POLITECNICO DI MILANO

School of Industrial and Information Engineering – Master of Science in Management Engineering

Investigation of Industry 4.0 Technologies Barriers and Ability To Enable Inclusive and Sustainable Industrialization and Fostering Innovation in Sudan

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Academic Year 2018/2019

Abstract

This study aims at providing a comprehensive explanation and a clear ranking of the challenges that prevent the adoption of Industry 4.0 technologies. Also, an understanding of how the benefits provided by these technologies can support Sudan in developing inclusive and sustainable industrialization and fostering innovation. Finally, the research aims at identifying the most critical Industry 4.0 technologies for Sudan considering the current barriers, and industries operating in it. Prior to collecting the required data, a review was carried out on the benefits of Industry 4.0 technologies in general and in the food industry and its current prospect in developing countries. A case study was conducted on a group of companies that operate in food industry in Sudan. In which 7 structured interviews were conducted with executive and senior management from the group. Which were then analyzed and coded resulting in the generation of 18 barriers that were grouped into five categories of barriers to Industry 4.0; political, economic, cultural, human and technology. Also, three categories of benefits were generated; IoT benefits, big data and analytics benefits and Industry 4.0 benefits. After that a questionnaire was conducted were the same manager and 4 more managers ranked and rated the 18 barriers that emerged from the coding to confirm the results. From the ratings it was possible to conclude that all the immerged barriers are true. The results of the ranking demonstrated that for Sudan the most critical barriers to Industry 4.0 technologies are sanctions, access to foreign currency, lack of competition and low income of locals. Despite that the study demonstrated the current application of IoT technologies and big data analytics and their ability in supporting companies in optimizing operations, reducing cost, materials waste and their impact on the environment and supporting the development of their community. Also, they enable companies to develop innovate products that meet the needs of the changing pace of human's lives. Moreover, the study demonstrated that in currently for Sudan IoTs, big data and analytics and cloud are the most important technologies, while autonomous systems, augmented reality and simulation are considered of value but not essential now due to the economic barriers that are faced by the country.

Astratto

Questo studio mira a fornire una spiegazione completa e una chiara classificazione delle sfide che impediscono l'adozione delle tecnologie Industry 4.0 in Sudan. Inoltre, per capire in che modo i benefici forniti da queste tecnologie possono sostenere il Sudan nello sviluppo di un'industrializzazione inclusiva e sostenibile e nella promozione dell'innovazione. Infine, la ricerca mira a identificare le più importanti tecnologie dell'Industria 4.0 per il Sudan, considerando gli attuali ostacoli e le industrie che operano in esso. Un caso studio è stato condotto su un gruppo di aziende che operano in vari settori dell'industria alimentare in Sudan. In cui sono state effettuate 7 interviste strutturate con manager esecutivi e senior manager del gruppo. Che sono state poi analizzate e codificate dando come risultato 18 ostacoli nella implementazione dell' Industry 4.0, raggruppate in cinque categorie: politico, economico, culturale, umano e tecnologico. Inoltre, sono state generate quattro categorie di benefici: Benefici di IoT, grandi quantità di dati e benefici analitici, benefici dei droni e benefici di Industry 4.0. Dopo che è stato condotto un questionario, gli stessi manager e altri 4 manager hanno classificato i 18 ostacoli che sono emersi dalla codifica per confermare i risultati. Dalle valutazioni è stato possibile concludere che tutte le barriere sono considerate importanti; mentre, i risultati della classifica hanno dimostrato che per il Sudan, le barriere più critiche alle tecnologie di Industria 4.0 sono le sanzioni, l'accesso alla valuta estera, la mancanza di concorrenza e il basso reddito locali. Nonostante ciò, lo studio ha dimostrato l'attuale applicazione delle tecnologie IoT, dei big data analytics e la loro capacità nel supportare le aziende nell'ottimizzare le operazioni, ridurre costi, materiali sprecati, il loro impatto sull'ambiente e sostenere lo sviluppo della comunità locale. Inoltre, queste applicazioni consentono alle aziende di sviluppare prodotti innovativi che soddisfano le esigenze del cambiamento del ritmo delle vite umane. Lo studio, ha anche dimostrato che attualmente per gli IoT Sudan, i big data e il cloud sono le tecnologie più importanti, mentre i sistemi autonomi, la realtà aumentata e la simulazione sono considerati di valore ma attualmente non essenziali a causa delle barriere economiche che deve affrontare il paese.

Acknowledgement

I would like to thank God Almighty for endowing me with the strength and perseverance I needed throughout the journey of my master's Program.

I have deep appreciation for my advisor Dott.ssa Federica Costa, who has been a great mentor and advisor. Learning under her tutelage was very fruitful, thanks to her advice and patience with me. Special thanks, appreciation and devotion to Ms. Ola Elmadih whom also supported me greatly with her valuable insights and support that in immeasurable. Finally, I would like to thank my family, friends and colleagues at Politecnico di Milano for their never-ending mental support and pushing me towards continuous success and being a better human.

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Summary

The evolution in Information and Communication Technologies and its integration into manufacturing is changing traditional industries and with it the new paradigm Industry 4.0 is emerging worldwide(Ngjeqari, 2016). Were the designation 4.0 is used to signify that it is the fourth industrial revolution which could radically transform the way goods are produced, developed and consumed and prompt the development of new business models, services and behaviours. The goal of industry 4.0 is to optimize value chains through the implementation of autonomously controlled and dynamic production. This is enabled by the real time availability of information and networked systems. The higher level of automation can be achieved through Cyber Physical Systems (CPS). Actuators, microcontrollers, sensors and communication interface allow CPS to work autonomously, connect to the production environment and thus resulting in a smart factory(Y. Lu, 2017). According to Boston Consulting Group, nine technology trends form the building blocks of Industry 4.0; Internet of Things, Big Data and Analytics, Cloud, Simulation, Additive Manufacturing, Augmented Reality, Autonomous Systems, Cyber Security and Horizontal and Vertical System Integration.

Transition from Industry 3.0 to Industry 4.0 involves four important aspect. First it requires building a CPS to connect all physical devices to the internet in order to enable smart products and production. Also, researching in the areas of Smart factories and intelligent production and realizing three integrations; horizontal, vertical and end-to-end integration. Beside that eight planning objectives must be achieved; i) systems standardization and building of a reference architecture ii) efficient management iii) establishment of reliable and comprehensive industrial broadband infrastructure iv) safety and security v) organization and design of work vi) staff training and continuing professional development vii) establishing a regulatory framework (Zhou, Liu, & Zhou, 2016) .

Industry 4.0 technologies are enabling the integration of the physical, digital and biological world and is impacting all disciplines, economies and industries. Making it of interest to researches and organizations around the world. Despite that there is still insufficient literature regarding Industry 4.0 both from a theoretical and empirical point of view. To arrive to the

research questions a systemic literature review was conducted to reduce bias and to understand the variables and intervention found in previous researches to ensure novelty of the thesis work. Scopus online database was used to search for articles, journals and books using keywords related to Industry 4.0 technologies general benefits, its benefits to the food industry and its status in developing countries.

For the purpose of this study the following Industry 4.0 technologies were considers; IoTs, big data and analytics, cloud, simulation, augmented reality, autonomous robots and additive manufacturing. This study was developed with the aim of providing a comprehensive explanation and a clear ranking of the challenges that prevent the adoption of Industry 4.0 technologies. Also, to understand how the benefits provided by these technologies can support Sudan in achieving the United Nation sustainable development goal 9. Focusing on the part of the goal related to the development of inclusive and sustainable industrialization and fostering innovation. Finally, the research aims at identifying the most critical technologies for Sudan considering the current barriers, and industries operating in it.

The Internet of Things represents smart objects that interact and exchange data with physical and virtual "things" in the network to provide value added services(Bibri, 2018). Utilization of IoT enables factories to manage their energy and improve their energy efficiency of their production systems by gathering real time data of the energy consumption in the shop floor. This allows them to incorporate such information in their practices to identify and reduce waste and improve energy efficiency(Shrouf, Ordieres, & Miragliotta, 2014). Through sensors and actuators objects can process information, configure themselves and autonomously make decisions regarding their operational functioning. Moreover, with an increasing need for industrialization the emission of hazardous gases and chemicals are increasing and so are environmental laws that require firms to be eco-friendly. IoT systems allows factories to monitor their emission of dangerous gasses in order to identify problems in machines and process that produce these gasses(Martillano, Dita, Cruz, & Sadhra, 2017). Furthermore, data from sensors in products may be used by manufacturers to improve their services or develop new innovative services and better products in the future. Manufactures can also take advantage of IoT to raise their productivity as its assists systems to automatically adjust in critical situations eliminating the need for human intervention in most cases (Uden & He, 2017). With regards to Supply Chain Management (SCM) adoption of IoT provides companies with higher profits, a decline in excess perishable products, rapid response to costumers needs and deliveries optimization(Haddud, DeSouza, Khare, & Lee, 2017)

Furthermore, big data and analytics is designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery and/or analysis. It provides several benefits for SCM and logistics such as; more precise prediction and management of supply chain risks, reducing supply chain waste, stronger partnerships and a higher response rate to environmental changes (Yuanyuan Lai, Huifen Sun, 2017). Moreover, big data enables firms to improve their internal processes and their supplier's performance with main benefits being in terms of cost and time. It also supports them in making more reliable decisions regarding suppliers selection and management of contacts (Moretto, Ronchi, & Patrucco, 2017). Through big data and analytics companies can optimize their production levels, usage of working capital and decrease maintenance and repair costs, achieve higher margins, profitability and increase their gross sales(Attaran, Stark, & Stotler, 2018). It also allows them to understand customer's needs, which marketing campaigns and promotions are effective in driving sales, customer engagement and traffic and optimize their marketing mix(Jelonek, 2017). Beside that by analyzing data from sensors in machines every part and procedure along the production line can be monitored and controlled to improve the manufacturing process and defects can be reduced (Wang & Alexander, 2015).

