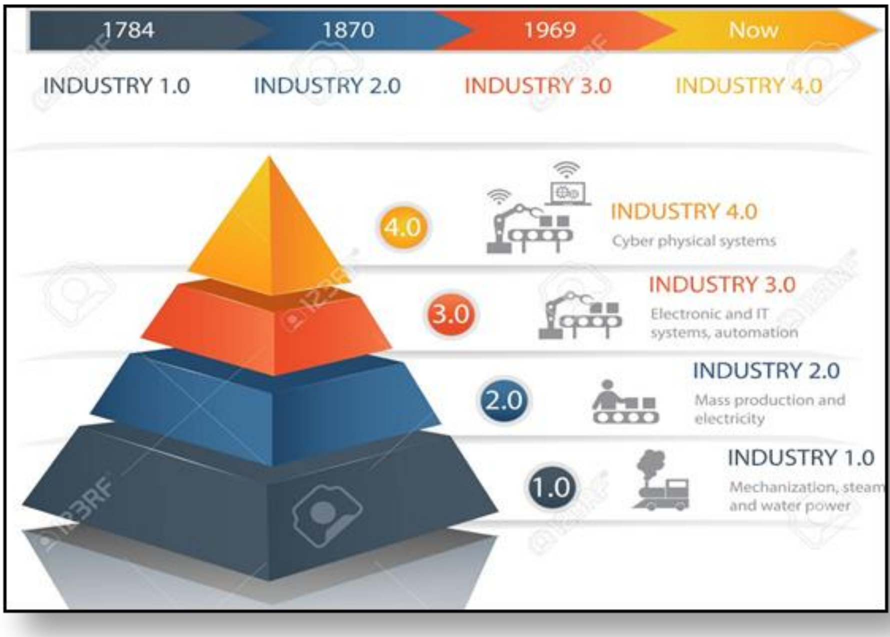

Figure 1 Industrial Revolution Stages in a hirachy

The industrial revolution started with I1.0 in 1784 and used water and steam power in operating business, then it was followed by I2.0 in 1870 using electrical energy in mass production. In the third revolution I3.0 in 1970, application of electronics and IT started entering the industrial field for further automation in the production. As new technologies developed, companies started studying the ability to adopt the newest technologies to fully automate production processes. Using technologies can reduce interference of human with machines directly to the minimum. Ultimately, the fourth revolution began in the 21st century.

On a global scale, there are nine technologies constituting this evolutionary process of Industry 4.0. These technologies aim to establish greater efficiencies and transform the traditional process of production as well as relationship between customers suppliers and producers. The nine technologies are: autonomous network, simulation, big data analytics, augmented reality, the industrial internet of things, horizontal and vertical system integration, additive manufacturing, cybersecurity, autonomous robots, and the cloud (Microsoft, 2018).

1.1.1 Industry 4.0 Framework Concept and Technologies

Industry 4.0 has been considered as a new industrial stage in which several emerging technologies are converging to provide digital solutions. Industry 4.0 adoption marks the new technological age aimed at transforming the way human beings and industries interact through availing mechanics that analyze data more proficiently and streamlining processes required in high-quality productions of goods at lowered costs. As a manufacturing revolution, the core objectives include stimulating economic shifts, heightening productivity, and fostering a drastic industry while enacting modifications within the workforce profile (Unterhofer, 2018). The conceptual framework for these technologies, can be divided into front-end and base technologies (Lichtblau et al, 2015). Front-end technologies consider four dimensions: smart manufacturing, smart products, smart supply chain and smart working depending on five elements: autonomous robots, simulation, system integration, additive manufacturing, and augmented reality. Base technologies consider four elements: internet of things, cloud services, big data and analytics and cyber security.

1.1.2 Role of Industry 4.0

Industry 4.0 is about smart and intelligent manufacturing, where adopting new era technologies is a must. Most companies in this revolution face the challenge of identifying and implementing the base technologies for the digital transformation because of the lack of implementation of big data and analytics (Lichtblau et al, 2015). Below figure 2, illustrate the relation between industry 4.0 and the areas in which there are four dimensions: smart factory, smart product, smart operation and data-driven services (Lichtblau et al, 2015).

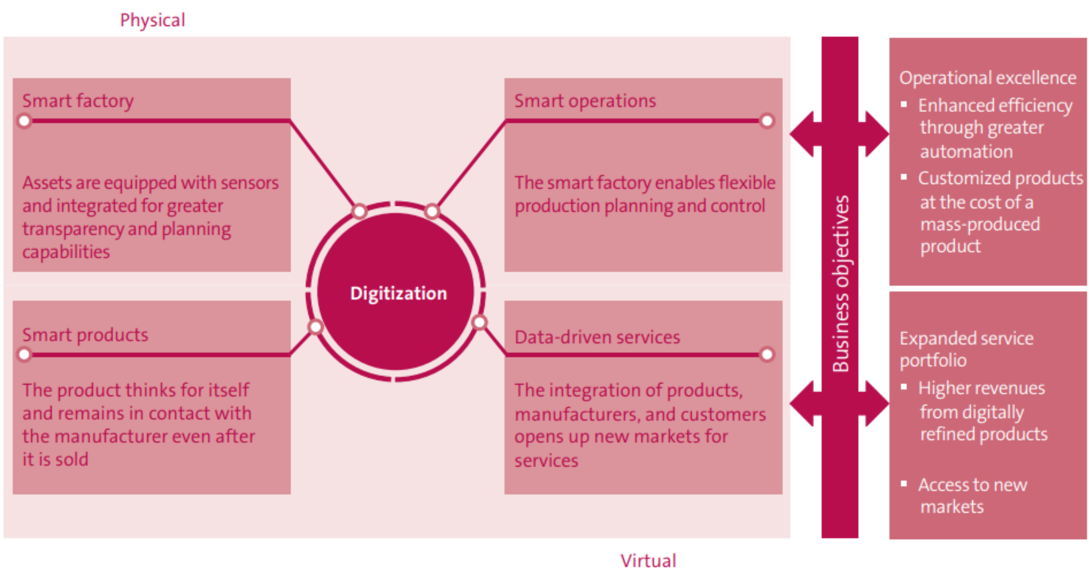

Figure 2 Role of I4.0 as Fusion of Physical and Virtual Layers

Industry 4.0 acts as fusion of the physical layer dimensions and the virtual layer dimensions, where the physical layer consist of the Smart factory and Smart products, and the virtual components are the Smart operations and Data-driven services (Lichtblau et al, 2015). Implementing any of the four dimensions requires a certain level of readiness.

- *Smart Factory:* is the expert level, where the full production cycle is completed without human interference. The cyber physical system connects both physical and virtual worlds using internet of things (IoT).
- *Smart Operations:* the level of the experienced companies where the physical and virtual worlds are integrated benefitting from the availability of data from digitization.
- *Smart Products:* is the intermediate level, where products equipped with technologies such as; sensors, RFID, etc. collect data and communicate with the systems through users.
- *Data-driven Services:* the beginner level. Companies in this level collect and analyze data to design new services and new business.

1.1.3 Digitization, Digitalization and Digital Transformation

Digitization, digitalization and digital transformation are three very different terms mainly in business.

Digitization is all about converting company information from a physical format (e.g. handwritten or typed on paper) to digital format to be used by computer systems (Chapo. 2018).

Digitalization on the other hand, is the process of transferring stored information in computer machines and hard drives to be more interactive by uploading the files and documents to be available online (e.g. to a cloud service for sharing with many people) (Chapo. 2018).

Digital transformation is a wider term that includes digitization and digitalization (Chapo. 2018). It is more about usage of technology by people than it is about technology itself. It requires empowering employees to do things in a new digital way to get business done with help of technologies.

Automation of industries and digital transforming of the processes depend on digitizing, digitalizing and automating the entire workflow of production. This is supplemented by decision making using wireless connectivity and integrated systems to link the machines and tools in the Fourth Industrial Revolution that will take the new technologies as a base for the industrial processes for the smart factories.

1.1.4 Advantages of Digital Transformation

Moving forward with technology improvement in business world, gains business a lot of benefits and advantages. These are discussed in the following sub-headings.

Real time updates

Doing business in digital way eliminates barriers between different applications processing on different platforms in the business field. It eases the integration between systems by collecting all data generated from different databases to generate combined reports in one dashboard reflecting what is happening in the current businesses. This real time digital reports provide live tracking on the full cycle, which supports in recognizing the waste -if any- in energy, predict required maintenance and raise productivity.

Effective and Efficient Relationships

Digitalization is the automation across the different systems. Placing all applications and IT projects in one cloud means you connected all your projects through Internet to have online state for every process in the industrial business.

Digitalization publishes the business online to reflect what is happening across industrial projects and this reduces the volume of human resources' power required for making decisions and taking actions. Creating a base of stress less workers can increase innovation and get more development products.

In addition to that, digitalization helps in improving supply chain management by using accurate data that supports in recognizing the desired suppliers and improving the communication with them.

Business Continuity – COVID 19

A disastrous event such as COVID-19 apparent the significance of digitizing businesses. All countries accelerate their movement toward digitization in order to ensure business continuity and avoid economic fall. This crisis shows clearly that advanced technology adopted in other countries recoup the situation faster than others. The period of this pandemic emphasizes the importance of digital transformation and adopting the trends technologies for the sustainability (İrge, Necmiyem Yazici & Ayşe, 2020).

It is a must for companies and governments -after stumbling- to rethink about their sustainability in future by improving their digitization strategy and if they do not have one to start building it.

Qatar is a country that is investing extensively in industry and technology as well, so combining both to transform production systems into I4.0 and automate the processes can be e a giant movement in this area.

1.1.5 Nature of Industry in Qatar

Qatar industrial field has developed drastically since 2017. Qatar government invest intensely in establishing modern infrastructure following most recent technologies as per latest specifications. As per Qatar industrial portal since 2017 till now, Qatar established 99 types of products such as food, beverages, wood, textiles cement, petrochemicals and oil industries (Qatar Industrial portal, 2020) in both type of businesses; business to business (B2B) and business to customer (B2C).

Qatar industrial field has 915 registered firms with different 490 licenses investing QR 293 billion. Qatar industrial exports jumped to achieve QR 257 billion and decrease the total imports to QR 106 billion of raw materials and necessary materials.

After examining the nature of the industrial fields in Qatar through the portal of Ministry of Commerce and Industry, we found that:

1. Qatar government can invest in cloud infrastructure to accommodate the industrial field challenges and their huge amount of data need to be hosted in a private secured cloud.
2. Qatar government can invest in cybersecurity to encourage all industrial firms to store their databases in the government cloud not any other public cloud and clear any concerns about their data privacy and security.
3. Qatar government also should invest in manufacturing all equipment and machinery needed to support the transformation to industry 4.0 like sensors and smart PLC /HMI.
4. Qatar already has agreement with SAP - German multinational software corporation - to empower Qatar government in energy, cement, oil and gas industries and Government human resources.

Qatar has a good financial position. This can enable Qatar to be one of the Middle East leaders in industry 4.0 by investing in interoperability and IIOT to move towards the smart factories.

1.1.6 Challenges with Digital Transformation in Qatar Industries

Because of the lack of information in the success of industry 4.0 most of companies are taking it very slow to move toward automation. Ambiguity about the opportunities and risks keep it less priority to the companies to invest in digital transformation.

Moreover, government support is very limited for the industrial private sector. Support in facilitating and improving the capabilities from the government can encourage the companies to step forward the transformation.

Therefore, the Qatari government should provide more trainings and workshops to improve employees' skills to prepare them for the new technologies and transition.

One more challenge that companies are facing is that some specialized systems/devices are not available. In the interview with IT head in the case study company, he mentioned that it will be valuable if the government provide support in supplying sensors that can be attached to the machines to enable the exact role of IoT to have smart machines and consequently smart production environment.

1.2 Scope

The aim of this thesis is to make a study in order to evaluate the awareness and readiness of Qatar factories for digital transformation to move toward industry 4.0. This study will assess Qatari industrial companies using an online survey. The contributing companies will be asked to provide information about the technologies used in their business and the future development plan to adopt innovative technologies in order to evaluate the readiness level for industry 4.0 adoption.

Also, a company in cement production will be taken as case study. Interview with the ERP and IT head in the company conducted to gather details about the current tools and technologies used in the production cycle of the company. The gaps for industry 4.0 achievement will be identified and how to convert to automated process.

1.3 Problem Statement

The previous sections have mentioned the various technologies that are amenable to Industry 4.0. Their applications in production systems depend on the type of technologies being currently implemented in various production systems. There are several ways for identifying the need to move towards industry 4.0. One way is to analyze the operating efficiencies of the current production system and compare with leading value indicators that have been achieved by similar production systems elsewhere. In general, industry 4.0 is instrumental in improving operating efficiencies in a sustainable manner. Therefore, it is expected that companies implementing industry 4.0 technologies can achieve more positive indicators in a more sustainable manner.

For example, some industries in rapidly developing countries generate harmful gases and chemicals that affect public health, safety, and welfare of citizens. These emissions also affect the health of human labors in such plants as well as the natural environment. Such operations are not sustainable. However, it has been observed that harmful gases and chemicals are byproducts of the various production systems. Hence, the emitted harmful gases and/or chemicals are usually associated with production inefficiencies. These inefficiencies can be greatly improved by implementing advanced technologies embodied in Industry 4.0. additional benefits of industry 4.0 are: higher productivity, improved flexibility, agility, and profitability. Therefore, there is a lot of motivation for undertaking an industry 4.0 project.

This study is an empirical investigation aimed at finding the awareness and readiness levels for industry 4.0 implementation and adoption in production systems in Qatar. The investigation will be facilitated by a case study of a cement production company in Qatar. The study will assess the process technology in the company and then project the findings to a framework that can be used to transform the case study from the currently acclaimed industry 3.0 into industry 4.0. As most factories in the similar business use similar tools and technologies, the study will develop an Industry 4.0 framework that can be used in similar production settings.

The framework can be used as a guideline on how other industries operating in the business environment in Qatar can achieve transformation.

The study will examine the role of various systems in the industrial processes of the case study and its platform and analyze them to find ways of introducing a transformation solution to bind together all non-connected platforms in the case study. Industry 3.0 systems in the case study generate different types of data. Data engineered solution are introduced in the study to gather the data and make required analytics. This study finally presents the level of companies' ability to move toward digitization and digitalization and propose a practical network model and data model for a digital factory in Qatar.

The main research question that will be pursued in this thesis is how to evaluate the current status and how to transform platforms and technologies into industry 4.0. This question can be answered by examining the following sub-questions:

1. With reference to the industrial revolution pyramid, what is the most common level of industrial revolution in Qatar industries?
2. To what extend are Qatari factories ready for digital transformation to higher industrial revolutions?
3. What are the barriers, challenges, and success factors in the transformation

process?