Deployment of additive manufacturing (AM) shortens companies supply chain, reducing inventory, increases flexibility and allows responding to market needs of mass customization, innovation and responsiveness, providing adopters a competitive advantage. In addition to providing freedom in manufacturing geometry complexity and the ability to reengineer products and processes(Busachi et al., 2018). Organizations can also take advantage of AM in after sales, adopting new business models by providing repair, remanufacturing or upgraded products, thus generating new profit sources(Despeisse, Yang, Evans, Ford, & Minshall, 2017). AM accommodates several processes into one step reducing material, energy, time and costs. It can also minimize or eliminate inventory waste, thus decreasing the amount of raw material needed, handling cost, lead time and quality problems. AM processes are greatly based on recycled materials and therefore they can contribute to more efficient use of resources and circular use of natural resources. (Despeisse et al., 2017).

Moreover, augmented reality (AR) can facilitate employees training resulting in faster and more accurate execution of tasks, with lower mental effort compared to traditional methods. It can also be employed by designers in the early stages of product design to develop a proof of concept. Also, to use virtual assembly features on the real assembly platform to determine parts assembly constrains early in the design processes (Chryssolouris, Mavrikios, Pappas, Xanthakis, & Smparounis, 2009). Beside that using AR allows optimization of warehousing operation, reducing error rates and rework and provides workers with more flexibility(Marie-H´el`ene Stoltz & Duncan McFarlane, n.d.). In addition, autonomous robots can be utilized to perform tasks in areas that can be hazardous to humans such as space and earth exploration, search and rescue and surveillance(Tareen, 2016). Also, to improve warehousing efficiency and in factories to perform repetitive tasks.

Cloud computing provides IT services to third world countries that traditionally did not have the resources for widespread deployment of IT services while reducing upfront costs. It also allows companies to easily scale their services which depends on accurate information according to customers demand. Since computing resources are managed by software they can be deployed quickly as new customer requirements arise. (Dubey, Wagle, & Jha, 2011). In addition, cloud manufacturing can be used raise the utilization of resources among several customers, lower the initial investments and cost of entry for small and medium size enterprises that want to benefit from high value of manufacturing resources. This in turn allows them to reduce their maintenance and upgrading costs. It also allows manufactures to lower their infrastructural and administrative costs and to scale their production and business according the customers demand. In addition, it can optimize industrial distribution and accelerate the transition of a distributed and high energy consumption manufacturing model to a centralized resource and green manufacturing model and from a production to service oriented model(Tao, Zhang, Venkatesh, Luo, & Cheng, 2011).

Through simulation an operator can train on a virtual machine until he has the skills and confidence to operate on the real machine thus minimizing the risk of damaging the machine. Also, by using advanced machine learning capabilities with optimal control and model predictive control techniques simulation can be used to determine problems in the real machine counterpart. It may also be embedded in a machine to increase its self-awareness and thereby to optimize its performance for given duty cycles, diagnose and make up for non-catastrophic faults and coordinate the operation with other machines with minimal operators input(Rodič, 2017).

This research was conducted based on a positivism philosophy as it aimed to work with an observable social reality in order to generate conclusions that can be generalized, just like physical and natural scientists do (Remenyi et al., 1998). Also, it was believed that the only phenomena that can be observed will lead to the production of credible data and, before collecting these data, existing theory was used to develop hypotheses. Moreover, a deductive research approach was used in which theory and hypothesis were developed. After which it was decided to use a multiple and embedded case study as the strategy for doing the research since the boundaries between the phenomena being studied and the context in which it is being studied are not clear. In addition, it allows a rich understanding of the context of the research to be obtained and to answer How and What questions and are used in explanatory and exploratory research. Furthermore, based on the research approach, strategy and time constraint it was decided to follow a mixed method, cross-section study.

The case study was conducted on a group of companies that operate in various sectors of the food, beverage and agriculture industry in Sudan. Data collection was based on interviewer-administered, structured interviews with seven executive and senior managers who were selected due to their extensive knowledge and experience regarding the research topic. Moreover, all respondents had an engineering background thus their knowledgeability of technical aspects was ensured. Thereby allowing the production of reliable and generalizable results. The interviews were conducted at the managers offices in English and lasted between 30-98 minutes. All the interviews were audio recorded and notes were taken in order to control bias and produce reliable data for analysis. Then the data from the interviews was analysed and codified manually to create categories that share common characteristics. Coding into themes was a four-step process; raw data, first cycle coding, second cycle coding, categorization. Were first a transcript was written for each interview and then a first cycle coding was done based on four coding methods; simultaneous, descriptive, process and value coding. In total 129 codes were initially generated from the first cycle coding. Then a second cycle of coding was performed, were the first cycle codes and their coded data were recognized and reconfigured to develop a smaller and refined list of broader categories, themes, concepts and assertions. In the second cycle coding, focused coding was used which involved searching for the most frequent codes in order to develop salient categories in the data corpus. A total of 55 codes were generated, form which 8 sub categories and two main categories, barriers and advantages were developed. The barriers category consisted of; economic, political, technology, human, cultural categories. While the advantages category consisted of; IoT, big data and analytics and Industry 4.0 benefits. After that a self-administered questionnaire was conducted and was filled in by the same managers in addition to four more managers in order to confirm the results of the interviews. Also, to rank and rate the severity of each of the identified barriers to the spread of industry 4.0 in Sudan.

The agricultural sector in Sudan is considered as one of the most important economic sectors in Sudan. It contributes to almost one-third of the country's national gross domestic product and almost two-thirds of Sudan's population live off agriculture. In agriculture the soil and irrigation can greatly affect the quality of crops. The case study demonstrated that IoTs and big data and analytics provide great benefits for agriculture in Sudan. IoT moisture sensors allow for real time analysis of soil moisture content at different levels of the soil. This is important to manage the irrigation of crops, in order to not starve or over irrigate crops as this will affect its quality and it helps in preventing water wastage. Moreover, data is provided in real time eliminating the need for the operator's frequent manual checks and the moisture sensors can be adjusted remotely, reducing fuel consumption required for moving in the farms and the need to travel long distances. Thus, reducing operating costs and carbon dioxide emission. Moreover, positioning of the moisture sensors along a farm requires to know first the soil properties. This is done by a machine that employs IoT and machine learning to take reading of the soil texture properties in order determine which areas share the same properties and displays them in a soil map. Then different irrigation rates are applied in each area based on the moisture sensors readings. In addition, drones are currently utilized in farms to take readings from the soil with respect to the soil composition i.e. the chemicals in it, as certain elements must be available in the soil to grow plants efficiently and this assist in optimizing the harvesting yield.

Moreover, radio frequency identification (RFID) tags allows farmers to keep full records of all the cow details such as feeding, injection and how much milk it produced. It also reduces the time and possibility of mistakes when recording cow’s data, increasing operational capabilities and reduces costs. In addition, if a cow’s yield decreases real time data allows necessary corrective actions to be taken. It is also believed that RFID can be similarly employed for livestock identification as it is becoming a governmental requirement for importation of livestock around the world. Since it provides authorities with an electronic means to trace the livestock lifecycle particularly when there is a disease outbreak in a region.

Furthermore, IoTs in manufacturing plants allows real time monitoring of performance and yield and big data from machines and sensors are analyzed to improve performance and make informed decisions. They also help production managers in managing and tracing production processes and to define weak points and further strengthen their competitive advantage. Manufacturing, plants can also be accessed online thanks to IoT technology from other countries to determine the faults in machines and fix them or provide the company with guidance regarding the problems observed so they can fix them quickly reducing the time to repair. Beside that RFIDs can be utilized for pallets tracking and can be combined with the company’s ERP to track materials ageing inside warehouses to ensure their utilization before their expiry date and thereby allowing for waste control. This is particularly important for companies that have many warehouses and various raw materials of high cost as the tracking of raw materials becomes more difficult.

Moreover, when it comes to fleet management utilizing RFID in distribution trucks tiers helps in keeping track of tiers conditions, enabling better management of tires throughout their lifecycle and replacing them whenever necessary. This is particularly important when there is a large number of trucks and when travelling to ruler areas where streets along the way can be dangerous and to not disturb operations. Furthermore, employment of handheld terminals by sales teams serve as a distribution demand allowing them to collect sales data that can be transferred directly to the company's ERP. In addition, big data analytics helps in better planning of production, raw materials, distribution based on orders and all sort of planning and allowing more precise utilization of resources and can be shared with suppliers to assist them in planning their production and inventories. Beside that analyzing big data from the social media, market and companies research organizations allows to understand the behavior of consumers, price elasticity and the amount and type of consumption in different parts of the country and their requirements and to develop new and innovative products. Also, application of these technologies in Sudan will result in creation of new jobs specially in the areas of big data analytics, product development and maintenance of these technologies. Also, it will result in training of labor which will help them in improving their efficiencies and adapting to new requirements of the world. This will provide them with better experience and improve their lives and is particularly true for companies driven by corporate social responsibility.   For Sudan in addition to the IoTs and big data and analytics considering the barriers currently only cloud is needed as it will enable IT services that are currently not available in Sudan, reduce investment costs supporting particularly entrepreneurs and small companies. Also, cyber security although is not within the scope of this research but is still considered essential to prevent breaching of companies' data.