4. How can companies at lower levels transform operations into Industry 4.0?

1.4 Aims and Objectives

The aim of this research is to develop a conceptual framework that can be used in developing countries to transform low levels production systems to industry 4.0. To achieve this aim, the following objectives will be addressed:

1- Establishing an assessment outline that can evaluate business process of companies and their readiness level for digital transformation.

2- Identifying the challenges, barriers and success factors that companies are facing toward moving to Industry 4.0

3- Develop a transformation process cycle helps companies in planning to move toward change.

Achieving the above objectives is expected to extend the results to the following outcomes:

1. Saving money and material from manufacturing processes.
2. Live monitor on continual quality improvements in production systems.
3. Gain more time in maximizing the profit by saving the time wasted on waiting for finding solution for problems.
4. Activate steps of the manufacturing process to become online to allow for real-time measuring, controlling and monitoring.
5. Using data science to integrate systems with different platforms and bound data to be correlated with other systems to acquire consistent and homogeneous data.

6. Minimize human presence and direct interaction with machines in harmful situations and circumstances.

1.5 Research Outline

The thesis is organized into five chapters, as described below:

Chapter1: (Introduction)

Represents the background of industry revolution and the role of technology in this field to digitize the processes and gives the problem statement, research question and the objectives of the thesis.

Chapter2: (Literature Review)

Shows the previous studies conducted on digitization and the pillars of industry 4.0. Also presents cases of adopting industry 4.0 in different countries

Chapter3: (Research Methodology)

In this chapter, tools and methods used in finding the results are explained.

Chapter4: (Results and Discussion)

Representing and discussing the results found.

Chapter5: (Conclusion)

Conclude the research and address the key findings, limitations, recommendations and future work.

CHAPTER 2: LITERATURE REVIEWS

This chapter seeks to review varied literature sources explaining the impact of Industry 4.0 on production systems and evaluating the adoption of Industry 4.0 processes engaged by other nations. This is expected to help in gaining a better understanding of the details involved in this transformative transition and its relevance to Qatar's manufacturers in order to come up with an appropriate approach for implementing Industry 4.0 in Qatar. Studies selected to review focused mainly on the I4.0 implementation using keywords like (I4.0, Industry 4.0, 4th Revolution, Industrial Revolution, Innovation and Technologies).

2.1 Revolution of Industry 4.0

In the manufacturing arena, revolution of Industry 4.0 contributed extensively in the transformation of isolated systems in production process into a fully integrated, flow. The idea of industry 4.0 is to change in traditional production by building more machine to machine relationship.

The development of production systems based on digitization will have an impact on business models, enterprise design, and innovation of organizations. With the advent of the fourth industrial revolution, companies are targeting the electronic automation of services, which will go a long way in fulfilling the needs of customers. Due to the increasing market pressure to provide services that serve individual customers' needs, information gathering, and communication have become important in developing products that suit the market. Digitization remains essential for organizations aiming to grow and expand their services, since the global networking system is rapidly changing and requires flexibility. The change and impact of advanced technologies in industry 4.0 is expected to cover all life domains by 2025 and the change is anticipated to be different in this revolution and much bigger than every previous industrial revolution (Sasi, Deepika, Philip &Shimol, 2021).

2.1.1 Business Models

Ibarra, Ganzarain & Igartua (2018) found that digitization is disruptive to the functioning of businesses, since it leads to changes in their structure and the environment as they begin to adopt new technologies. In most cases, changes in technology are not well received by people, which affects production and creates a gap between employers and employees. (Rachinger et al., 2018) states that it is a managers' responsibility to prepare their workforce for these changes and explain their benefits. Furthermore, they should direct employees on how to integrate these changes into their daily routines. In recent years, the internet, mobile devices, and changes within business networks have created multiple channels that companies can utilize to transform their operating models and retain customers. While companies focus on being competitive, successful business models in this digital age must be complemented by technology-focused individuals who embrace the digitization of production systems (Ibarra et al., 2018). Therefore, it is imperative that people begin to embrace this radical change for the better.

Machine-machine communication business model because of industry 4.0 has been impacted clearly in the business processes. Instructions and decisions are made by machines according to the received data and information. So, it is essential to use appropriate information and accurate data to get the correct results in addition to have the appropriate communication and technology to move to industry 4.0 (Leyh et al. 2017). In (Leyh et al. 2017), the authors mentioned that companies face challenges in addressing and implementing appropriate information and communication technologies to map business models and combine systems to adopt industry 4.0 and be fully automated.

2.1.2 Enterprise Designs

The fourth industrial revolution is essential in the transition to a digitized environment. The most important aspect of these digital changes is the requirement for improved production, which has led to smart concepts being increasingly applied in newer factories. Currently, businesses are more focused on addressing the concerns of suppliers and customers, providing diverse products, decentralization of the business, improved interconnection of services, and retaining autonomous management. Through the digitization of systems, communication becomes quick, and information can be accessed anytime anywhere. The inception of computerized systems has made recording information easy and accessible, easing transaction processing (Bley et al. 2016). The digitization of systems has had a significant impact on enterprise design, since it creates networks that connect different departments within an organization, facilitating rapid communication.

Bley, Leyh & Schaffer (2016) recommended to use tools that help in evaluating the readiness of enterprises for industry 4.0 as many companies overestimate their capabilities and available resources.

The customization of business ideas from the perspectives of suppliers and customers is integral to gain the benefits of these designs, ensuring that products provided meet the expectations of the market, along with the digital requirements. Bley, Leyh & Schaffer (2016) acknowledge that the formulation of any digital platform considers four factors; knowledge, organization, technology, and processes. These are typical factors that characterize the digitization of projects. However, the success of any enterprise design depends on the competency of company employees, a customer-driven attitude, and the initiation of services based on operational needs of the business. Therefore, digitization is essential in building business models that encapsulate the requirements of customers and suppliers, while giving companies a competitive edge in the market (Kayikci, 2018).

2.1.3 Innovation

The requirement for the implementation of smart concepts in industries is increasing among manufacturers. In an increasingly unstable market with a constantly changing environment, and where technology is applicable in every sector of business operation, innovation is at the lead of every performance-based initiative. Adopting the advanced technologies by the lead companies due to their capabilities and resources availability would increase the gap noticeably in the market (Sasi, Deepika, Philip &Shimol, 2021). For companies aiming to remain competitive, investment is required into not only new equipment, but also into human resources and training (Pyka, 2017). Today, both graduates and experienced employees are worth competing for, and companies must be able to retain them as competitive in the current market paradigm. Automakers like Tesla, Ford, and General Motors have automated their production by introducing networked devices, robots, and sensors into their production processes (Sjodin, Parida, Leksell & Petrovic, 2018). Innovations aids the implementation of improved approaches of delivering services to the market. Further, it provides companies with a competitive advantage by finding more efficient ways of operating.

However, digitization of systems requires personnel to become familiar with and accept these changes (Sjodin et al., 2018). Although organizations are benefiting from technological applications, the long-term effects have not been fulfilled owing to a lack of studies.

The new technologies in production have given companies the ability to focus on the customization of products to meet consumer needs and to tailor products as per market needs. Businesses with flexible organizational structures should particularly focus on IT-supported networks to ensure on-time service delivery (Pyka, 2017). Therefore, the digitization of production systems is increasing innovation in businesses and requiring talented people.

2.2 Adoption Process in Different Nations

Different countries world-wide started digitizing their companies and adopting Industry 4.0 technologies to automate the production processes in their factories. The following sub-sections provides a review about the experience of implementing industry 4.0 and how they can benefit this research in developing a digitization model applicable to in Qatar's companies.

2.2.1 Hungary

In a study conducted on Hungarian companies, the adoption process of industry 4.0 was conducted in varying degrees depending on the nature of the company. The primary focus was on the adoption of the internet of things in the existing industries. Three behavioral patterns are identified in the exploitation and integration process of I4.0 in the Hungarian environment.

The first step was the extensive collection of data. This phase is achieved through the placement of technological software designed to capture data and desired observation. For the companies who experience this phase, they underwent a 30% performance increase which was attributed to gathering more information through sensors and cameras (Nagy et al., 2018). The second stage involves the transformation of data into information pertinent to decision making. Judging from the interviews conducted, the interviewers cited the necessity of developing intricate infrastructure essential for data storage necessary in streamlining the manufacturing processes. A majority of the Hungarian industries were facing challenges in attaining the adequate capacity needed for data interpretation and analysis (Nagy et al., 2018). Therefore, when incorporating the internet of things, data conversion was critical in performing database cleaning, recognition of distorting effects and errors, as well as ensuring there is transparency in result presentation. The third level was the utilization of results through big data analytics and machine connectivity (Santiago, 2018). Well-trained personnel were required for this process to facilitate reprogramming of the hardware and software mechanisms and develop appropriate algorithms and software (Nagy et al., 2018). The successful execution of these phases in Hungary has been fundamentally important for real-time data analysis and access.

2.2.2 Germany

Germany is a pioneer who succeeded in avoiding the high costs of energy, workforce expenses, and decrepit infrastructure. However, the nation is now one of the biggest providers of I4.0 technologies, facilitating significant players in the field, for example, Siemens and Bosch. The nation's I4.0 methodology is protective - safeguarding local production and expanding adaptability to react to emergencies in universal markets. At the same time, hang on to the skills necessary for an export-surplus model (Santiago, 2018).

2.2.3 Japan

Japan has been witnessing a period of plateaued value creation, draining jobs, and shrinking finances, particularly in the industrial sector. It is about time the country relaunches industrial growth. However, in the face of an aging population, offshoring, and several difficulties arising from prolonged disinvestment, Japan is bound to see tough times ahead. Although a decidedly industrialized nation, Japan was relatively late to adopting I4.0, particularly among the developed nations. Lacking a head start, the nation, in order to gain back adaptability and resilience, will now have to work on the existing levels of automation (Santiago, 2018). Likewise, I4.0 is expected to drive the passion for industry among the Japanese youth. Further, it is most likely to restore the craftsmanship and improve work quality in the manufacturing units.

In general, it is essential that a base should be ready in the manufactures for digitizing productions systems and adopting Industry 4.0 technologies. Tools and machines should be well recognized, and input and output data defined to have clear ideas of how to combine them. In addition to the tools, well trained employees are essential to implement and operate the digitized model.

All these factors can be defined only after evaluating the level of maturity and readiness for the business to move toward the change.

2.3 Needs and Importance of Industry 4.0 Adoption

The role of industry 4.0 is to improve the overall performance of normal machines by converting them to self-learning machines that interact with neighboring machines and systems.

In addition to that, Industry 4.0 gives the ability to monitor real time data, track the status of products and set instructions to control production processes.

The following sub-sections discuss the value of I4.0 for customer and business that can encourage companies to move toward this technology.

2.3.1 Customer Value Creation

One of the core important outcomes associated with industry 4.0 is the prioritization of customer value creation. This revolution is designed in a manner that stimulates a digitized transformation through all departmental components of a company/manufacturing enterprise. Therefore, placing an importance on the need for an organization to have an internal structure whose corporate traditions and strategy implementations protocol facilitate the uptake of industry 4.0 components (Nagy, Ojah, Erdei, Marte, & Popp, 2018). For enterprises lacking an elaborate intra-framework, systemization is a solution proficient in reinforcing a corporate strategy that is in line with the current industrial revolution. With such an impactful influence, digitization has become a priority for global manufacturers as it ensures a cohesive change of company processes to elevate customer value creation (Nagy et al., 2018). Additionally, with the interconnectedness of the nine technologies of I4.0 further escalating the rate of goods production, this movement is able to ensure exhaustive investment of the numerous opportunities created by adopting digitization (Nagy et al., 2018). Coupled with increased efficiencies in industrial processes, achieving higher value creation is easily attainable.

2.3.2 Business Relations

The 4th industrial revolution impacts business relationships in diverse ways. Primarily, it aims at improving the relationship between customers, suppliers, and manufacturers. It has availed faster data processes mechanisms leveraged by manufacturers and producers in improving relationships with clients (Nagy et al., 2018). One of the benefits associated with this outcome is improved service/product planning, as companies are now empowered with data analytical methodologies that can analyze customer data for an extended period of up to five years. These planning processes will be availed by information collected from improved customer relations, as manufacturers are able to develop better understanding of client needs and engage innovative technologies in designing products and services that meet these demands

(PwC, 2019). Consequentially, this will assure order fulfillment, supplier centralization, as well as efficient product development (PwC, 2019).

The second benefit is the creation of a digital ecosystem between the manufacturers, customers, and the supply chain actualized by the internet that will allow the dissemination of information between these channels which will be accessed through the cloud. The main advantage gained from this ecosystem is coordination of activities to heighten efficiencies and boosting transparency (PwC, 2019).

Additionally, it will avail an opportunity for benchmarking and learning elemental in transforming the relationship between the customer and suppliers with better, positive outcomes in the form of product accessibility.

2.4 Literature Reviews Summary

Most researches in the domain of industry 4.0 focuses in the area of manufactories and in the last years academics all over the world increased their attention to I4.0.

Different countries have researched Industry 4.0 using different approaches. Examples of used approaches are the framework method, model method, and also case studies were used (Kamble et.al, 2018). Other researchers followed the theoretical approach and literature review methods and came up with many publications in this field.

As per the literature reviews we can conclude that there is no generally accepted definition of Industry 4.0. Therefore, future research, and publications should seek to establish a notion that can be well embraced by all or most academics and industry experts (Barata et.al, 2018). Most of the study focuses on technology management and offers a general discussion of the principles and hypotheses of Industry 4.0.

In addition to that, majority of companies and industries worldwide face challenges in addressing and implementing the appropriate information and communication technologies to map business models and combine systems to adopt industry 4.0 for fully automation. Therefore, many entities overestimate their capabilities and resources' skills, and this make an essential to have accurate inputs for evaluating the readiness of enterprises for industry 4.0.

As per literature reviews, most researches focused on technologies and innovations, they noticed some gaps between the targeted digital transformation process and the environment capability and manpower skills. Also, there is lack of studies in this subject for the industries in GCC and Qatar in particular. Therefore, this research will focus on assessing the readiness of Qatar industries to adopt industry 4.0.

CHAPTER 3: RESEARCH METHODOLOGY

The overall research process used in this thesis started by discussing literature reviews and identifying the gaps based on the studies. Then an online survey used as data collection tool to collect data. The online survey is an easy not limited implementation method that gives numerical scoring results that are easily analyzed through graphs, charts, and percentages and as the target of this paper is to evaluate readiness level, numerical data and quantitative method are appropriate method.

Stakeholders have been chosen from the portal of Ministry of Commerce and Industry in Qatar. Upon that, the build survey had been shared with different companies to measure the readiness level. The data collection covered multiple areas to get required assessment results. Afterward, collected data was analyzed and scored to find out the readiness level of Qatar Factories for digital transformation.

For more detailed and realistic implantation proofs, a Qatari Cement Company was taken as case study for demonstrating the transformation process.

That means mixed method is used in the research. The survey generates quantitative data, which helps in meeting the aim of evaluating the readiness level as numerical data as percentages and degrees are required for this purpose. In addition to that, qualitative method is used by the interview conducted in the case study. This method is used to fulfill the requirement of details for how the factory operate. The outputs from the interview were non-numerical data, it varies between pictures, processes explanations, and business details.

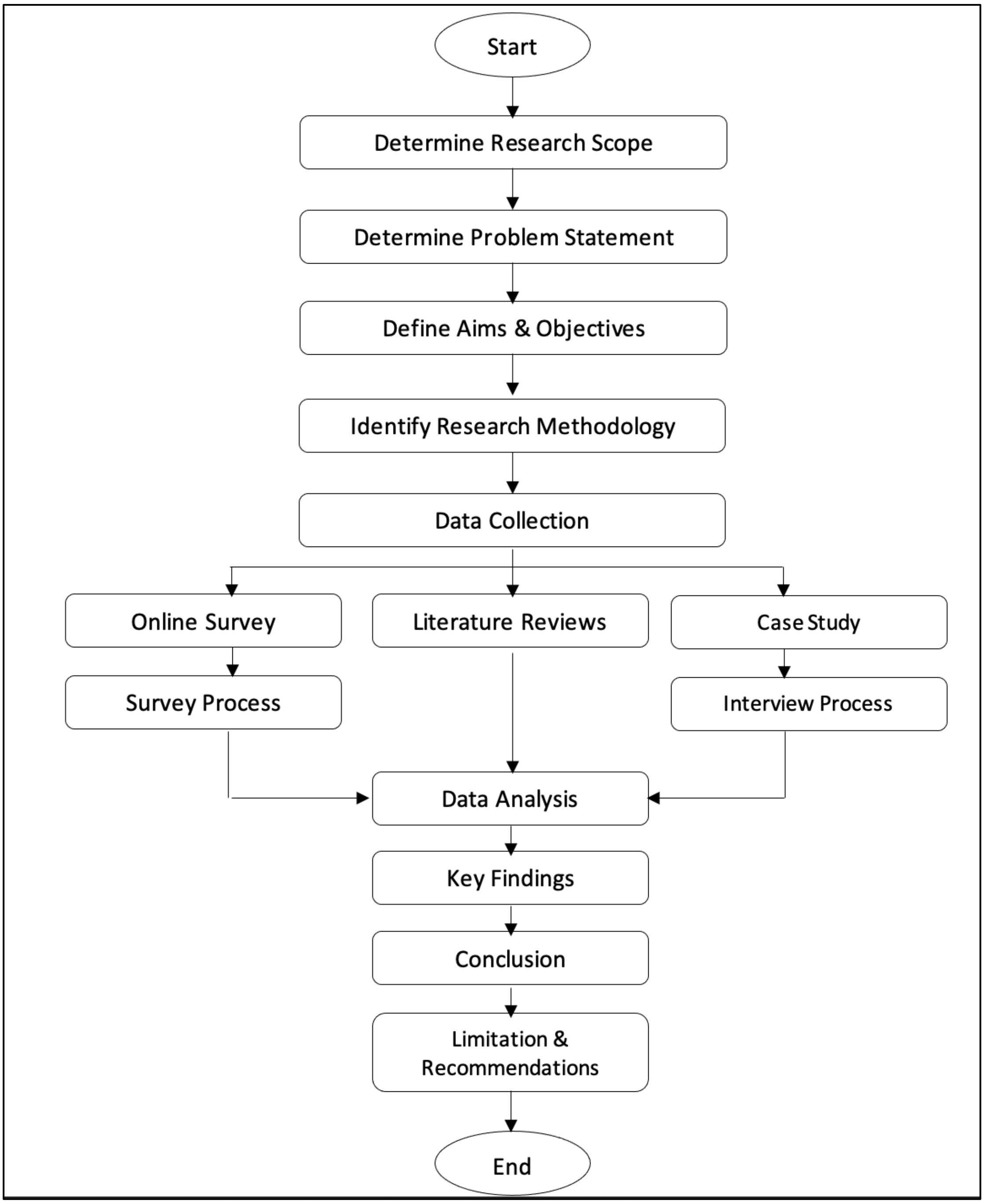

Figure 3 Research Process

3.1 Readiness Assessment Model (Online Survey)

A lot of researches and tools were reviewed in this field. German was the heart of digitalization in the early years and, they have the lead in this journey. The Readiness Assessment Model in this research was developed as online survey simulating online self-check model used to indicate business level of readiness by a German foundation called IMPLUS foundation. The survey was modified to meet Qatari industries upon the availability of tools and qualifications with respect to the difference between both countries growth. The survey relies on the four dimensions of Industry 4.0; smart factory, smart operations, smart products, and data-driven services. In addition to that, strategy and organization, and employees were also considered as general important dimensions.

After analyzing the responses on the assessment model, a company can be placed in a certain level from 0 to 5, as shown in Table 1, in the readiness maturity levels (Lichtblau et al, 2015).

Table 1 Digital Transformation Readiness Maturity Level (Lichtblau et al, 2015).

Level #	Strategy	Investment	Systems Integration	Equipment Infrastructure	IT Security	Skills
Level 0 Outsider	Default level for the companies that do not meet any industry 4.0 requirements					
Level 1 Beginner	Pilot initiatives in various departments	In single area only	Few IT systems support some production processes	Partially satisfy integration requirements	Planning phase	Can find few skills in the company
Level 2 Learner	Strategy is developed and measuring indicators identified	In few areas	Some data automatically collected	Partially satisfy integration requirements	Solutions are in place and expanded	Employees have required skills in some area

Level #	Strategy	Investment	Systems Integration	Equipment Infrastructure	IT Security	Skills
Level 3 Intermediate	Strategy is formulated	In multiple areas	Integration through interfaces and linked data in key areas automatically collected	Infrastructure is upgradable to accommodate future expansion	Solutions are implemented, Cloud-based solutions are planned to accommodate	Efforts made to expand employee skills
Level 4 Experiences	Use Industry 4.0 strategy and monitor with appropriate indicators	Made in nearly all relevant areas	Support most production processes and collect large amounts of data and s atisfies future integration requirements	Further expansion is possible becau se of availability of required equipment	Solutions are used in the relevant areas, and IT is scalable through cloud-based solutions	Company has the necessary skills to achieve this status and further expand
Level 5 Expert	Already implemented I 4.0 strategy	Throughout the entire company	Implemented comprehensive IT system support in its production and automatically collects all the relevant data	Satisfies all the requirements for integration and system-integrated communications	Cloud-based solutions deliver a flexible IT architecture	All necessary skills are available

The automation pyramid (figure 4) can be used to get more clear examples on the six readiness levels.

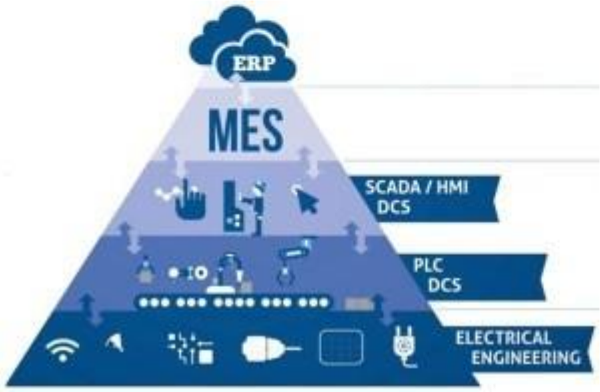

Figure 4 Automation Pyramid(Kumar, 2019)

Table 2 Readiness Level According to Automation Pyramzd

Technologies in the automation pyramid	Industry 4.0 Readiness level
Automation pyramid not integrated, cloud only for storage	Outsider
ERP is integrated with MES and Scada	Beginner
ERP is fully functioned and integrated with MES, SCADA over cloud	Learner
MES, SMART PLC, ERP fully integrated using data engineering over cloud	Intermediate
Fully integrated with IIOT and smart sensors and data engineering is used to collecting all data in one namespace	Experiences
Using Machine learning to simulate management decision making, the industry process fully automated and integrated together	Expert

Figure 5 shows the survey process that was used in this thesis. The survey developed with total of 23 questions. Part one of the questions started by asking for general information about the company to find out the relation between the company specialization and the digital transformation process. General questions about Industry 4.0 is shared to measure the knowledge about industry 4.0 and its technologies. Last part of the survey displayed more detailed questions regarding Industry 4.0 to measure the readiness of the companies toward transformation. Comparing to a technologically advanced country like Germany -the innovator for industry 4.0 revolution-, it worth to consider their transformation journey. Different assessment processes are reviewed and compared to develop one that suits the Qatari market.

Collecting data and responses for the survey depended on the portal of Ministry of Commerce and Industry (MOCI).

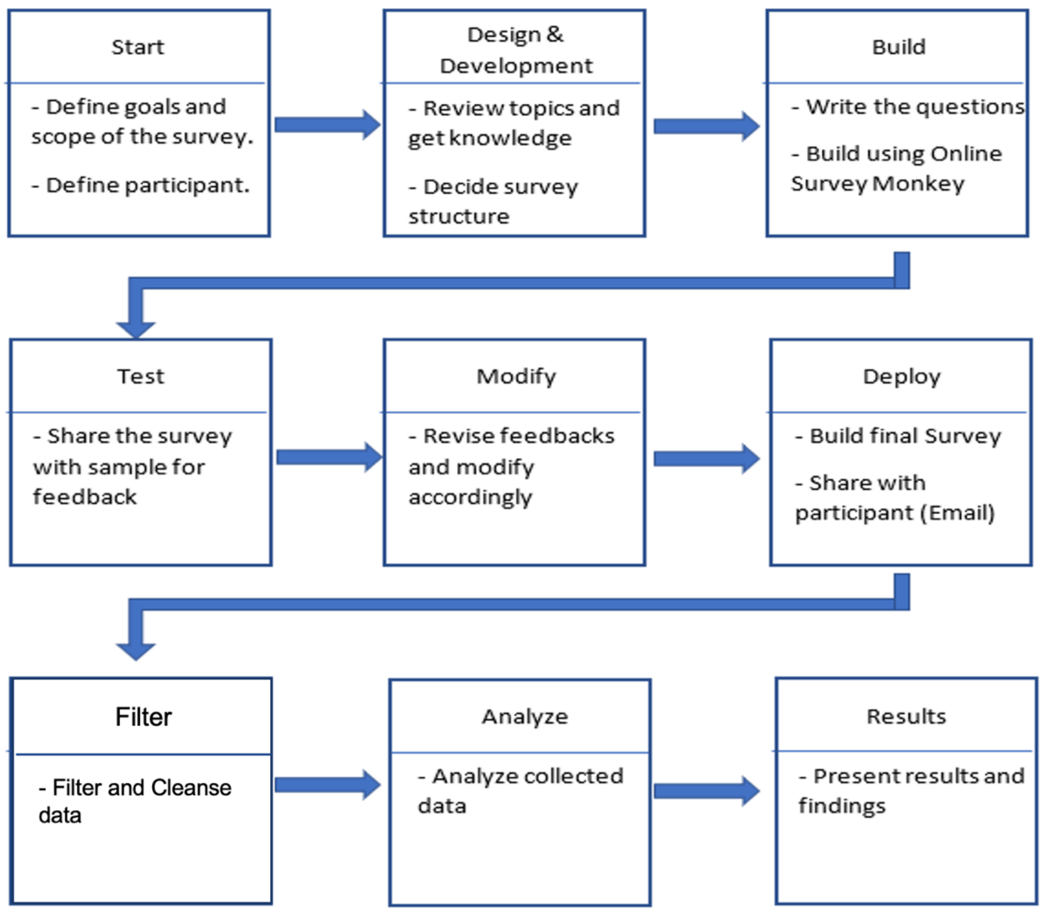

Figure 5 Survey Process

3.2 Case Study

The case study company is a Qatari cement company volunteered to be taken as a case study in this research. The head of ERP and IT in the mentioned company is interviewed to go through the production cycle. The company already uses advanced technologies but not have fully integration and automation among the processes. Taking in consideration cement related products release huge amount of carbon dioxide and harmful gases, so automating cement production process and reducing human interference can solve this challenge.

Also, relaying on innovative technologies allow real time optimization which minimizes the time consumed in each step of the production cycle with related activities like energy consuming for longer time.

Figure 6 shows the interview process that was followed to collect data about the company.