From the results of the questionnaires the mean rating for each of the barriers was calculated along with its standard deviation in order to understand the strength of each barrier on its own in preventing the spread of Industry 4.0 technologies. From it was determined that the 18 barriers obtained are either of strong or moderate effect. Then the average ranking was calculated for each barrier by multiplying and summing the weight of ranked position by the response count for the answer choice by each respondent and dividing it by the total response count. Based on the average ranking sanctions imposed by the US on Sudan is considered as the most significant barrier to Industry 4.0 technologies. Since they prohibit financial services and transaction, which include import and export of goods, services and technology. In addition, any violations or attempts of violation would result in criminal fines up to $1 million USD and custody up to 20 years which caused US and global financial institutions to stop dealing with Sudanese banks. This made the access to foreign resources and thus Industry 4.0 technologies very difficult, since it is not possible to purchase the products even if they are produced in other countries. Due to the sanctions it became difficult to link other countries and foreign companies are discouraged in operating in Sudan. Moreover, even if Industry 4.0 technologies are purchased from outside Sudan companies face difficulties whenever maintenance or updates are required specially if they contained any parts coming from the US.

Difficulties in accessing foreign currency is the second most critical barrier and this is mainly due to the independence of South Sudan which contained most of the oil reserves that contributed significantly to hard currency from exports and government corruption and lack of good governance. Which in turn contributed to difficulties in acquiring industry 4.0 technologies since such technologies are imported. Moreover, the lack of competition and entrance of disruptive technologies encourages companies not to upgrade their technologies. Also, the low income of many consumers discourages companies from investing in some of Industry 4.0 technologies, since they have to increase the costs of their products to recover their costs but the consumers wont be able to afford the increasing in prices. Thus, it is not possible to invest in technologies such as 3D printing for producing pasta, although it reduces waste. In addition, many local suppliers cannot afford the capital required to procure Industry 4.0 technologies and the government does not provides loans to support introduction of new technologies.

Beside that internet services are unreliable for long term use which is essential for proper operation of IoT technologies and cloud and internet service providers do not sign any service level agreements with their customers, so there are no penalties for poor internet services. This is also made worse by the frequent power outages that can last several hours due to deficiencies in electricity supply. Furthermore, the high cost of operating cloud from other countries does not make it appealing for companies though they demonstrate interest in it. Also, local suppliers are not used to providing data on the internet, so companies utilize big data analytics for local procuring. This is even made worse by the lack of interaction between the companies and the public.

Humans also pose barriers to Industry 4.0 technologies because they are not used to change as it is not common in Sudan. Beside that many people fear change as they think they will lose control to the new technologies and are not able to see the potential and added value it will provide them. Moreover, people need time to adapt and accept new technologies because if they are not convinced with it they will not use it, which in turn slows down the utilization of these technologies. Beside that as with all modern technologies the lack of compatibility of previous technologies with some Industry 4.0 technologies prohibits their utilization.

To support the diffusion of Industry 4.0 technologies both the private and public sector in Sudan must work on spreading its information through exhibitions and cases that demonstrate its potential across the value chain. In addition, to develop the workforce to meet the requirements of operating these technologies. Beside that good governance is necessary to help Sudan in being released from Sanction and government financial support is essential for the diffusion of these technologies. Moreover, it is recommended to further explore the utilization of Industry 4.0 technologies in the mining industry and water, electricity and telecommunication infrastructure as they can substantially upgrade these sectors.

Chapter 1 Introduction

1.1 Industry 4.0

The first industrial revolution started in 18th century when steam engines entered factories allowing mechanization of physically demanding and highly repetitive tasks. Which resulted in a rise of productivity and decrease in production costs. While the second industrial revolution started in the 19th century where oil and gas-powered linear assembly lines were introduced in factories allowing for great efficiency gains that enable mass customization. Then the third industrial revolution began in the 1970s and was characterized by the application of electronics and information and communication technology to automate production, enabling technological advances and increase in productivity. Industry 4.0 is a term used to refer to the now on-going fourth industrial revolution and is rooted back to Germany. In 2011 the term was coined in a strategic program formed by the German federal government with universities and private companies. The program was aimed at developing advanced production systems to boost the national industry productivity and efficiency. (Frank, Dalenogare, & Ayala, 2019).

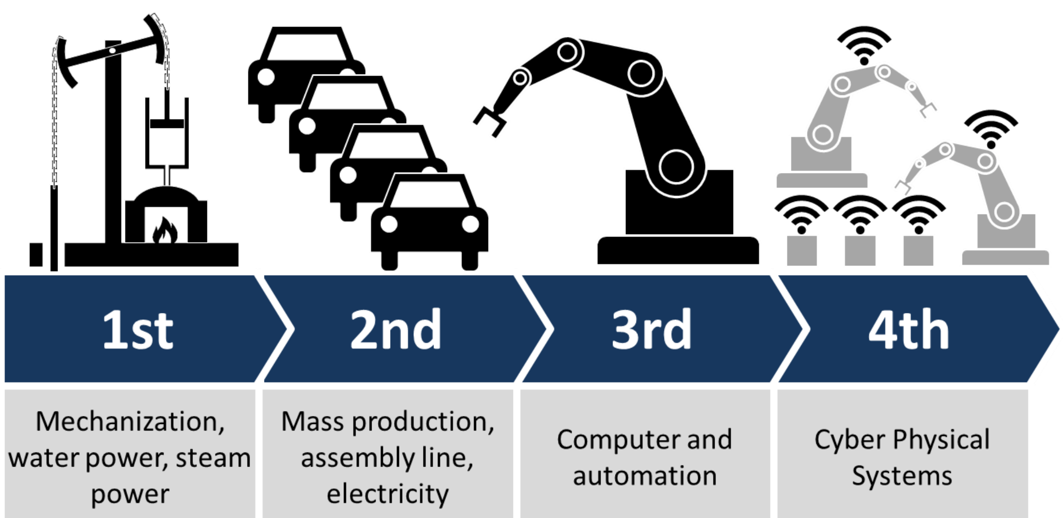

Figure 1.1 The four industrial revolutions ("The four inustrial revolutions," n.d.)

Digital technologies have spread massively in the past years in manufacturing and production processes. Rapid development in sensors, Internet of Things, Big Data, artificial intelligence, rapid prototyping and augmented reality technologies have noticeably transcended into the manufacturing industry(Nagasawa et al., 2017). This led to the paradigm of Industry 4.0

which could radically transform the way goods are produced, developed and consumed and prompt the development of new business models, services and behaviors. It allows transformation of factories into smart and autonomous production. Industry 4.0 facilitates real time horizontal and vertical internet-based connection of machines, objects, humans and information and communication technologies for the dynamic management of complex business processes. It aims to overcome contemporary challenges such as , volatile markets and demands, decreasing innovation and product life cycles, increasing global competition and customers' needs for customization(Müller, Kiel, & Voigt, 2018).

From an economic viewpoint of Industry 4.0 enabled transparency and interconnection of processes allows their optimization, increasing efficiency, flexibility and achieving higher levels of quality. Since, smart manufacturing technologies, new value propositions and growing demand enable load balancing. For this, smart products are need that allow companies to increase their competitiveness. In the same manner higher process transparency can be achieved in intra and inter-firm logistics, enabling firms to lower their logistics costs. Moreover, adoption of industry 4.0 also provides several advantages from an ecological perspective. As demand and process become transparent, intelligent scheduling of task and process is enabled, thereby load balancing can be optimized and lower energy is consumed. This is based upon enhanced process simulations and prediction of energy consumption through smart energy systems. In addition, manufacturing design may be improved through direct interconnection between the product usage and design, resulting in better product lifecycle management including recycling. Thus Industry 4.0 may contribute to the reduction of greenhouse gas emission, reduction of waste and improvement of resource usage. In addition, in logistics it is possible to reduce the transportation process, unnecessary material flow and waiting time, wrong deliveries and damaged goods through data transparency along the supply chain. Decentralization of production close to consumers further reduces logistics costs and environmental impacts. In terms of the social dimension Industry 4.0 can provide several benefits to employees, enhancing their ability to learn tasks through intelligent assistance systems and human interfaces. However, it is expected that simple tasks will be replaced, while tasks such as monitoring, collaboration and training will be needed. Thereby it is expected that new job profiles will emerge with the decrease in the need for manual labor in contrast to IT skills. Also, tasks that require planning, monitoring and decision making can be assigned to autonomous systems(Müller et al., 2018).

Industry 4.0 provides tremendous industrial growth, however it may also disturb the sustainability of current industrial systems. Which may further cause earth ecological imbalance in terms of higher resources consumption, climate change problems, global warming and higher energy requirements. Moreover, rapid industrialization may also contribute to degradation of health and safety of employees. In this sense, industrial production systems must be balanced economically, environmentally and socially in employing modern technologies (Kamble, Gunasekaran, & Sharma, 2018). Among the other issues related to Industry 4.0 is that huge amounts of information flow occur in its platform creating cybersecurity threats and data privacy issues. Working virtually on servers or platforms requires that employees are aware of cyber security, a critical aspect of cyber physical systems (CPS). Since, CPS have become more vulnerable to cyber-attacks with the advancements in IT. Another issue regarding Industry 4.0 is the lack of IT infrastructure which is needed to support its implementation. The Internet of Things plays a very important role in Industry 4.0 framework. However, the lack of solutions for effective communication and signal coverage can significantly block various products and services from sharing or providing information.