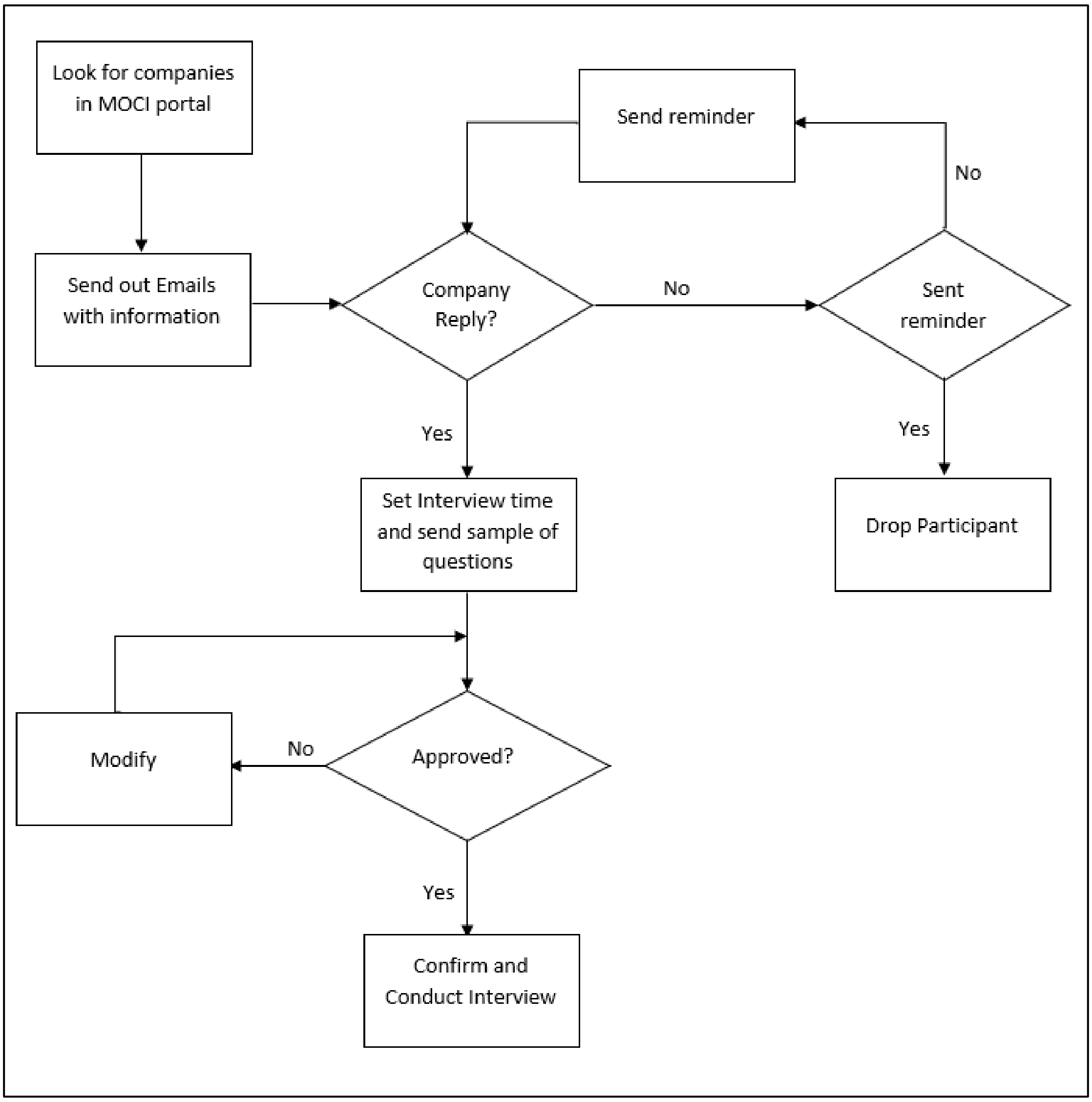

Figure 6 Interveiw Process

3.2.1 Technologies in the Operation Cycle

Referring to the automation pyramid, the case study company manipulate different types of data using different tools and technologies. Figure 7 expresses the workflow architecture for the business cycle in the company.

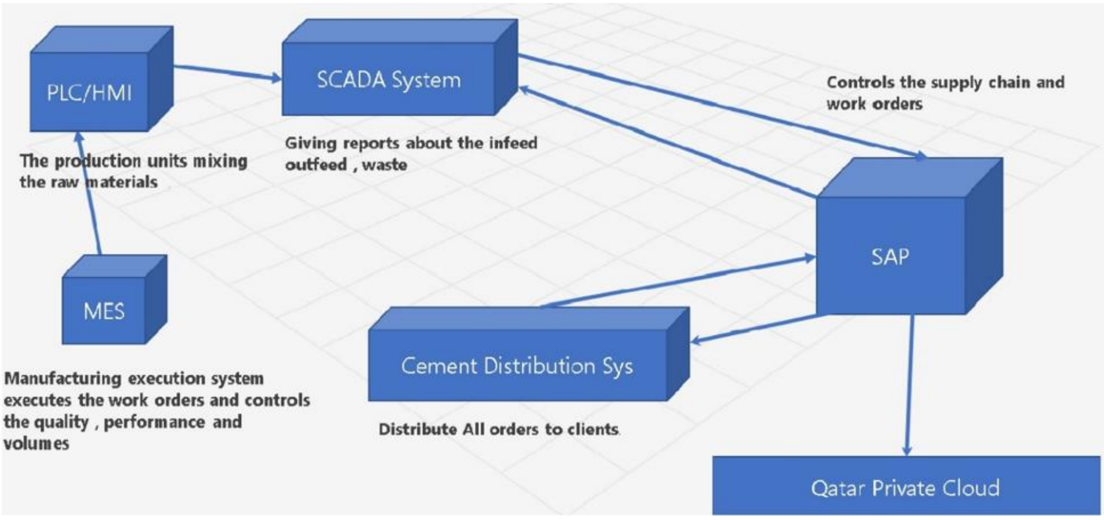

Figure 7 Production Cycle Architecture for the Company

Production cycle in the company starts from MES (Manufacturing Execution System) which is responsible for the rations of the ingredients and how compounded together to produce the cement or the final product. MES generates reports about the performance of the production processes and the Overall Equipment Effectiveness (OEE). OEE considers the various subcomponents of the manufacturing process, i.e., Availability, Performance and Quality.

PLC/HMI is the platform responsible for the infeed of the raw material like Gibson, rocks and sand and responsible for the outfeed of the Cement as a final product. This platform also gives the waste value and the state of each node in the production cycle and which state in each process to follow up the production cycle.

SCADA system installed from Siemens is a computer-based system for gathering and analyzing real time data. SCADA system is used to monitor and control process and procedures. Finally, SAP (ERP) is the dominant responsible for the following;

1. Monitoring the inventory system and checking the lead points for the required materials for productions to generate purchase orders PO.
2. Receive sales orders and validate production lots.
3. Calculate the profits from sales.
4. Calculate the expenses from the purchase orders and the internal payroll.
5. Control the delivery of the shipments to customers through in-house built in application.
6. Manage the supply chain of the factory and the purchase orders.
7. Manage the payroll and HR of the factory.

3.2.2 Challenges in Case Study Company with Current Process

There are generally many challenges facing the Company as any other company that planning to move to new technologies and adopt industry 4.0

- **Data differentiation:** Different systems with different platforms generate different types of data. All data should act together and exchange information between each other to automate the manufacturing processes. The challenge is how to combine all collected data out of all these systems in one place as one database for authorization to apply required engineering. The solution for this challenge depends on two technologies in Industry 4.0 which are data science and data engineering. Implementing specialized applications that rely on data science can unify and analyze data that comes from different platforms automatically. Examples of such applications are tabular data streams using hive technology, streams using storm technology, and big objects data.

- **System Automation;** as explained the operation cycle in the company is not fully automated and human interference is required in between steps and activities. Industry 4.0 implements full automation by applying IIOT using sensors and WIFI for automating all manufacturing processes. IIOT make it possible for information to travel between machines with no human interference so the process becomes fully automated.
- **Human interference and decisions making delay:** During the execution of the manufacturing process there are a lot of manual reports about the status of the machines, the waste of the materials, the infeed and outfeed of each process. These reports are generated by different systems, examined by staff, committees, and/or decision makers for orders/changes. Also, during the operation some machines can be suspended or get damaged and need maintenance or replacement and need human interference to make proper actions. Machine learning can solve this challenge by collecting all common problems as cases and list specific criteria for each case and when the problem or the case appear in the system, the machine learning examines that case based on the predefined criteria and execute the suitable decision automatically for that case with no human interference. As example of applying machine learning, when the active sensor on the PLC/HMI reports for offline equipment, or insufficient machine due to maintenance failure then an instruction is sent by sensors to the ERP to issue a maintenance order to the supplier. The technician will be notified for a site visit to maintain the failed machine. Depending on machine learning helps

in creating a database for all known cases and register any new problem and prepare an instruction set to be executed when any case reoccur which eliminates the chance of wasted material, time and efforts.

3.2.3 Technology Readiness Level in the Case Study

Based on the interview held with the Head of ERP and IT in the company to explain in detail the production process in the company. We found the following:

1. SAP is used there as ERP, it prepares the sales orders, payroll, purchase orders, shipments delivery, supply chain management.
2. SAP receives reports manually from SCADA system.
3. No integration between SAP and MES nor PLCs /HMI.
4. Financial data, reports, revenues and expenses are calculated in SAP but there is no automation between MES, or Scada with SAP.
5. The company developed a transformation strategy and started the required investment to control all industrial equipment using Internet and cloud.
6. Sufficient resources skills and training for improvement are available.

Referring to automation pyramid and readiness maturity level in table 1, having above points in a company can place it in readiness level 3 as intermediate from administrative and requirements perspectives. On the other hand, the technology level is almost at level 1 as beginners due to limited integrations between systems.

3.2.4 Analysis for Intelligent Factory Area

The idea of the digital factory is to make equipment interact with other through sensors, Wi-Fi and human interference is just to consume software to operate the equipment towards less paper and no manual work on sites.

The value of the digital factory can be clearly shown in decreasing the human mistakes, decreasing the waste of the material used, and reducing the time for taking decisions.

In our case in the Cement Factory, the systems are not connected together, workers must take reports manually from each system to the technical people who held committees, meetings and send emails and memos to each other to get final decision.

The process of taking the schedule from the ERP to the MES, giving the instructions to the PLC/HMI to run the instructions wasting a lot of time, material and demand a lot of people to collaborate.

Transforming into digital factory will reduce the chance that manufacturing processes affecting the health of the workers on the long run and causes a lot of diseases and consuming a lot of money on treatments and medications.

The implementation of industry 4.0 can help Qatari factories to move to more digitized environment and gain the technologies benefits to improve their businesses.

First step in the transformation process is to collect MES and SCADA data into one namespace and model these data into one data model to create the integration from database level and store all data in the cloud.

Second step is connecting the essential equipment using sensors through WIFI with the broker which will interprets these inputs into readable data formats can be sent to the appropriate system.

Third step is applying machine learning to have smart enough machines that can act full cycles with zero human involvement.

3.2.5 How to transform to Industry 4.0

In this case implementation we can propose to setup the cloud environment which will be used for the following:

1. Receive the IOT data.
2. Collect data from different platforms.
3. Perform a modeler using specific language to model these data and prepare it for data engineering and data analytics.

The required software and tools to setup the data analytics environment and the machine learning database can be as followed:

1. Cloud services as cloud platform.
2. Data from SAP of the company showing the supply chain orders.
3. Spread sheets from inhouse software for the distribution showing the orders delivered to the customers.
4. CSV files from the SCADA showing the active devices and inactive devices.

Figures 8 and 9 presenting the interface of SCADA and MES.

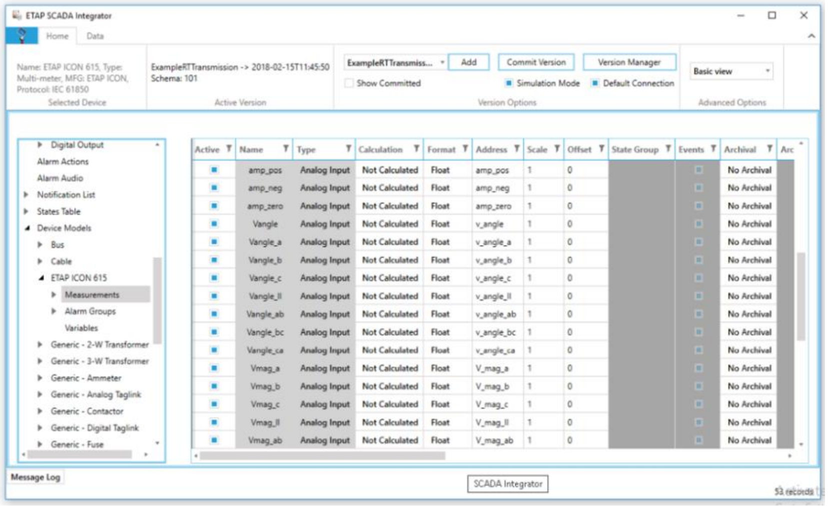

Figure 8 SCADA screen showing the active devices and inactive devices.

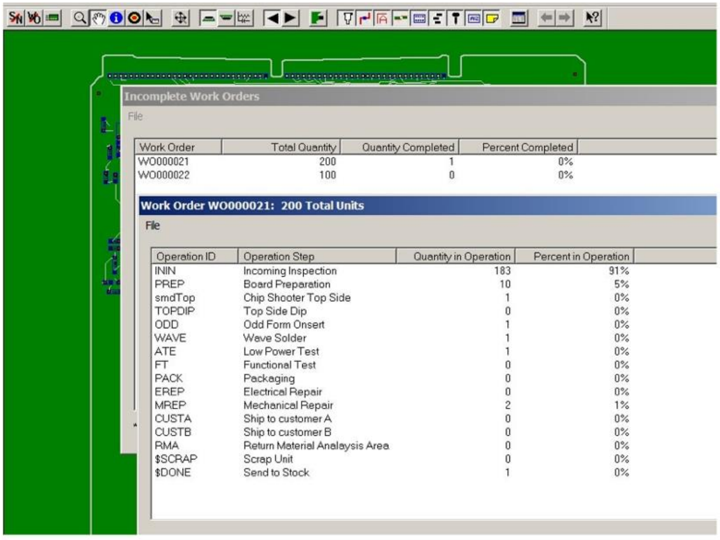

Figure 9 Daily Work report on MES

Using cloud platform to present all data and information in one dashboard

1. The daily waste of the raw material.
2. The percentage of the performance.
3. The supply chain orders generated from SAP.
4. How much orders for the products shipped to the customers or other plants.

Next step applied is to integrate load and integrate the data from mentioned different tools (waste data from the MES combining it with the supply chain data from SAP combining it with the active and inactive machines) to monitor the performance of the factory by displaying it on dashboard showing online activities of the whole production systems working in the factory.

The steps used as follows:

1. Load the data from the files using the apache HIVE technology.
2. Insert these different data into table in the cloud.
3. Query these data to get analytics data ready to be shown in the dashboard.

Theoretically, implementing above proposed plan can solve the challenges in the cement company, where the data differentiation challenge is solved using Data since and Hive technology which collect all data and give the ability to querying these data to give real time reports and statistics.

The Automation challenge solved using IIOT Technology -which will be described in the next section- by adding sensors to the machines which read and send data directly to the cloud.

Finally, to solve the delay in taking decisions, live dashboard is proposed to have a full detailed picture about all machines and resources statues.

3.3.5 Transformation Technology Requirements

1. IIOT

The idea of IIOT is to get all data and information in hands by converting the machines to be smart using sensors which will convert the analogue data output from the machines into digital bits can be sent into packets on a specific channel using Wi-Fi to the server applications which interpret the digital signal into specific information.

2. Data science using data engineering analytics

The data science role is solving the problem of data differentiation coming from different platforms and combine them together in one place in a normalized form to feed the machine learning repository to introduce real-time data analytics reports in one dashboard.

3. Machine Learning

Machine learning technology used to build a database of required actions from machines depending on incidents or issues. For example, when a machine failed to operate properly the sensor will send the data to the proper application, which will send this data to the machine learning database to examine the failure. Based on the examination, an order placed for maintenance in the ERP.