Several governmental institutions started to study and assess the implementation of Industry 4.0 technologies in their countries, such as the United States, Canada and Germany. Also, within the context of some developing economies, such as Brazil, the National Confederation of Industry conducted a survey to identify the challenges for Brazil in implementing Industry 4.0 technologies. The survey focused on the application of additive manufacturing, simulation, usage of cloud services, Internet of Things services and remote monitoring technologies in three areas; product, process and development. High cost of implementation was pointed out as the main internal barrier for advancing on Industry 4.0 and lack of skilled workforce was indicated as the biggest challenge among external factors. In addition, the results demonstrated that a feature of digitalization in the Brazilian industry is the focus on processes, hence increased efficiency and productivity. These findings assert another study that was undertaken in Mexico, which is responsible for the production of 80% high-tech exports of Latin America. Similarly, the Indian government presented an initiative in 2014, with the aim of positioning the country as one of the main hubs of global design and manufacturing. However, there is still a need to obtain a broader understanding of the benefits and challenges posed by the adoption of Industry 4.0 technologies in these contexts(Tortorella & Fettermann, 2017).

1.2 Structure of the thesis

The remaining part of this dissertation was organized into five main chapters as described below:

Chapter 2 – Literature Review: This chapter encompasses a comprehensive overview of the literature to provide a definition of Industry 4.0 and its technologies. Also, to provide a deep understanding of the general benefits obtained from the application of each technology in general and a focus on the food industry. It then provides a review of the literature regarding industry 4.0 in developing countries and finally an introduction to the United Nations Sustainable Development Goals for 2030.

Chapter 3 – Methodology: The third chapter describes the research questions, its objectives and the methodology employed to achieve the research objectives. It also provides justification for the research philosophy, approach and strategy that was adopted for the dissertation.

Chapter 4 – Data & Analysis: This chapter provides an analysis of the main finding obtained from the interviews and the questionnaires and interesting facts related to the study that emerged.

Chapter 5 – Discussion and Conclusion: The last chapter of the dissertation will provide a clear explanation of the major findings obtained from the research and recommendations to support the diffusion of Industry 4.0 technologies in Sudan and future practitioners.

Chapter 2 Literature Review

2.1 Literature Review Scope and Methodology

The scope of *Section_2 Literature Review* is to provide a comprehensive overview about the Industry 4.0 Technologies found in literature. It begins with an explanation of the Industry 4.0 paradigm and each of its technologies, while focusing on the benefits derived from the application of each technology in general and providing examples of their application. Then it will demonstrate the application of Industry 4.0 technologies and their benefits in the Food Industry. The final part of the literature review is devoted to understanding the Food Industry in Sudan and concludes by providing an explanation of the United Nations Sustainability Goals for 2030.

Among the available literature review approaches it was decided to follow a systemic literature review. Which is defined as “A form of secondary study that uses a well-defined methodology to identify, analyze and interpret all available evidence related to a specific research question in a way that is unbiased and to a degree repeatable”(Kitchenham, 2007). It enables the reader to evaluate the procedures, assumptions, evidence and conclusion made by the authors and not to take their conclusions as a certainty. Also, it allows to reduce bias through extensive literature searches. In addition, it is sincerely evidence-based as it focuses on understanding the variables or interventions found in former researches(Tranfield, Denyer, & Smart, 2003).

The following steps were followed to select, evaluate and interpret the available literature:

1) An online database, Scopus was used to search for the available literature, as it includes smart tools for tracking, analyzing and visualizing research. Among the various search fields provided by Scopus the search combination “Article title, Abstract, Keywords” was selected as it is was the most convenient and precise. After which a systemic, unbiased and comprehensive search was performed using the Boolean operator AND that is nested in Scopus search. Below are some of the combinations of keywords that were used for

searching: “Industry 4.0” AND “Technologies”, “Additive Manufacturing” AND “Benefits”, “Internet of things” AND “Benefits”, “Big Data Analytics” AND “Benefits”, “Augmented Reality” AND “Benefits”, “Simulation” AND “Benefits”, “Autonomous robots” AND "Agriculture", “Pasta” AND “Cloud Computing” and “IOT” AND “DAIRY”.

2) After that the search results was refined by including limits that exclude irrelevant researches to each topic and provide results focused only the relevant ones. The following limitation were used:
    - Language: English
    - Subject area: Engineering, Business Management and Accounting and Energy
    - Document type: Article, Conference paper, Book Chapter
    - Year: from 1993 to 2018

A crucial part of the literature review was to identify the benefits obtained from Industry 4.0 technologies. Following the first two steps Scopus generated 455 results for “Additive Manufacturing” AND “Benefits” of which 68 were beneficial. For “Internet of Things” AND “Benefits” 681 results were obtained from which 39 were used. As for “Big Data Analytics” AND “Benefits” 121 results were generated of which 23 were useful. Also, for “Augmented Reality” AND “Benefits” 331 results were generated from which 31 were useful. For what concerns Food & Beverage industry in particular for dairy, agriculture and pasta a total of 52 results were obtained of which 13 were useful to identify the benefits of Industry 4.0 in the Food & Beverage industry. In addition, for the methodological aspect of the thesis 3 books were used and from which the definition and justification of the strategies adopted to develop this dissertation will be discussed in section 3.

2.2 Defining Industry 4.0

According to Yang Lu there is no specific definition for Industry 4.0, but it is rather defined based on the various perspectives of scholars. A definition was provided to Industry 4.0 in spring 2014, by three German associations of ICT, mechanical engineering and electrical industry (VDMA, Bitkon and ZVEI). Stating that its goal is to optimize value chains through the implementation of autonomously controlled and dynamic production. This is enabled by the real time availability of information and networked systems. The higher levels of automation can be achieved through Cyber Physical Systems (CPS). Actuators, microcontrollers, sensors and communication interface allow CPS to work autonomously, connect to the production environment and thus resulting in a smart factory(Y. Lu, 2017). According to Hermann et al (2016) it is a collective name for technologies of value chain organizations and is composed by Internet of Things, Internet of Services, CPS and smart factories(Erboz, 2018). Sanders, Elangeswaran and Wulfsberg (2016) defined it as an industrial revolution that applies principles of CPS, internet, smart systems and future oriented technologies with enhanced human-machine paradigms. Enabling identity and communication of all entities in a value stream, leading to IT enabled mass customization in manufacturing(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019)(Frank et al., 2019) (Sanders, Elangeswaran, & Wulfsberg, 2016). Industry 4.0 was also defined by many as "a comprehensive transformation of manufacturing industries through the introduction of internet and digitalization these transformations consider revolutionary developments in the design and manufacturing processes, operations and services of manufacturing products and systems"(Tjahjono, Esplugues, Ares, & Pelaez, 2017). Rüßmann et al (2015) stated that 9 trends, form the building blocks on Industry 4.0; big data and analytics, autonomous robots, simulation, Internet of Things, the cloud, additive manufacturing, augmented reality, cyber security and horizontal and vertical integration(Erboz, 2018).

2.3 Strategic plan towards Industry 4.0

When transitioning from Industry 3.0 to Industry 4.0 Germany developed a strategic plan to implement Industry 4.0. This plan can be summarized into the four points below;

1) **Building a network:** A Cyber-Physical System (CPS) must be built in order to connect all physical devices to the Internet. The CPS includes five functions; computing, coordination, communications, precision control and autonomy. By integrating the virtual and physical world, smart products and production become possible.

2) **Researching two major themes:** Smart factories and intelligent production are the main themes under research. Smart factories are the key component of the future intelligent infrastructure. They focus on intelligent manufacturing systems and processes, and networked production facilities. While intelligent production focuses on logistics

management, human-computer interaction, 3D printing and other advanced technologies, that may be applied to the whole industrial process in order to create a personalized, highly flexible, and networked industrial chain. Future smart factories will also include things-to-things interaction which aims at creating better services to meet customers' needs. Smart devices and Information and Communication Technology are also the basis of these two major themes

3) **Realization of three integrations:** The three integrations are horizontal, vertical and end-to-end integration. Horizontal integration is the integration between a resource and an information network within the value chain, in order to achieve cooperation between enterprises and provide real-time products and services. While vertical integration refers to networked manufacturing systems within the future intelligent factories and personalized custom manufacturing as alternatives to traditional fixed production processes. Industry 4.0 allows pervasive sensors, intelligent control systems, terminal systems and communication facilities to form an intelligent network within the CPS. Interconnection can be man-machine, machine-machine, man-man or service-service, in order to achieve complete vertical, horizontal and end-to-end integration.

4) **Achievement of eight planning objectives:** Industry 4.0 is achieved through eight planning objectives that can be summarized as follows:
    - Systems standardization and building of a reference architecture: Uniform standards must be developed so a network can be connected and integrated between different factories and companies.
    - Efficient management: Future factories will consist of large and complex systems that need to be efficiently managed. Thus, appropriate plans and an explanatory model must be developed to optimize the management.
    - Establishment of a reliable and comprehensive industrial broadband infrastructure. Industry 4.0 requires that its communication network meet certain standards and to be reliable, comprehensive and of high quality.

- Safety and security: Production facilities and products must not pose a threat to people or the environment. Also, products misuse or unauthorized access to production facilities must be prevented.
- Organization and design of work: In order to meet with the increasing needs to achieve humane, automation, green production and management.
- Staff training and continuing professional development: Companies are obliged to train their employees and to establish lifelong learning and continuous professional development programs to help workers in meeting the requirements of their new job and skills.
- Establishing a regulatory framework: New innovations bring new problems e.g. enterprise data, liability, personal data and trade restrictions. Thus standards, agreements, model contracts, auditing and other means of control are required.
- Improving resource usage efficiency: Using new materials, processes, technologies and other measures can help improve resource usage efficiency. While decreasing and balancing the impact of resource utilization on the environment due to pollution and destruction(Zhou et al., 2016).