4. Cyber Security

To secure all data transfer between machines, systems, suppliers and customers.

3.3.6 Case Study Summary

The cement company in this case already works on strategic plan to move toward industry 4.0. Although systems and applications used, the process itself still not automated. They use the full functions of ERP system, for finance, HR, supply chain, and etc. Beside the ERP, the other automation pyramid layers are implemented; MES, SCADA and PLC.

In operation level, the production process depends mainly on manpower to feed in data to the systems, monitor progresses and generate orders and reports. The production cycle has no automated data exchange mechanism.

In technical level, the company as mentioned apply the all layers of automation pyramid, but with no integration between them. The PLCs in this case are missing smart sensors, as the PLCs alone deal with large amounts of big data. The sensors build in PLCs added the ability to capture deep data and monito more specific items. The cloud used in the production process as storage unit only to store data comes from PLCs. They are not implementing the full functionalities of the cloud. Cloud computing has the ability to provide infrastructure for IOT platform that can play the main role in connecting embedded devices to interact and collaborate with each other and collecting, exchanging and analyzing data.

With these gaps in operation and technologies there is no across platform nor vertical automation in the company's production cycle between the devices and systems.

CHAPTER 4: RESULTS, IMPLEMENTATION AND DISCUSSION

Industry 4.0 is the IT capabilities to organize, automate and integrate the production cycle in innovative ways to reduce the costs, wastes, labor costs and efforts and time consumed to produce qualified products.

In this research, the industrial firms in Qatar were surveyed, examining the volume of production, labor volume, revenues, the availability of raw materials, the transportation, the nature of required services and products. Also, a cement factory has been taken as case study to examine the production process maturity.

4.1 Survey Analysis

Total of 102 companies contributed in the survey, but only 52 responded to all questions where others considered some of the questions as confidential or not applicable to their companies. The companies' activities varied between oil and gas, food and beverages, cement industries, medical industries, and others. Around only 10% of the companies classified as small size company with 10-49 employees where medium and large enterprise companies take the majority with equal percentages. This equivalents the general factors for the companies contributed in the survey.

In addition to that, the role of the contributed people in the survey took places between projects managers, IT managers and business analysts, which can be considered as indicator for having good understanding in the industry 4.0 in the level of business and management.

Part two of the survey developed to get information about the technology base of the companies that are targeting to move toward digitization and digitalization. Details of the survey are described in the following section.

- *What forms are used to store data?* Defining the varieties of data used in the data exchange mechanisms give indication on the requirements for data analytics in industry 4.0 approach. As shown in the figure 10, companies use more than one form of data which required data engineering in the transformation process. Around 80% of the companies as shown in figure 10 are aware of this requirement and are planning to use data engineering to collect all data from different IT projects and query these data to wherever it stored in Scada, MES or ERP to act as one data source for dashboards and management reports.

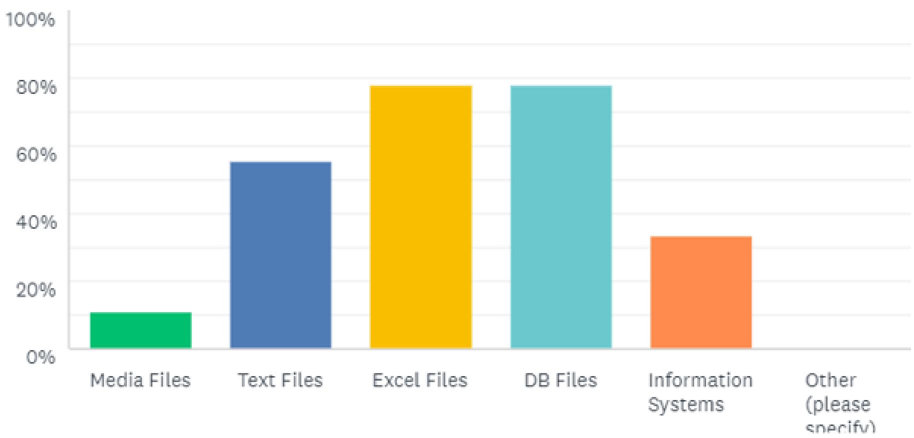

Figure 8 Forms of stored Business Data

- *Sharing Data:* 90% of the companies use EDI (Electronic Data Interchange) to share information with suppliers, customers and partners which means using digital media and eligible to move forward. For shared data it is necessary to analyze them to meet the required results needed to feed the receiver. Around 78% of the companies agreed on the importance of considering Data engineering for this purpose. Figures 11 and 12 illustrate companies' responses in the survey.

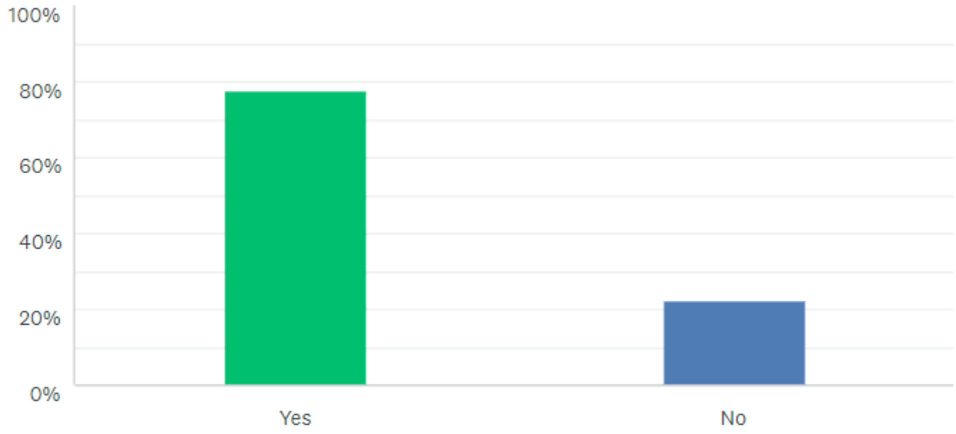

Figure 9 Companies will Use Data Engineering in Data Analytics

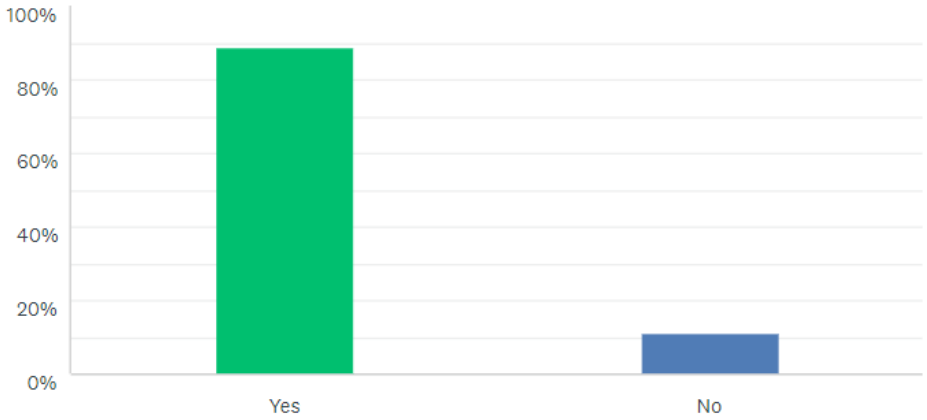

Figure 10 Companies Use EDI to Share Information

- **Company Strategy:**

This part started with indicating the level of information and readiness of the companies to implement fourth industrial revolution's technologies; (IOT, Big Data and Analytics, Cloud Computing, Software and systems for production, ERP – Enterprise Resource Planning, Systems Integration, Human–Machine Interfaces, Robots, Data security, protection and privacy, Simulation, AR–augmented reality, VR-virtual reality, AI– artificial intelligence, ML– machine learning, Additive Manufacturing, Cyber Security, Industry 3.0, Industry 4.0, Digitization, Digitalization). In a scale from 1 to 4 where 1 is low and 4 is high, most companies fluctuate between levels 3 and 4 in having information about the technologies and lower level in the readiness to implement the mentioned technologies for digital transformation as shown in figures 13 and 14.

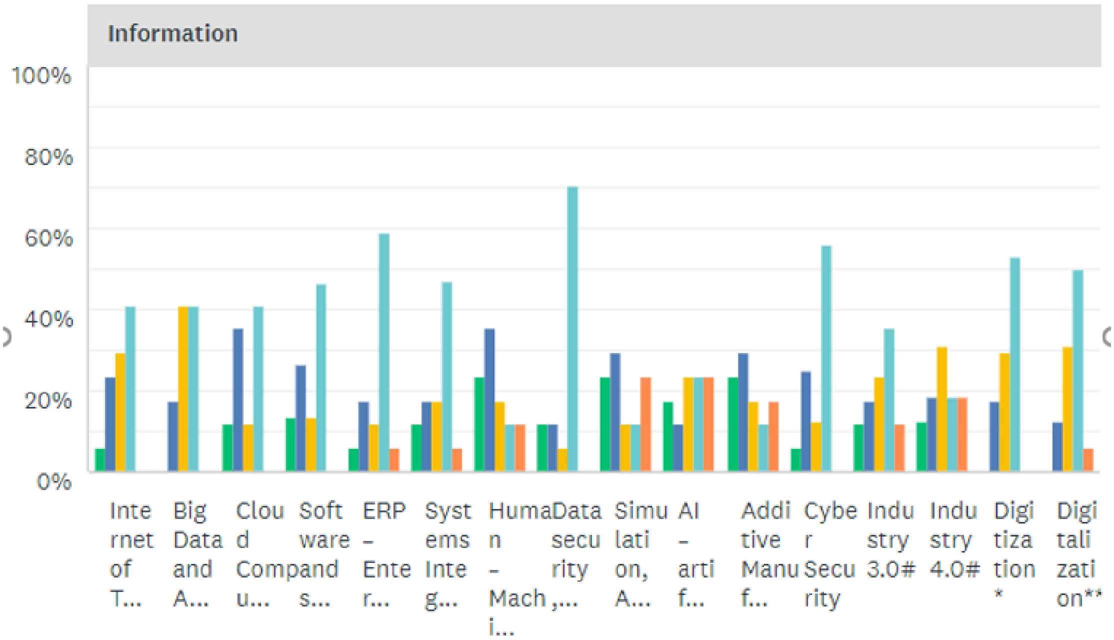

Figure 11 Level of Information in Implementing Technologies

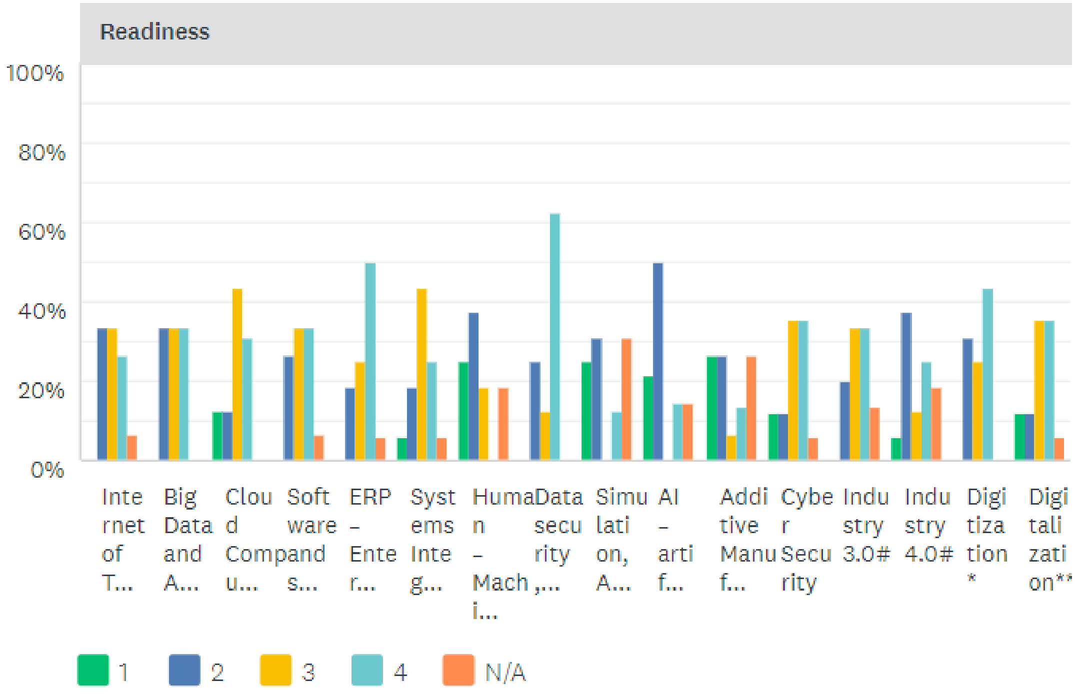

Figure 12 Level of Readiness in Implementing Technologies

Regarding the government support in the company strategy, it is very important to advance the level of awareness of the transformation process by providing training courses and importing experiences to train and held workshops to sharpen the employees with the recent technologies and knowledge. As per the companies' feedback more than 70% of the companies acknowledged getting the government support in the need license for the software, where 30% claimed not getting any government support. Qatar Digital Government (QDG) Training Program from Ministry of Transport and Communication provide workshops for all entities in IT related programs, and 55% of the contributed companies in the survey confirmed having continues courses and workshops. Figure 14 shows the government support in the digital transformation strategy based on surveyed companies.

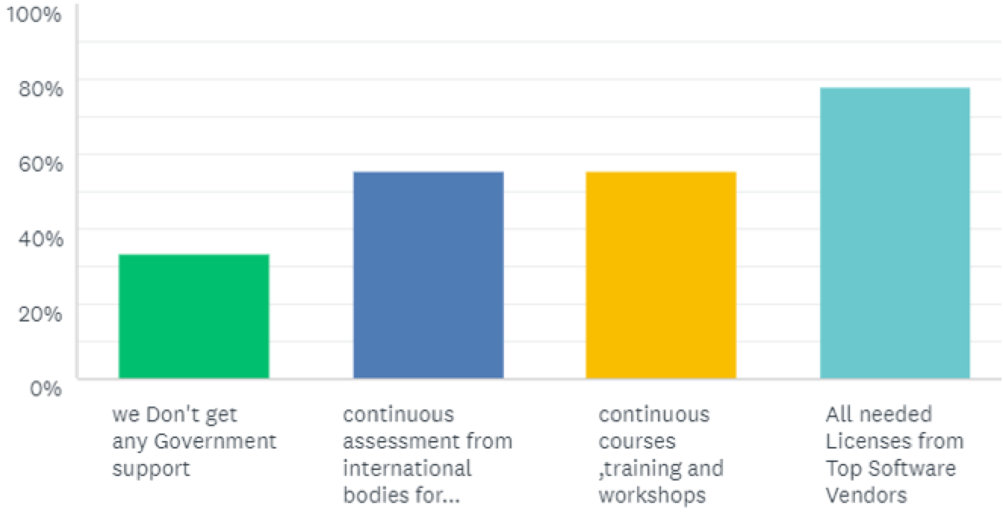

Figure 13 Government Support in Digital Transformation Strategy

In reflecting the four dimensions of industry 4.0, around 77% percent of the companies stated that their strategy plans to fulfill the smart operation level where enables flexible production planning and control. This dimension requires level 4 skills as experience in the scale of readiness. Figure 16 presents the strategy plan targets for the companies as respect to I.4 dimensions.

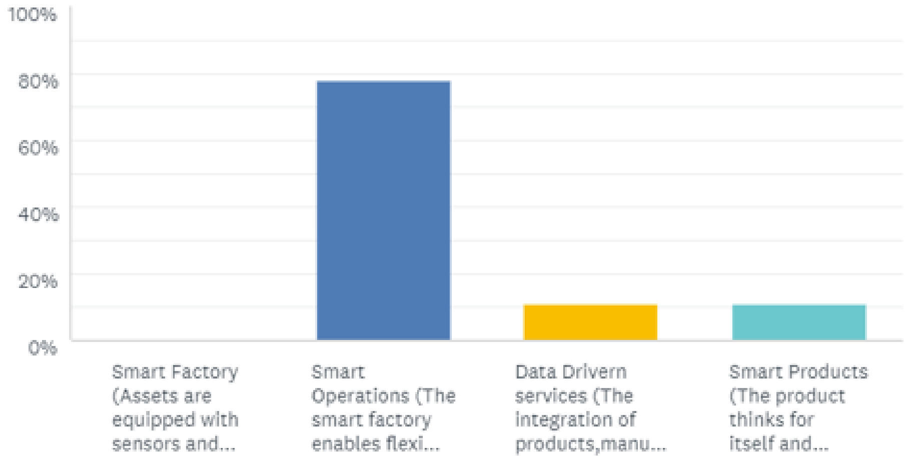

Figure 14 Strategy Plan Targets for the Companies as Respect to I.4 Dimensions

- **Human Resources**

Managers, workers, and all different levels of employees are a major factor affected directly by the digital transformation. Many tasks that will be automated will end up the human presence in these roles and for other roles the staff will require new skills and qualifications. As per the survey and results shown in figure 17, 74% of the company's employees are from bachelor's degree in education level and with average age between 29 to 40. This level of staff is a good base to build required skills and train them for the new movement in the business. Although, the investment is considered low in employees' skills improvement, almost all the contributed companies use different channels for train their staff such as internal/external courses, self-study and cooperation with other companies.

Figure 15 Human Resource Factor

- **Challenges and Obstacles:**

Contributed companies were asked to select from given choices the biggest Obstacles for Digitization and Digitalization operations capabilities in their company and their responses varied as shown in below table. Majority of the companies agreed about the lack in having clear digital vision and strategy with 70%. Difficulty in collaborating with business partners around digital solutions is also one of the big challenges that face the companies.

Table 3 shows the obstacles and challenges that the companies are facing toward digitization and digitalization operations.

Table 3 Obstacles for Digitization and Digitalization Operations

Obstacles	Percentage
Lack of a clear digital vision / strategy and of support / leadership from top management	70.59%
Lack of standardization, norms and certification for Factory of the Future	23.53%
Inconsistent processes across multiple production facilities	5.88%
Lack of knowledge about providers	17.65%
Lack of necessary talent / skilled people	23.53%
Difficulty in collaborating with business partners around digital solutions	35.29%
Difficulty in coordinating actions across different organizational units	17.65%%
Uncertainty about in / outsourcing	17.65%
Lack of automation, information and infrastructure technologies	17.65%
Change management	29.41%
Unclear economic benefits and digital investments	17.65%
Difficulty in demonstrating ROI	5.88%
High financial investment requirements	17.65%
Unresolved questions around the data security and data privacy in connection with the use of external data	29.41%
Concerns about loss of control over your company's intellectual property	17.65%
Concerns about damaging corporate image and loss of customer trust in case of data violation	11.76%

- **Integration Pyramid:**

Implementing integration according to the automation pyramid can classify the companies in appropriate readiness level for digitization. In case of implementing full integration i.e. fully implemented the IIOT, sensors, smart PLC, ERP all over cloud means the company is on level 4 as experienced. Where partially integrated means place the company in level 3 as intermediate, and no integration means they are not t ready yet for the industry 4.0 and still in beginner level.

One question in the survey targeted to know the level of automation pyramid tools used in the company and the level of integration between them. As per the survey result shown in figure 18 and 19, around 90% of the companies use ERP and MES, 70% uses SCADA and few companies have smart PLCs and sensors. With availability of these tools, only 55% of the contributed companies declared having partial integration between them and 44% have no integration.

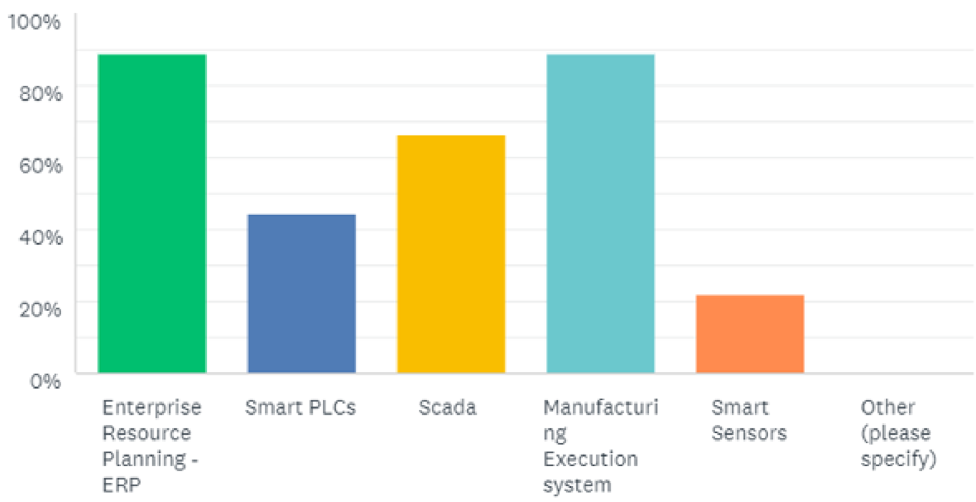

Figure 16 Available Tools in the Company

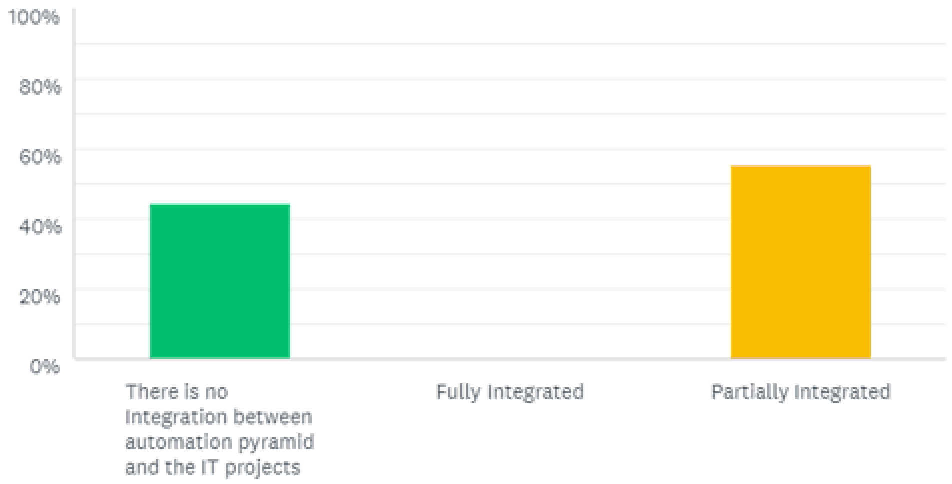

Figure 17 Level of Integration as per Automation Pyramid

- **Industry 4.0 Technologies**

One question in the survey asked to grade the technologies impact on how people work after transformation. Figure 20 shows, in a scale from 1 to 4 where 1 is low and 4 is high, more than 50% scored big data with high score in transforming work in next 5 years followed by the cloud.

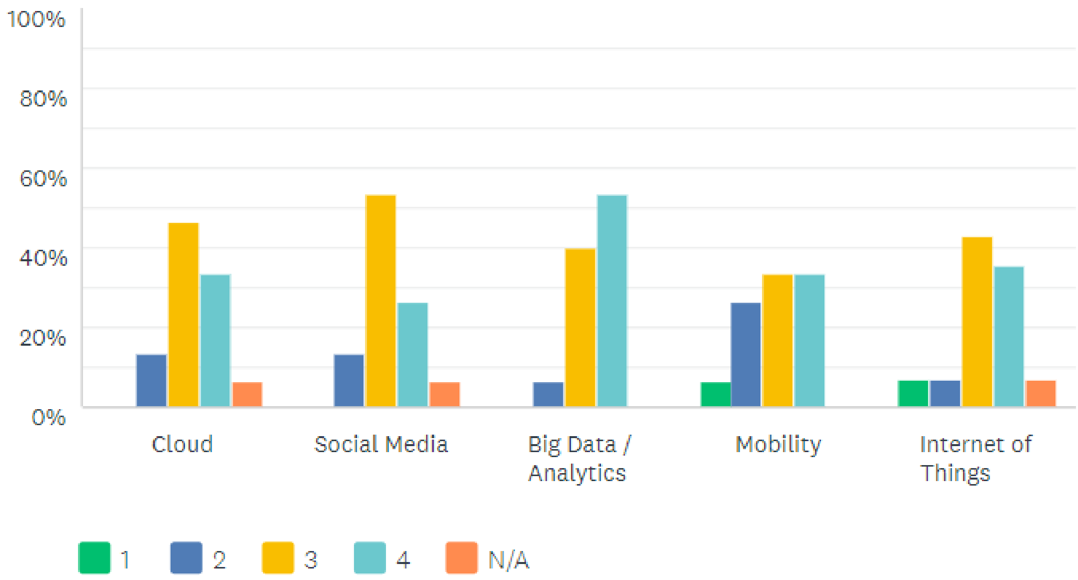

Figure 18 Technologies to Transform Work

- **Industry 4.0 Technology – Cloud:**

Cloud services is a main infrastructure to transform industry automation. Depending on which benefits will be used you know how much dependency you will use the cloud services. The use of cloud is one of the aspects of Industry 4.0 implementation in the dimension of smart operations. Contributed companies in the survey have been asked about the importance to have cloud. All the responses as shown in figure 21 represents the high awareness of the companies about the services of the cloud technology.

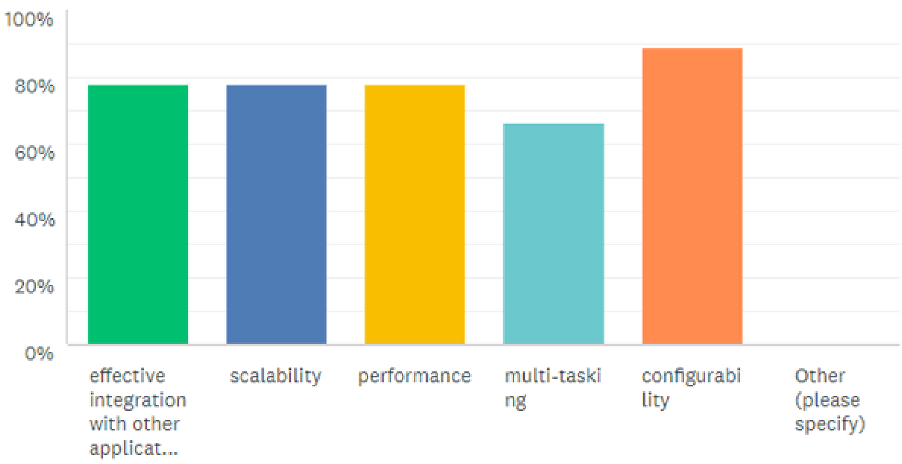

Figure 19 Importance of Cloud Services

As in figure 22 the survey shows that the companies vary in using different types of cloud models. Around 50% of the companies use the hyper cloud and 50% the private cloud. The cloud mode depends on the security level required in the company and the level of data confidentiality. The hyper model is the suitable for integration with external source.

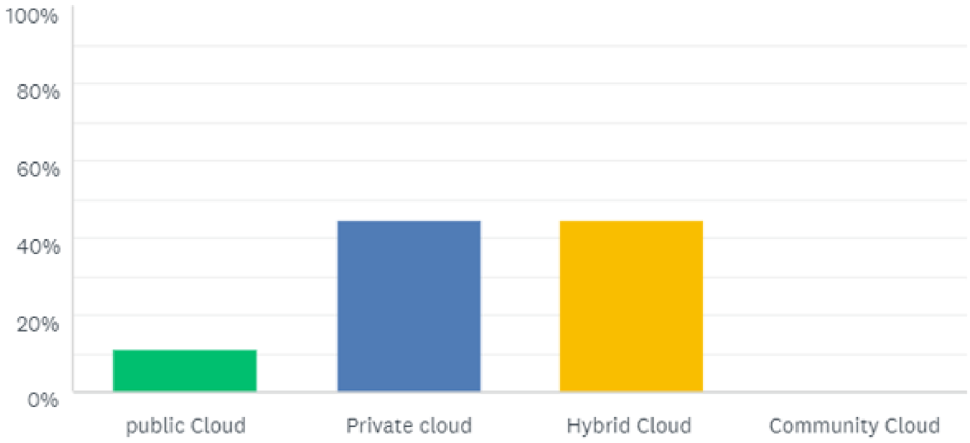

Figure 20 Types of Cloud Deployment Model

- **Industry 4.0 Technology – IIOT:**

Depending on IIOT as an interconnection among the vertical systems in the automation pyramid, is a remarkable shift in the industry 4.0, not using it place the company as learner in the readiness level. Nevertheless, the survey results that around 70% of the companies are not using IIOT as shown in figure 23 and very few considering IIOT in wide area.