2.4 Benefits of Industry 4.0 Technologies

2.4.1 Internet of Things Benefits

The Internet of Things (IoT) is a network based on interoperable communication protocols where smart objects interact and exchange data with physical and virtual “things” in the network to provide value added services. Key IoT technologies include Radio Frequency Identification (RFID), sensors, Near Field Communication(NFC), Wireless Sensor Networks (WSN), machine learning, predictive analytics and big data management tools(Bibri, 2018).

IoT can provide companies with benefits in many areas, allowing them to obtain a competitive advantage in the modern business environment. With regards to Supply Chain Management (SCM) the adoption of IoT will provide companies with higher profits, a decline in excess perishable products, rapid response to costumers needs and deliveries optimization

(Haddud et al., 2017). Perishable product supply chain faces several issues such as logistics inefficiency and extended delivery time which results in large losses in these products. However, such problems may be resolved through IoT which provides a systematic and intelligent network. A study was able to demonstrate this through two revenue models that calculated the revenues for a perishable product supply chain with and without the utilization of IoT. It proved that the usage of IoT for large enterprises can greatly enhance their supply chain by harmonizing its wholesale profits and total costs incorporating the logistic cost, thus increasing its total revenue(Lin, Lee, Lau, & Yang, 2018). Lee et al. (2013) developed an RFID based process mining system for quality assurance in garment industry. They utilized fuzzy association rules to identify the relationship between the quality of products and the process parameters. In which they proved that the production time and cost of rework were improved and the number of defects were reduced(Taylor, Lee, Ho, Choy, & Pang, n.d.). In addition, the usage of RFID can considerably improve the performance of distribution systems by 33.8% and stock availability by 45.6%(Kang, Kim, & Lee, 2018).

From a logistics point of view, connecting machinery and manufacturing resources to an IoT environment provides a greater degree of tracking and control. This will also make possible the use of other paradigms such as predictive manufacturing, cloud manufacturing and big data analytics(Ge & Zhong, 2018). IoT along with BDA allow logistics firms to reduce their fleet operating cost, improve driver's safety and reduce pollution caused by vehicles. Live data from sensors in vehicles provide information about the engine, speed, breaking and location of the vehicles that are used in training programs. While BDA is used to optimize routing reducing fuel consumption, provide recommendation for the best refuelling times and forecast proactive or predictive maintenance(Hopkins & Hawking, 2018). In addition, IoT may provide advanced location based services using GPS allowing drivers to select the most cost and time efficient routes(Bibri, 2018).

IoT can support factories in energy management at the production level and improve the energy efficiency of their production systems. By gathering real time data regarding energy consumption in the shop floor and providing them to the management at any location. This allows them to incorporate such information in their practices to identify and reduce waste, and to improve thier energy efficiency(Shrouf et al., 2014). IoT devices can be integrated with Building Energy Management systems for real time monitoring and control of electrical, electronic and mechanical systems in industrial and commercial buildings. Thus, reducing energy consumption. Through sensors and actuators objects are able to process information, configure themselves and autonomously make decisions regarding their operational functioning(C. H. Lu, 2018).

In today's global business environment, the need for industrialization is increasing. This leads to an increase in the emission of dangerous chemicals and gases in the environment. However environmental laws and acts are increasing pressure on companies to monitor and reduce their impact on the environment. Through an IoT system industrial plants can self-monitor their emission of gases such as Nitrogen Dioxide, Carbon Monoxide and Sulphur at any time. Thus, allowing them to identify issues in their machines and processes and to take the necessary corrective actions and decisions to reduce their emission(Martillano et al., 2017). Usage of IoT is expected to result in significant improvement in the quality of air and water through advanced monitoring tools thereby assisting in environmental protection. In addition pervasive sensors can be used to detect and remove pollution in water and air that is detrimental to the public health(Bibri, 2018).

Wide spread of internet connected devices with sensors allows companies to improve their delivery of services and exploit the provided data to understand if interventions are effective. In addition, data coming from sensors in products can be used by manufacturers to design better products in the future. Also, to develop innovative after sales services to customers such as proactive maintenance to avoid products failure. Uden and He summarized some of the benefits of IOT for knowledge management. Stating that it allows to generate better information and analysis from various products, company assets or operating environment. Which in turn substantially improves decision making. Also, sensors in products allow companies to track their movements, monitor the customers interaction with the products and use it to make informed decisions(Uden & He, 2017). Enabling companies to tailor services to customer needs and to advise customers in several matters related to the product usage. Also, to develop new solutions to enhance the customers utilization of the products or make changes in the product to support customer success(Rymaszewska, Helo, & Gunasekaran, 2017). Manufactures can take advantage of IOT to raise their productivity as its assists systems to automatically adjust in critical situations eliminating the need for human intervention in most cases. Finally obtained information can support in making long term decision and in complex planning and decision making(Uden & He, 2017)

2.4.2 Big Data and Analytics

Big Data Analytics is defined as “a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery and/or analysis”(Yuanyuan Lai, Huifen Sun, 2017). Big Data for organizations comes from two main sources internal and external. Internal sources of data include mainframe logs, emails, digital documents, business process events and all sorts of structured, semi structured or unstructured data in an organization. While external sources of data include; data available on social media, hints from third parties, customer complaints in regulatory websites and competitor’s product literature. Such data can be provided to companies free of charge by the public or for a paid subscription. Big data can also be classified into five types namely; machine-to-machine, biometrics, web and social media, human generated and bug transactions data(Sathi, 2012). Big data is characterized by four V’s (Variety, Volume, Velocity and Veracity) that allow it to be differentiated from other data. Big data comes from large sources of data as previously explained which makes it very big in terms of volume. In addition, due to the high number of different sources there is a need to test the veracity or quality of such data. Moreover, the volume of big data is more than terabytes and petabytes exceeding tradition data storage and analysis techniques(Jelonek, 2017). To analyze big data company’s analytics infrastructure, require massive parallel processing and bigger pipes due to the high velocity or throughput of data. Also nowadays analytics is being included in business processes using data in motion with lower latency(Sathi, 2012).

Efficient supply chain management and execution require precise forecasting and demand planning. Using wrong method in data processing will result in false impressions generating unreliable forecasts and data that is impractical for decisions making. To improve the forecasting accuracy BDA extracts the necessary information for forecasting decisions. Thus, overcoming the gap between data and the forecasting method and improving the forecasting accuracy. In addition, the impact of price changes can be determined if enough data on analog changes in the past is available. Some of the benefits that BDA can provide for supply chain management and logistics includes; more precise prediction and management of supply chain risks, reducing supply chain waste, stronger partnerships and a higher response rate to environmental changes. In addition, it allows companies to reduce inferiority due to information asymmetry as they make use of both internal and external data to analyze trends and changes in the market(Yuanyuan Lai, Huifen Sun, 2017). Designing the supply chain network is a strategic decision that determines the physical configuration of the supply chain. Using BDA, Wang et al (2016) were able to develop a mixed integer nonlinear model that selects locations of distribution centers based on big datasets for customer demand, transportation and warehouse operation. They determined that big data provides additional information such as service level and penalty data. Thereby providing the possibility to design complex distribution networks. Through big data analytics companies are able to better understand customer needs and markets trends and thereby build more responsive and agile supply chains. In addition, through the multiple sources of data local and global firms can proactively plan supply chain activities e.g. depending on events, weather or natural disasters. Allowing supply chain mangers to be more alert about external future events(Tiwari, Wee, & Daryanto, 2018).

Adoption of big data allows firms to improve their internal processes and their supplier’s performance. The main benefits being in terms of cost and time. With larger volumes of data companies can make more efficient and reliable decisions regarding suppliers’ selection and contract management. In addition, comparing the big data allows to reduce errors and improve the quality of the output. Furthermore, big data enhances the detectability of problems in supply chain which in turn makes the management of the procurement process more flexible e.g. when searching for an alternative supplier. Having more information about the suppliers cost structure and the market on the web allows companies to increase their scouting capabilities, further negotiate and obtain lower prices(Moretto et al., 2017).

BDA provides benefits in terms of speed and efficiency allowing organizations to gain a new competitive edge. Also, the opportunity to optimize their production levels, usage of working capital and decrease maintenance and repair costs. Moreover, it allows firms to achieve higher margins, profitability and increase their gross sales(Attaran et al., 2018). Through BDA companies can understand customer's needs, which features delight customers and thereby improve products/services or develop new ones resulting in higher customer satisfaction(Wang & Alexander, 2015). They can even determine which marketing campaigns and promotions are effective in driving sales, customer engagement and traffic. Also to optimize the marketing mix for a given marketing goal(Jelonek, 2017).

In addition, it facilitates mass customization in manufacturing and enables companies to reduce their warranty cost through warranty analysis(Wang & Alexander, 2015). By analyzing data from sensors embedded in machines every part and procedure along the production line can be monitored and controlled to improve the manufacturing process. Factories can develop self-regulating processes that minimize waste, avoid costly or dangerous human interventions and increase their productivity. Furthermore, data from machines can be used to enhance the simulation and testing of manufacturing processes. Mining big data in manufacturing provides the ability to track defects, enhance the monitoring and detection of quality problems. By tracking all parts that enter a product through big data companies have the ability to reduce defects as they can determine which part or area of the production process leads to problems. This in turn allows to improve the quality of supply. Furthermore, predictive diagnostics can be performed for part or product failure, thus enhancing the quality of finished products(Wang & Alexander, 2015).