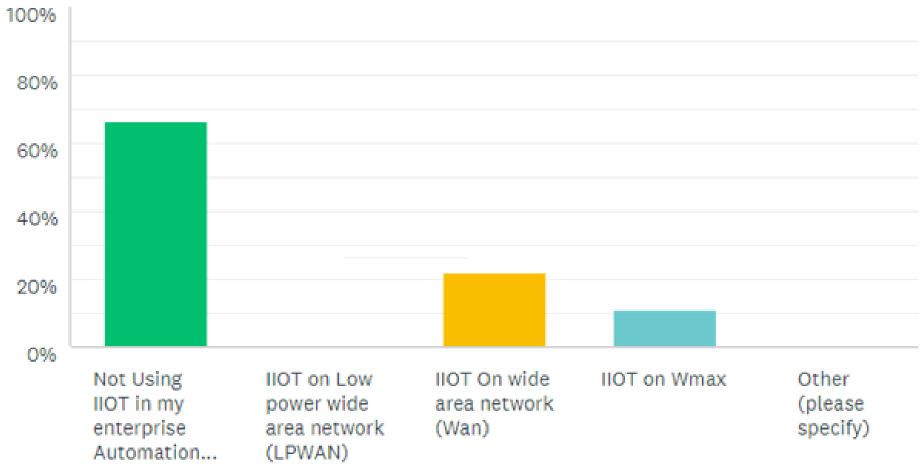

Figure 21 Using IIOT

4.2 Industry 4.0 Transformation Concept

The aim of this research is to develop a conceptual framework that can be used in developing industries to transform low levels production systems to industry 4.0.

Based on the collected data from the survey and the interview with a company, following figure explains the process of any basic industry.

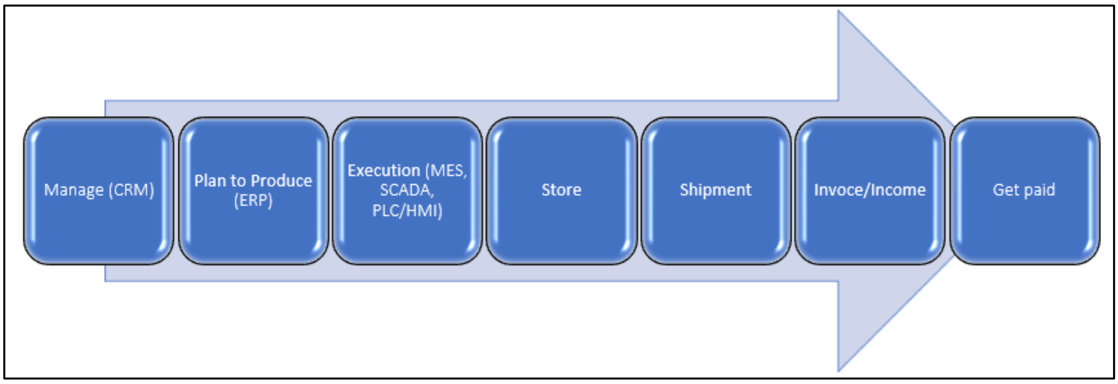

Figure 22 Industrial Structure

1. CRM: Manage the business and internal/external relationships.
2. ERP: Must have system from the beginning as it is responsible for schedules, work orders and raw materials.
3. Execution systems (MES, SCADA, PLC/HMI): for monitoring, collecting data, control, identify problems, and maintain efficiency on production.
4. Store (warehouse), shipment, and invoicing process handle by ERP.

   The main target of the production process is to maintain the Overall Equipment Efficiency (OEE) by managing the availability, quality and performance.

   First step in implementing I4.0 is to have integration between the systems as shown in figure (25).

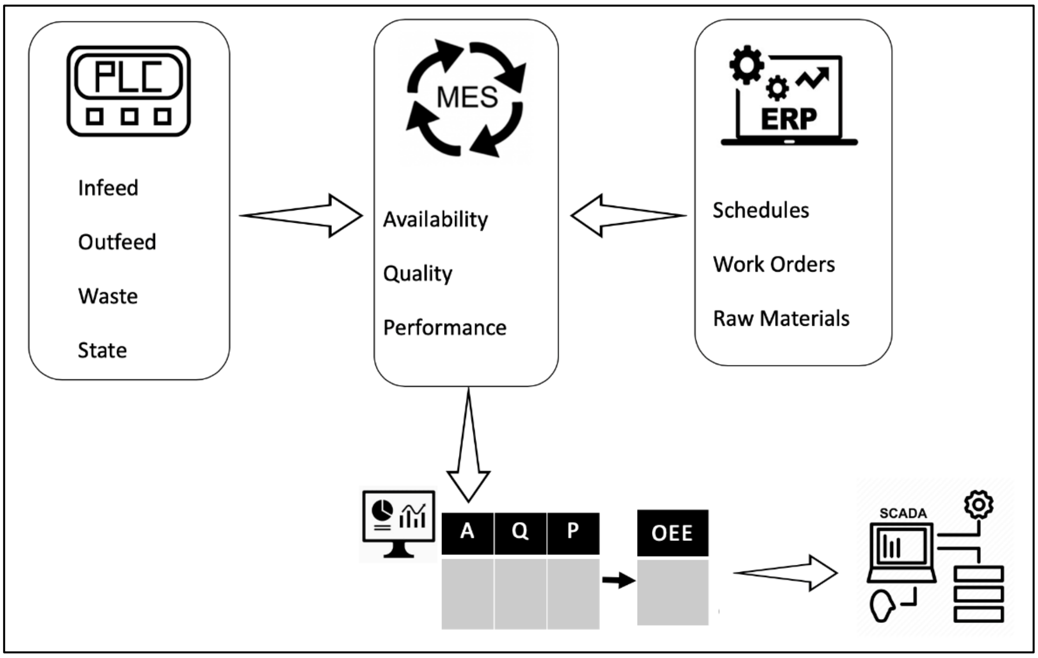

Figure 23 Systems Integration

In the integrated version of the industries, the MES get feed from the PLC and ERP to execute the work and based on that it generates reports in a dashboard to monitor the OEE. Any decreasing in the OEE the operator send instruction to the SCADA to speed up or down the production process and recalculate the entered data based on the values of A, Q, and P.

The instructions sent by the operator are sent –in this case – with no accurate feedback about the status in PLC and ERP, which affects in load of work orders, cause shortage in raw materials, and impacted the financial status.

Implementing industry 4.0 technologies can eliminates these issues:

Cloud – Machine Learning: uploading data to the cloud and implementing machine learning application taught the machines how to react based on experienced scenarios.

IIOT: in case of no integration between ERP and PLC, nor between PLC and SCADA. IIOT supported devices allow all systems to be connected by subscribing in a central location where all data are shared as shown in figure (24).

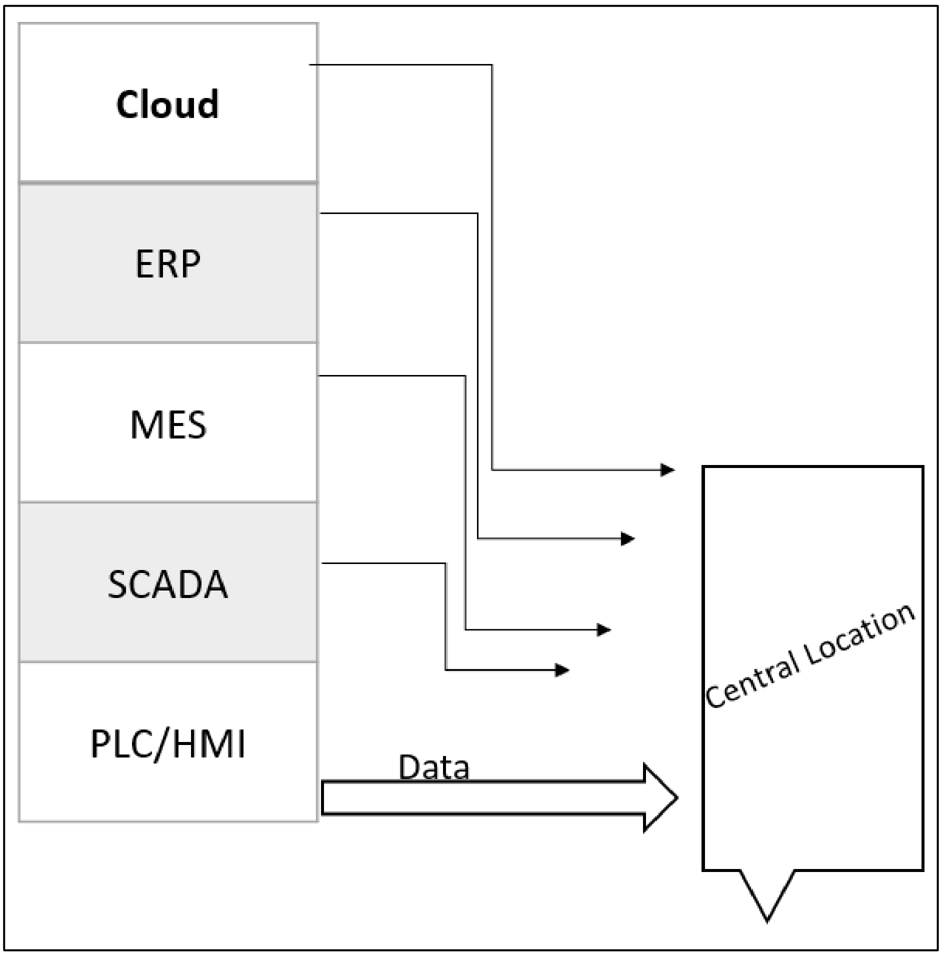

Figure 24 IIOT Concept

Theoretically, the above-mentioned proposal can add following features to the factory:

1. No paper or manually work.
2. People consume from software and equipment interface only equipment.
3. Decrease number of errors as data fed from trusted resources automatically with no human interfere.
4. Real time metrics.

5. Big data analytics from machine learning applications which helps in predictive and forecasting.

4.2.1 Pre-transformation Process

Before adopting the technical integration mentioned in above section 4.2, it is essential to prepare the pre-requisites. As mentioned in the literature reviews most companies have difficulties in evaluating the level of readiness for their companies for digital transformation.

Digital transformation should start with reviewing all available resources in the company and by resources it includes manpower, equipment, technologies, skills, knowledge, budget and any other factors can be part of business process digital transformation.

In this research, the online survey was used evidenced that there are many gaps in the companies that should be filled in order to move toward industry 4.0 adoption. Therefore, the business process change plan cycle in figure 25 is proposed as a means for evaluating and identifying gaps that may hinder the transformation process. The cycle is general and target the business workflow, so different type of industries can follow it. The concept is to examine all phase, where each industry will detail their own processes, technologies, tools, skills and all other resources.

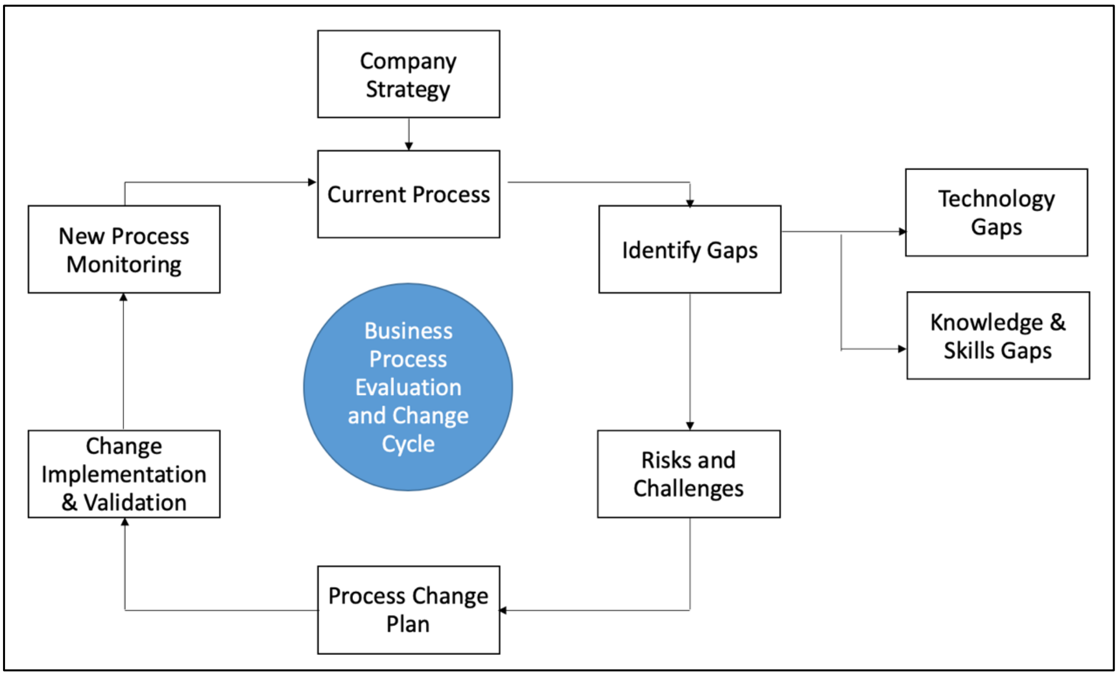

Figure 25 Business Process Change Plan Cycle

1- Company Strategy:

As first step, company strategy should be reviewed. Digital transformation is a process that requires prior planning for long term. Management level should consider this movement in the strategic plan which should be aligned with the country vision and set the goals for the different departments and sections based on their roles with proper timeline.

2- Current Process:

Study the current implemented process and the full production cycle in the industry. All steps should be considered with no exceptions, the managerial, technical and practical ones. The characteristic of each machine and the connection with others, the used technologies and tools, the hierarchy of requests, all these consider as inputs for the transformation process.

3- Identify gaps:

The idea of industry 4.0, although it has been under study for long time, is still does not have a clear definition. Companies should work on defining their transformation process in the strategy plan in-order to work on identifying the gaps in all levels. Digital transformation depends majorly on using advanced innovative technologies. So, implementation of trend technologies is a must as initial step. As shown in the survey results, there are companies already using new technologies, but still not at the level of adopting industry 4.0 because of the isolation between the systems and machines. Full integration between the process phases is the core idea of digital transformation. In addition to that, employees should be ready to control and deal with digital environment. Therefore, it is mandatory to improve the skills and knowledge of the workforce. Trainings and workshops should be a main part of the transformation plan and the government can include more private sector companies in the government training programs to achieve the QNV-2030 together.

4- Risks and Challenges:

After identifying the gaps, there will be challenges in fulfilling them. The idea here suggests having a team for risk management. This team is responsible for listing the risks and challenges in the beginning and working on facilitating them, and as the improvement is going on, the team will continue monitoring the status and forecast any future risks and get the resolution ready in advance. Benchmarking is recommended to evaluate situations and cases and a registry can be created to record all risks for reference.