2.4.3 Additive Manufacturing

Additive Manufacturing (AM) is an explicit term used for what was previously known as rapid prototyping and 3D printing. Were rapid prototyping was used to create a quick prototype or basis model from which the enhanced models and the final product are made. However, users of rapid prototyping realized that term is inadequate as it does not describe is recent application. Since many parts are now manufactured in the machines and cannot be named as prototypes. Also, because parts are fabricated using an additive approach. AM directly fabricates a model generated by a three-dimensional Computer Aided Design (3D CAD) system. Through AM parts are made by adding thin material layers each layer being a thin cross section of the part obtained from CAD data(Ian Gibson & Stucker, 2015).

AM can significantly shorten companies supply chain, reduce inventory and increase flexibility. More importantly it can respond to today's market needs of mass customization, innovation and responsiveness, providing adopters a competitive advantage. AM can considerably minimize the prototyping time, hence reducing design time and allowing firms to be more responsive to the market. This is particularly important in design or contracting phase, in small and medium size enterprises allowing them to gain a first mover advantage and acquire demand faster than competitors. Moreover, AM eliminates errors, misunderstanding and uncertainty related to the project and improves the quality of the product through improved prototype. One of the greatest advantages is that it provides freedom in manufacturing geometric complexity and the ability to reengineer products and processes(Busachi et al., 2018). With AM comes high levels of automation and part consolidation which allows parts to build as a single piece and eliminates the need for assembly leading to a great reduction in terms of labor, storage, handling and logistics costs(Luo et al., 2016).Organizations can also take advantage of AM in after sales, adopting new business models by providing repair, remanufacturing or upgraded products. Thereby generating new profit sources(Despeisse et al., 2017).

Adopting AM allows production of small quantities of custom products at a lower cost, with the ability to produce different products in the same batch, thus maximizing volume utilization(Despeisse et al., 2017). This is possible as direct production from 3D CAD models eliminates the need for object specific tools, molds or punches and there is no switch over cost(Ford & Despeisse, 2016). Thus, companies can respond faster to changing customer needs and the lead time to market is reduced. Also, less material is used as materials are only accumulated were an object needs to be built and lightweight products can be built(Lum, Palazotto, & Dempsey, 2017). It is also possible to include more functionality in an item or enhance products functionality. AM accommodates several processes into one step obtaining a near net or net shape reducing material, energy, time and costs. In addition, it can minimize or eliminate inventory waste, thus decreasing the amount of raw material needed, handling cost, lead time and quality problems(Despeisse et al., 2017). It also allows for almost 100% material utilization as most of the material involved are used in manufacturing the final product and so it reduces material waste(Sisca, Angioletti, Taisch, & Colwill, 2016). Past researches demonstrated AM ability to infuse agility in firms' operations and this increases customers service level. In terms of spare parts and products AM allows manufacturers to move their production closer to their customers through decentralization(Oettmeier & Hofmann, 2017). This also results in lower safety stock, higher customer satisfaction and the ability to move from make-to-stock to make-to-order with a zero stock level(Spalt & Bauernhansl, 2016).

Li et al. (2017) performed a simulation to compare AM based spare parts supply chains to traditional ones. They concluded that AM supply chains are superior in terms of variable cost and can be considered as a green manufacturing technology. Since its total carbon dioxide emission was lower and its main source was the usage or raw material for AM(Li, Jia, Cheng, & Hu, 2017). AM processes are greatly based on recycled materials and therefore they can contribute to more efficient use of resources and circular use of natural resources. Also, they enable the assembly of products with less material diversity and this improves materials recyclability(Despeisse et al., 2017). Kianian et al. (2015) conducted a case study for three AM actors in Sweden to understand its impact on employability. They found out that it contributes to jobs creation in the manufacturing and service sector. With more jobs being created in the stages of product development and production of low volumes complex products without impacting mass production jobs in emerging economies(Kianian, Tavassoli, & Larsson, 2015).

2.4.4 Augmented Reality

An augmented reality (AR) system combines and aligns real world objects with virtual objects interactively and in real time. Making them appear as if they coexist in the same space in the real world. Although most researches focus on the sense of sight through head mounted displays (HDM). AR may be applied to all senses including touch, smell and hearing. Some applications also require real objects to be removed from the perceived environment(Azuma, Behringer, Feiner, Julier, & Macintyre, 2001). Through a process called registration an AR system aligns the virtual object with the real world by tracking the orientation and position of the user's head. Although AR systems share some common hardware technologies with virtual reality (VR) research there is substantial difference between them. Since virtual reality aims at replacing the real world, while AR supplements it(Fener, 2002).

In several industrial areas such as manufacturing, and assembly workers are given instruction and trained for their tasks through written documents or traditional displays that inform them the specific steps to follow. However, traditional methods of training and instructions are suboptimal as they are perceptually inefficient demonstrating static images that cannot represent complex actions and objects. In addition, they overload workers memory and are difficult to recall if displayed in live trainings and used a few days after. These cognitive limitations can be overcome using AR, resulting in faster and frustration free performance (Baldassi et al., 2017). Several AR based manufacturing applications have been developed including object calibration, laser printer, aerospace and automotive maintenance. Hyundai introduced an interactive user guide that uses AR to demonstrate parts of the engine and dashboard in order to give guidance as to how to fix minor car issues(Kim, Kang, Choi, Choi, & Hong, 2017). In an experiment, users were asked to assemble LEGO sets using AR and a paper manual. The results showed that the users were able to execute the tasks more accurately, quicker and with reduced mental effort with AR than with paper manuals(Baldassi et al., 2017). Segovia et al. (2015) evaluated the impact of using AR for technicians training in a machines tools workshops for a coordinated measuring machine, lathe and milling machine. They proved that AR training significantly reduced the mistakes and time needed for machining and dimensioning of a part and eliminated the operator’s dependency on the experts. Analyzing the three processes, a saving of 27.36% was achieved in the lathe, 26.54% in the milling and 45.16% in the measuring machine respectively(Segovia, Ramírez, Mendoza, Mendoza, & González, 2015).

AR can be used by designers in early product design stages to develop a proof of concept. It allows them to use virtual assembly features on the real assembly platform to determine parts assembly constrains early in the design processes. In addition, by working on the real assembly platform, designers can design the assembly in a more practical manner. Through an AR interface, designers can combine some of the benefits of physical and virtual prototyping. Also, an AR environment requires fewer computational resources compared to virtual environment.

Chryssolouris et al. (2009) developed a web based, real time collaborative platform with VR and AR integration for products demonstration, review and customization. It provides easy and quick exchange of data among various designers whom can view and interact with the prototype at the same time. Also, it results in a user friendly environment for the assessment and improved communication among designers throughout the lifecycle of the product(Chryssolouris et al., 2009).

Warehousing operation may be optimized through the usage of augmented reality technology. Error rates and rework can be reduced as the device displays the product sought, the steps to be followed and limits the workers need to make decision. It also provides workers with more flexibility as the information can be displayed anywhere and allows them to have their hands free for other work. For routing operations, it allows faster movement by anticipating the next move. In addition, if a worker is interrupted his next operation is not affected and they can double check products or storage locations with automated recognition. It can even provide warnings in case of danger and information for safety purposes(Marie-H´el`ene Stoltz & Duncan McFarlane, n.d.). DHL and RICOH conducted a pilot project were employees were provided with AR hard and software to see if the quality and efficiency of picking will be enhanced compared to working with paper pick lists or hand-held scanners. Results showed that the performance of each picker was increased by 25% and higher time saving per task was achieved when AR was used instead of hand-held devices(Hammerschmid & IMC Krems, 2016).

2.4.5 Autonomous Robots

Robotics have achieved a great success in industrial manufacturing. Robot arms and manipulators alone constitute a 2-billion-dollar industry. There are several types of robots and they can be classified in various ways e.g. based on their complexity or similarity to humans or animals and their way of movement. Autonomous robot are types of robots that are capable of making independent decisions based on the situation they face rather than performing a predefined set of motions. However, since most of autonomous robots are mobile, it is possible to define an autonomous robot as a mobile robot that is able to make decision(Roland, R., SIEGWART, & NOURBAKHSH, 2004). Requestees for autonomy are sensors, actuators, processors, and intelligence algorithms. Sensors perceive information about the surrounding environment and transfer information to the processor which acts as the brain of the robot. The processor processes the received information and controls actuators that drive the behavior of the robot accordingly. Intelligence algorithm serves as the brainpower of the robot autonomy and are embedded into processors to provide the robot with autonomy. Currently robots are being developed with more than one processor which facilitates fast processing and allows them to perform multiple tasks(Marchlewitz & Winzer, 2015).

Nowadays mobile autonomous robots are used in several sectors including electrical mobility, agriculture, sports, military combats, manufacturing and firefighting. Their ability to perform tasks autonomously makes them an excellent option for exploring regions that are hazardous for humans such as space and earth exploration, search and rescue and surveillance (Tareen, 2016). One of the first industrial application of mobile robots in factories is the Autonomous Guided Vehicle (AGV). Which work by following a path that can be visible, invisible or marked by a high contrast surface. It is also equipped with sensors to avoid obstacles and is used to transfer materials around the factory, however AVGs have limited autonomy.

Contemporary e-commerce companies are investing huge amount of effort and time on robotics and automation research to support in improving their warehousing efficiency. Amazon made a competition called Amazon Picking Challenge to encourage foster advance in technology. Participants were required to develop software and hardware that autonomously search, and picks products in their warehouse and places them in a target location. In fact, Amazon is now testing an autonomous robot called Scout that delivers packages in Washington(Huang & Mok, 2019). Dehne et al. (2017) designed an autonomous mobile robot MARWIN to carry out maintenance and inspection tasks for the European XFEL accelerator in Germany. In general accelerators are overbooked which limits the beam time for researchers and therefore it is necessary to minimize the maintenance time of an accelerator. However, maintenance cannot be performed without checking that there is no residual radiation, and this is where autonomous robots like MARWIN can be taken advantage of(Dehne, Hermes, Möller, Bacher, & Desy, n.d.). Abdellatif et al. (2017) designed and implemented an autonomous forklift that uses Microsoft Kinect to acquire maps of its environment and then coverts them into top views for navigation. The robot is capable of lifting cargo in warehouses and stores from one place to a target location while avoiding static and dynamic obstacles(Tareen, 2016).

2.4.6 Cloud

Cloud computing is a result of the convergence of two trends in information technology (IT). The first is IT efficiency were the power of current computers is used with a higher efficiency through highly scalable hardware and software. The second is business agility, were IT may be used as competitive tool through rapid deployment, parallel processing of batches, using compute-intensive business analytics and interactive mobile apps that respond to the user's requirements in real time. Several scholars attempted to define cloud computing and its characteristics(Olaru, 2014). The National Institute of Standards and Technology in the US defines cloud as "a model for enabling omnipresent, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"(Mell, Grance, & Grance, n.d.). Though there are numerous definitions for cloud computing they share common characteristics for a cloud that is pay-per-use, elastic capacity, self-service interface, virtual resources that appear to be infinite, elastic capacity and development tools and APIs that enable developers to build applications.

Cloud computing greatly reduces costs of compute-intensive business analytics for small firms, which was previously available only to large firms. It also provides a great advantage by enabling IT services to third world countries that traditionally did not have the resources for widespread deployment of IT services. Also, cloud computing can almost provide an instant access to resources without the need for capital investment which leads to faster time to market in many businesses. Considering IT as an Op-ex can significantly reduce the upfront costs in corporate computing. Moreover, the cloud can act as an adaptive infrastructure that can be shared and used in various ways by different end users. Users are separated from one another and the infrastructure flexibility allows the computing loads to be balanced instantly as more users join the system. Furthermore, cloud computing can reduce IT barriers to innovation as can be seen from many successful startups such as Facebook, YouTube and Tripl. It also allows companies to easily scale their services which depends on accurate information according to customers demand. Since computing resources are managed by software they can be deployed quickly as new customer requirements arise. This is because cloud computing aims to increase or decrease resources through software APIs based on the client load(Dubey et al., 2011). Thanks to cloud computing new applications and services are possible such as; i) mobile applications that are location and context aware and can respond to information provided by humans and sensors in real time e.g. humidity sensors in shipping containers; ii) analysis of terabytes of data in a short periods of time through parallel batch processing; iii) business analytics that uses various resources to understand consumers buying habits, supply chains etc... from large amount of data; iv) extensions of compute-intensive desktop applications that can offload the data crunching to the cloud while leaving the interpretation of the processed data at the front-end(Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011).

From the idea of cloud computing a new manufacturing paradigm was developed, which is the cloud manufacturing. It is a computing and service-oriented model based on advanced manufacturing models, enterprise information technologies and is supported by cloud computing, virtualization, IoT and service oriented and advanced computing technologies. Cloud manufacturing comprehends the sharing, circulation, high utilization and on demand use of several manufacturing resources and capabilities by providing cheap, safe, high quality and on-demand use of manufacturing services throughout the manufacturing lifecycle. The utilization of cloud manufacturing can provide several advantages to manufactures. First, in conventional manufacturing models it is estimated that only 15-20% of their IT resources are utilized, while other manufacturing resources are even lower. However, using a cloud manufacturing platform can raise the utilization among several customers to at least 40% for IT resources. As with cloud computing it also reduces the initial investment and lower cost of entry for small and medium size enterprises that want to benefit from high value manufacturing resources. This in turn allows them to reduce their maintenance and upgrading costs. Cloud manufacturing also allows manufactures to lower their infrastructural and administrative costs and to scale their production and business according the customers demand. In addition, it can optimize industrial distribution and accelerate the transition of a distributed and high energy consumption manufacturing model to a centralized resource and green manufacturing model and from a production to service oriented model. It can also generate new manufacturing models or process and deliver manufacturing services that were not possible before(Tao et al., 2011).

2.4.7 Simulation

Simulation modelling has developed significantly from its first application in the 1960s as a technology used by mathematical and computing experts to a tool used to solve various design and engineering problems. The rise of Industry 4.0 has also led to changes in simulation modelling as it requires modelling of manufacturing and other systems using the virtual factory concept and advanced artificial intelligence for process control that includes autonomous adjustment to operation systems. This new simulation modeling paradigm is best described as the Digital Twin. It extends the use of simulation modelling across the product life cycle where first products are developed and tested in a virtual environment and then each phase in the product life cycle uses the information generated by the previous phases. Combining simulation models with real life data allows accurate maintenance and productivity prediction.

Digital twin of a process or a part of it has several uses in an organization. For instance, using an in line Digital Twin an operator can train on a virtual machine until he has the skills and confidence to operate on the real machine. It also accelerates the operator's ability to learn and minimizes the risk of damaging the machine. Also, it can be used to determine problems in the real machine counterpart by using advanced machine learning capabilities with optimal control and model predictive control techniques. Moreover, Digital Twin can be embedded in a machine to increase its self-awareness and thereby to optimize its performance for given duty cycles, diagnose and make up for non-catastrophic faults and coordinate the operation with other machines with minimal operators input(Rodič, 2017).

2.5 How does Industry 4.0 benefit the Food Industry?

The food industry refers to all companies that produce, process, manufacture, sell and serve food, dietary supplements and beverages. Where the aim is to provide good and healthy food that is produced in an efficient and sustainable manner that does not affect the environment. Nowadays demand for efficiency has increased, as advance in technology allows companies to offer products with higher levels of added value to compete with manufacturers who have low production costs(Luque et al., 2017). The global food and beverage industry was valued for $5.7 trillion US in 2008 and is a major contributor of growth in all economies. Although the economic crisis had an impact on most industries including the food & beverage industry, leading to an increase in food prices, transportation cost and lower consumers spending. The Food & Beverage industry was rather less affected in comparison to the other industries(Haase, 2003).

Heat stress is a global issue that causes cows to produce less milk with the same nutritional input and this in turn increase farmers production cost. However, the impact of heat stress can be minimized by electronically monitoring the cow's temperature and taking the necessary actions. According to the US Department of Agriculture approximately $2.4 billion USD losses per year from animal deaths can be prevented by electronically checking vital signs in cows(Ilapakurti, 2015). To help resolve this problem Ilapkurti et al. (2017) developed a prototype based on IOT. Their system architecture was based on five tiers; mobile sensor core, data base tier, service tier, user interface tier and sensor data analytics platform. A mobile interface periodically connects and retrieves values of sensors placed on cattle. Then in line rule processing compares the values and if certain set rules are violated it alerts the user. It also uploads the values in a cloud and saves them on a local phone. Using pattern detection and machine learning the system correlates the relation among various dairy optimization factors e.g. the effect of medication and vitamins on cattle milk output. Also, it analyzes historical data in relation to the weather forecast and determines if any changes in the weather has affected the cattle and based on that it provides insight to dairy personnel's if similar changes in the weather is forecasted in the future. The system helps farmers improve their operational efficiency, save costs and provides insights to address cattle issues(Jaya Shankar Vuppalapati, Santosh Kedari, Ananth Ilapakurthy, Anitha Ilapakurti, sharat Kedari, 2017).

Nowadays governments around the world are moving toward the enforcement of RFID for livestock identification. This allows the authorities to track and trace animals particularly when there is a disease outbreak across the region. RFID can also be used with farm management practices to help farmers optimize their cattle milk yield and quality. Since it enhances the ability to monitor the herds health, minimize their illnesses, speed up the milking process, optimizes feed to suit the cow's production and lactation cycle. Furthermore, utilizing RFID for automation helps to reduce workers inputs, thereby allowing workers more time to take care of the cows or to perform other activities. It is believed that the adoption of RFID in dairy farms will continue to grow worldwide to the point that it will become mandatory to survive in the dairy market(Trevarthen & Michael, 2008)

Precision agriculture is a farming management concept that uses Information and Communication Technologies (ICT) to enhance crop yield and ensure sustainable growth. Nowadays Wireless Sensor Networks (WSN) are being used is precision farming because of the advance in IoT, market pressure, rise in environmental regulation and growing populations. A survey regarding farms in Netherlands demonstrated that two fifth of the farms adopted sensor based farm monitoring(Steeneveld & Hogeveen, 2015). Moreover, simultaneous advances in Nanotechnology and IoT led to the emergence of a new networking technology, Internet of Nano Things (IoNT) which can be useful in monitoring dairy activities at nanometer range (Kyildiz, Ornet, Nstitute, & Echnology, 2010). The use of Wireless Nano Sensor Networks (WNSN) in dairy farms can provide several advantages. First, it allows to monitor the soil conditions in order to replenish soil nutrients and ensure good quality grass. Since early detection and treatment of plant and animal diseases is good for their welfare and thus improves the quality of their production. Also, the Nano sensors can be powered by bioconversion of animal waste, promoting green computing. A large number of nanodevices may be used together to form a WNSN that results in increased transmissions reliability despite the failure of nodes(Bhargava, Ivanov, & Donnelly, 2015). It is expected that IoT will provide more morphogenic change in the future allowing to develop sustainable agricultural practices rather than providing incremental changes through precision farming. This is particularly true since agriculture may have to be performed differently in the future, responding to biodiversity needs(Kidd, 2012).