5- Process Change Plan:

The change action is the most critical phase in the transformation process. Although it was a success initiative that make differences for the companies starting it earlier, it is now became a mandatory. The innovation in technologies accelerate improvement in other fields. Plus changing in business operations are moving toward digital transformation globally. So, planning for changing the production process in any industry should include parties from every unit including internal and external stakeholders and partners.

Below figure 26 shows the steps for the proposed plan for transformation:

Figure 26 Process Change Plan Steps

a. Current state workshops:

    1. Conduct introduction meetings with the stakeholders.
    2. Review existing processes documents.
    3. Identify pain areas and gaps.

b. Cross functional workshop:

    1. Discuss and confirm observations with business teams.

2. Discuss industry standard practices.
3. Discuss integration scenarios.
4. Made design decisions for workflow changes.

c. To-Be process design:

1. Re-develop business workflow processes and production cycles.

d. Technical workshop:

1. Discuss the to-be process design with IT and production teams.
2. Discuss the integration points and prepare the architectures.

e. Management workshop:

1. Present the final output.
2. Propose recommendations and future continues improvement plans.
3. Discussion and approvals.

Findings from conducting above steps can be fed in a decisions table as exampled in below figure 27, listing the required changing decisions in first column, in second column addressing the benefits of adopting the proposed change, following with impacts in the existing state with the volume of changes, and finally the management comments.

	Decision Required	Benefits, if adopted..	Impact	Management Response
1	Upgrade existing ERP system	Full functionality of the system	Modify workflow*	Approved
2				
3				
4				
5				

Figure 27 Decisions Table

At this level, the company is aware about all the needs and requirements to move on in the journey of industry 4.0. All used systems should be advanced and smart, I 4.0 technologies to be available (IIOT, smart sensors, cloud functioning with full services, data engineering gradually based on availability and capability, and later on can enhance the process more with machine learning), all level employees should be skilled and trained. All the requirements will be obvious once the gaps are well-defined and found solutions to fulfill them as per industry 4.0 features.

6- Change Implementation and Validation:

In figure 28, the next step after developing a process change plan is change implementation and validation. As any major change in organizations, it should start with pilot to validate the success level and correct any mistakes might appear in this phase before the real implementation. The benefit of starting with pilot, that it gives the ability to test different scenarios under variety of conditions. If results from pilot test satisfy the organization, then the change can be implemented in real cycle. All processes in the business cycle changed gradually based on approved plan to fulfil the digital transformation goals.

7- New Process Monitoring:

The new process will be new experience and new working environment. A team should be dedicated for continuous monitoring to maintain efficiency. Even though a pilot phase is tested, the real data in actual scale could fluctuate in results. This phase is a nonstop phase that require observing the performance of new process and the outcomes to ensure success of transformation and maintain efficiency.

For companies, to continue delivering the value of their business, it is very important to follow the new trends. As technology is never stop growing, business should always keep an eye on the market. The business process change cycle will keep repeating itself every time new trend show up. Therefore, for companies to sustain competing, it would be uncertain to stop at one change with no improvement if everyone else in the market is continuously improving their processes and tools.

4.3 Discussions

The research started as shown in figure (28) with reviewing number of papers and researches conducted in this area. The reviewed papers showed the impact of fourth industrial revolution in business models and enterprise designs for the companies. Researchers emphasized on the importance of accepting the change by the people dealing with it, and to avoid resisting the transformation companies should work on developing the manpower simultaneously with the development of business.

Researches showed that there are still some concerns and ambiguous in unifying the definition of industry 4.0 and the proper steps to adopt it. Countries worldwide stepped in the track and started the journey years ago. From their experiences we found that some companies faced challenges in addressing the level of readiness for digital transformation. This first step worth taking it seriously, as overestimating the capacities might make gap between current status and targeted vision, also underestimation could cause extra efforts and costs. Therefore, it is a must to have proper mechanism to set the companies in right places.

This thesis sought to answer the following questions to evaluate the current status and to identify the process to transform platforms and technologies into industry 4.0.

1. *With reference to the industrial revolution pyramid, what is the most common level of industrial revolution in Qatar industries?*

As per the results from the survey, most Qatari companies use IT systems and technologies in their production processes. Yet, it is mandatory in 4^{th} revolution to have integrated systems and fully automated process, one can place Qatari industries in the 3^{rd} level.

2. *To what extend are Qatari factories ready for digital transformation to higher industrial revolutions?*

The survey results show that around 90% of the companies use IT systems and technologies. Referring to the integration pyramid, the companies are using ERP, MES, SCADA and also PLCs. In addition to that, taking in consideration that 90% of the companies implementing data engineering and started deploying cloud services we can notice that the industrial field in Qatar is progressing well in preparation stage. Going back to Readiness Maturity Level table (Table 1) and the Automation Pyramid implementation levels (Table 2), the maturity level for Qatari companies can be considered low as beginner in level 1. As long as the companies have strategy plans and initiatives, they can accelerate the process and move on to higher levels of readiness till they fully adopt the digital transformation.

3. *What are the barriers, and challenges, in the transformation process?*

As any other change and improvement, difficulties are exist. In digital transformation process the barriers differ from one company to another. The main challenge the company facing up as per the survey is the absence of clear digital vision from top management level. This concern was delivered to the interviewed head in the case study, he returned the cause of this lack to the fact of not having one clear accepted definition for Industry 4.0, which make it hard to the managers to set a clear and fixed strategy.

Other barriers varied between the availability of infrastructure and technologies to build the digitalization environment, the talent and skilled people to operate the transformation and the financial investment requirements, which some companies consider it risky because of the unclear concerns about the automated data flow between systems and storing confidential data in the cloud.

4. *How can companies at lower levels transform operations into Industry 4.0?*

Based on the challenges addressed by the companies in the survey and interview, companies –especially the once behind the digitalization movement- needs to invest more. Starting with preparing the transformation team by training programs and development plans. Some companies' staff already have the knowledge about industry 4.0 and the new technologies, the action plan for the strategy should take place to move on without any lateness as the technology changes rapidly and delaying the transformation can increase the gap comparing to the companies started working on the digital transformation.

In addition to that, inputs collected from a company that is performing in Qatar environment. The results gained from the company showed the maturity in technology usage in the production process with the industry. Although, there were no implementation for I4.0 concept due to lack of its smart technologies.

Based on data collected through this research, the concept of i4.0 factors is explained.

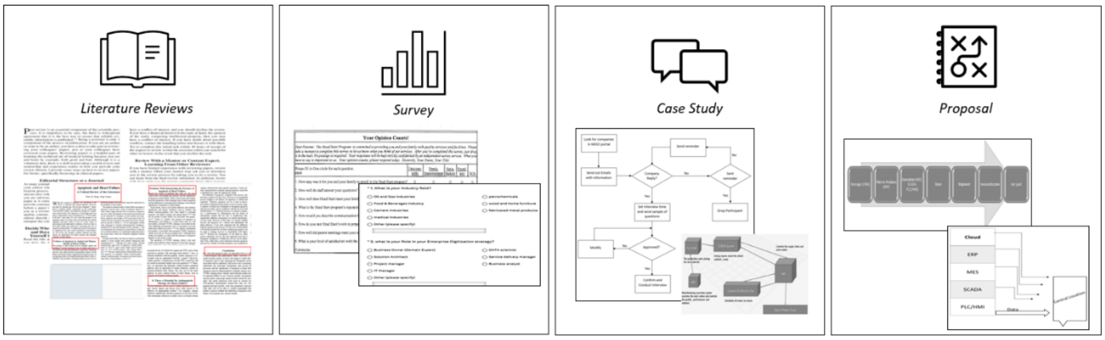

Figure 28 Thesis Process

Finally, a change plan process is proposed for companies in order to start the digital transformation journey as they have first to evaluate the environment, tools, technologies, and all resources.

CHAPTER 5: CONCLUSION

Qatar government stated in Qatar vision 2030 "Wherever there is an environmental cost to be paid for economic progress, it must be compensated with investment in technologies that help improve the environment" (QNV-2030). Based on that, entities diverted their plans to invest in technologies and improve the businesses. Qatar Industry 4.0 Congress 2020 held in March 2020, was the largest conference in Qatar for the 4th industrial revolution. They addressed major industry developments such as Industry 4.0, smart automation, manufacturing future, industrial IOT, future factories, additive manufacturing, Artificial Intelligence, robotics, cybersecurity, big data, and several other related fields. This event proved the interest of Qatar to improve the industrial level.

In this research, after an online survey and a case study, we noticed the awareness of people about the role of improved technologies and how much it is important to the country. In the conclusion, the contributed companies in the survey responded to a number of questions targeted at measuring their awareness about industry 4.0 and the readiness level for the digital transformation and adopting industry 4.0 transformation. After analyzing the results of the surveys, the following conclusions were arrived at:

- ❖ Some contributors in the survey in particular small companies commented that the questions in the survey were valuable and informative that push them to consider the planning for improvement.
- ❖ Companies can do more investment on employees' skills to have qualified manpower that can implement the transformation especially that Qatar is one of the leader countries in the digital transformation and working on the vision of making Qatar a 'smart country'.

- 90% of the companies are deploying cloud and have readiness to use cloud technologies and ready to use the data engineering and data analytics to work on the transaction in different forms of data from different sources.
- IIOT is a main concept in industry 4.0 and digital transformation, almost all contributed companies are not using IIOT including sensors as communication and interconnecting data.

5.1 Key Findings of this research

The aims of this study as mentioned in the chapter 1 is shown in below table 4 with explanation of the achievement.

Table 4 Aims Acievement

Aims	Achievement
Establishing an assessment outline that can evaluate business process of companies and their readiness level for digital transformation.	An online survey consist of 24 questions was built and distributed among industrial companies that are selected from MOCI portal. The questions varied to cover the key requirements for digital conversion and to clarify the companies' awareness, knowledge and capabilities for the transformation.
Identifying the challenges, and barriers that companies are facing toward moving to Industry 4.0	The surveyed companies were asked questions to highlight the challenges and obstacles they are facing within the current status and the barriers to move with the new technologies. Most of the companies agreed on not having clear vision for the digital transformation so they can plan based on it properly.
Develop a transformation change plan process cycle helps companies in planning to move toward change.	A cycle for companies is proposed to go through each process and what teams are required to implement the change, following with validation and monitoring phases.

5.2 Research Contribution

The research was conducted to assess and evaluate the level of readiness of Qatari companies in various industrial sectors particularly for digital transformation and place in industrial fourth revolution. As stated in the literature reviews, most countries and companies face difficulties in evaluating the maturity level of production cycle, process and procedures, and manpower skills. In this research a case illustration of how to evaluate process is demonstrated for Qatari companies. Surveying the market is an essential step to have a general picture that helps in building the base or getting a start point.

5.3 Limitations and Recommendations

In the phase of data collecting and analyzing, it was noticed that not all companies are ready to share the requested data and information and consider them certain level of confidentiality. In addition, inconsistency in some provided data from same company resulted in the elimination of data from these companies to have more accurate results.

Also, most companies have restrictions and policies provided by Ministry of Interior that do not allow them to share specific types of information and data.

For the case study, it was planned to have more than one company to study and analyze the live process. Only one company welcomed to share information and details about their business production cycle. After the contribution of the case study company in the research, we faced some issues because of the COVID-19, that made difficult to assess the proposed transformation model and build a live prototype. Visiting company sites was very much restricted even for company staff. Therefore, there were shortage on the number of the team members that are not able to volunteer in extra activities for testing.

It is recommended that the industrial sector get more support from government and for the companies to improve employees' skills and start the transformation movement to achieve the goal of the vision to make Qatar a digital industry hub in the world.

In addition to all points discussed in previous chapters, the lacks and deficits cannot be because of technologies and skills only. One should consider the resistance of cultural and organizational change. Making changes require gradual steps to move from old models built over decades to innovative process.

Expanding researches in this topic in the region is highly recommended to reach the advanced levels. As digitalization is not one hand effort. It needs collaboration from researchers, authorities, government and the companies to shed light on industrial revolution from technological innovation perspective.

In addition to that, business resilience should be taken into account. While business process is going through transformation phases, business continuity should be maintained. Thus, it is recommended to focus on the importance of business resilience.

5.4 Future Work

The researches in industrial revolution will always be continued. As economy is growing and technology is growing the studies will continuous. For this research, the proposed change cycle should be taken in practical stage for testing and evaluating the capability of it in changing the production cycles in Qatar industries by adopting the advanced and smart technologies.

Business resilience is not less important than digital transformation, so companies' proficiencies in maintaining business continuity after digital transformation is a major topic to be considered and studied.

After all, economic is continuing in development and improvement. At the time companies working on adopting industry 4.0, developers are formulating industry 5.0. It used to take around a century to introduce new industrial revolution in the past, but now all fields witnessing acceleration in the improvement. Hence, it should be taken in consideration the concepts behind industry 5.0 while going through industry 4.0 journey. One hint here, is that in I4.0 it was all about smart processes and machine to machine business eliminating manpower, where in I5.0 human is return back to the field in-order to accomplish the target behind this new revolution which is about delivering customer experience.

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APPENDICES

Appendix A: Abbreviations

Table 5 Shortcuts

Shortcut	Full Name
I 4.0	Industry 4.0
IIOT	Industrial Internet of Things
PLC	Programmable Logic Controller
HMI	Human Machine Interface
MES	Manufacturing Execution Systems
SCADA	Supervisory control and data acquisition
EDI	Electronic Data Interchange
I 5.0	Industry 5.0

Appendix B: Consent statement for survey and interview

For the survey, an email sent to all selected companies from MOCI portal with below statement:

> " *Dear Respectful Recipient,*
>
> *I am a master student in Qatar University, working on a thesis to assess the level of factories readiness for digital transformation and adopting Industry 4.0 in Qatar.*
>
> *Highly appreciate if you can give 5 minutes of your valuable time to answer this survey or share it with the concern department;*
>
> *Regards,*
>
> *Fatima Abulhussain*
>
> *Contact ####* "

For the interview, a call made with PR representor from some companies and based on that an email sent with below statement:

> "*Dear,*
>
> *In reference to our call conversation, we are working on a masters in transforming industry 3.0 to industry 4.0 for Qatar university and need to know what IT projects implemented in the Qatar cement like ERP systems, Scada, what MES used, what PLC/HMI systems working. So, we can investigate on the transformation areas to achieve the industry 4.0*

realization. Therefore, we are requesting conduct an interview with member of IT, operation or production team to get more details about the service catalogue for all applications and projects automating the production process.

Appreciating your cooperation

Best regards "

Only one company –cement company- welcomed to collaborate and share details.

"Refers to your mail. We are more than happy to help you and share our views."