There is a need for agriculture to improve quality of products and services by using data analysis to reduce investment costs. In precision agriculture data is collected as structured and unstructured datasets and includes data regarding; crop patterns and rotation, soil nutrients and types, weather conditions, GPS data, machines data such a yield and fertilizers rate. Thus, using big data can help support precision agriculture in several ways by allowing the extraction of insights and intelligence from data that can be used to address several important farming decisions. Big data analytics and ICT can help farmers in water management and to increase their productivity by predicting events that are harmful to farming and to decide on the pesticides and fertilizers to use. Brendre et al. (2016) developed an application to predict rainfall using an unsupervised method for big data processing and forecasting. It also provides suggestions to farmers regarding crop patterns and water management which is important for yield management(M.R. Bendre, R.C. Thool, 2016). Big data analysis can also be used by agricultural firms to determine how much food to produce, store and distribute. Which can assist in creating a food/nutrient security information system. BDA in food warehouses can help in enhancing accessibility to food aided by zero defect supply chain and paving the path for better market integration(Sharma & Parhi, 2017).

According to the Food and Agriculture Organization of the UN beef is the largest contributor to carbon footprint in agriculture. In addition, some governments and consumers are placing pressure on reducing emission form beef. Analysis of big data from farms can help in identification of ecofriendly farmers, since reduction of carbon footprint is obtaining attention around the world and many countries are setting targets to reduce it e.g. in the EU a target of 40% emission reduction was set for 2020. However, most of the focus is on manufacturing and logistics emission. While agriculture as well contributes actively to carbon emission e.g. in the USA it is responsible for around 9% of the carbon emission. Thus, to achieve their targets countries must focus on decreasing the emission of all sectors including agriculture(Singh, Kumari, Malekpoor, & Mishra, 2018).

The first usage of Additive Manufacturing in food dates back to 2007 where a group of researches introduced an open source extrusion based AM machine with a syringe(Periard, D., Schaal, N., Schaal, M., Malone, E., Lipson, 2007). After that several companies and organizations designed machines for different applications from pasta to chocolate. Table 1 shows AM categories, their commercial solution and the material used in food.

Table 2.1 AMTs categories – Additive food manufacturing

ASTM CLASSIFICATION (AM PROCESSES)	COMMERCIAL TECHNOLOGICAL SOLUTION	FOOD MATERIAL
Powder Bed Fusion	Selective Laser Sintering	Sugar
Directed Energy Deposition	n.a. for food	n.a. for food
Material Jetting	Polyjet	n.a. for food
Binder Jetting	3D Printing - Inkjet Printing	Sugar, Protein powders
Material Extrusion,	FDM	Chocolate, Pasta Dough
Vat Photopolymerisation	SL	Eggs white, package
Sheet Lamination	LOM	n.a. for food

Additive manufacturing is currently used in the food industry for content and shape customization, rapid prototyping and tooling and bioprinting. Natural Machines developed a commercial printer that uses hot melt extrusion to print hamburgers, cookies and pizza with various ingredients(Sun et al., 2015). Marko Manriquez developed a 3D printer Burritbot that makes customized burritos from an iPhone app by extruding beans paste and several Mexican sauces(Pallottino et al., 2016). Barilla in collaboration with TNO a Dutch Applied Research Centre Developed a prototype 3D printer of pasta that uses Fused Deposition Modelling (FDM) technology. It allows to customize the pasta in terms of shape, color and taste. The printer takes 2 minutes to extrude pasta that takes 3 minutes to cook, making it possible to make a plate of pasta in 5minutes(Savastano & Amendola, 2018).

AM has several advantages in the food industry, the most important is the ability to customize food in terms of shape and nutritional content. Additive Food Manufacturing (AFM) can be used to control people’s diet and ensure that the needs and preferences of people affected by intolerances are met(Pinna et al., n.d.). It can help reduce costs and errors in large care centers and hospitals that need to serve a range of special meals daily. Particularly if modified meals that differ in texture are needed for individuals with difficulties(Kouzani et al., 2016). In addition, AFM allows companies to have simplified supply chains that are agile and close to the market. Thereby having a make-to-order strategy with low overriding cost and being close to the consumer. Furthermore, a great advantage would be the ability to use ingredients that are rich in nutrients like mushrooms and algae that cannot be used with traditional techniques(Pinna et al., n.d.).

Autonomous robots are used in several fields including surveillance, field scouting, agriculture and factories to speed up operations or to perform repetitive tasks. In the agricultural sector autonomous robots can help to optimize yield, decrease labor costs and collect necessary information such as ambient and crop conditions, soil fertility, pest and disease. They can be used for several tasks including weed control, hauling, sorting, harvesting, grading and packing. Kumar et al. (2018) designed and fabricated a seed sowing robot with the aim to reduce labor and time and increase profitability. Using a microcontroller, the robot can autonomously perform several activities including seed sowing, plowing and applying fertilizers. In addition, it includes an ultrasonic sensor to detect and avoid obstacles. They finally observed several advantages from the robot including higher efficiency, yield, cropping frequency and reliability. Also, the seeds can be immersed to any depth improving the plants germination and seeds are spaced in a way that allows the plant to capture light properly(Kumar, Kalyan, Kumar, & Dilip, 2018). Robert developed a low-cost autonomous vehicle to demonstrate the capability of robots in seed selecting. The robot is capable of selecting seeds with a 98% efficiency in seed selection and provides a seeding sowing that is five times faster than the traditional seeding methods. In addition, it is capable of a picking rate of 90 min per seed and one robot can be used to sow an acre of field in 1.5 hours. This can also reduce the need of labor to do such work(Bouge, 2016).

An autonomous patch robotized patch sprayer was made by Gonzalez-de-Soto et al. (2016), for site specific herbicide application in agriculture and is able to work in a group of autonomous robots. It consists of a commercial agricultural vehicle chase and a customized direct injection spraying boom. Also, on-board remote sensors were used to provide the robot with weed data for treatment. The robot was capable to achieve over 99.5% weed detection and treatment without falsely detecting good crops as weed. This in turn saves a significant amount of herbicides and reduces soil and ground water pollution(Gonzalez-de-Soto, Emmi, Perez-Ruiz, Aguera, & Gonzalez-de-Santos, 2016). In Europe 1.3 million tons per year of pepper are harvested in greenhouses and thus in 2015 the first commercial robot in greenhouses SWEEPER was made in order to harvest peppers. SWEEPER runs on a railway within a greenhouse and contains an arm with six DOF that has a gripper. It first uses cameras and pattern recognition to identify a pepper, once detected it performs a color analysis to determine if the pepper is ripe or not. If it is ripe the robot moves it articulated arm and picks the pepper. Preliminary results showed that the robot is capable of harvesting ripe peppers in 24 seconds with a 62% success rate. Using SWEEPER in greenhouses can solve several problems that are faced today such as labor cost and availability and food quality and safety(Bouge, 2016).

Governments and consumers around the world are placing pressure on companies to become more sustainable with transportation and manufacturing being the main areas of concern in terms of pollution. Regarding supply chains the main issue is with CO_2 emission from vehicles. Moreover, in developing countries manufacturers are using sustainable supply chain management to limit their impact on the environment, however this doesn’t contribute to a cost-effective performance. Nevertheless, usage of autonomous robots can help overcome this problem. To prove this Gružauskas et al. (2018) performed a simulation for logistics network using data from specialist in the food industry. The simulation demonstrated that using autonomous vehicles in distribution would provide a 5% reduction in transportation costs and 22% in CO2 emission compared to a traditional distribution method(Gružauskas, Baskutis, & Navickas, 2018).

2.6 Industry 4.0 and developing countries

Developing countries are countries with a less developed industrial base and a lower human development index compared to other countries.They include, in decreasing order of economic growth or size of the capital market; newly industrialized countries, emerging and frontier markets and least developed countries. Usually developing countries share some common characteristics. For instance, they have low level access to safe drinking water, hygiene and sanitation, energy deficits and high levels of pollution. Moreover, they are often characterized by a widespread of poverty, low levels of education, governmental corruption at all levels and lock of good governance(Althor, Watson, & Fuller, 2016).

Given the nature of developing countries the process for formation of Industry 4.0 in developing countries has its own particularities and differs from that in developed

countries. In developed countries the process of formation of Industry 4.0 started earlier and aimed at marketing and social results. While in developing countries there is no state policy for the formation of Industry 4.0, and they face financial barriers and seek economic goals. However, in developing countries the initiators to Industry 4.0 are economic subject (companies) whom anticipate larger flexibility and effectiveness to the directive approach (state initiative), which is applied in developed countries. Moreover, the industrial orientation of developing countries, related to their international production and specialization on industry, predetermines formation of Industry 4.0 as an infrastructure building sphere that stimulates modernization of economic systems as a whole(Bogoviz, Osipov, Chistyakova, & Borisov, 2019).

Jantan et al. (2018), conducted a case study regarding Industry 4.0 in Bangladesh, where they tried to obtain insights regarding the challenges for Industry 4.0 in Bangladesh focusing on readymade garment, leather, shipbuilding, tourism and agriculture industry. According to them the lack of government support and corruption in government bodies are challenges that kept Bangladesh outdated and taking a significant amount of time to take the advancement of the technologies to automation. Also, the lack of knowledge of employees particularly at a managerial and key planner level has been a barrier for implementing technological integration to create automation in manufacturing industries in Bangladesh. Another barrier is the poor infrastructure of the country such as the poor communication processes, poor Internet broadband disbursement and the country is prone to floods and natural disasters. Also, the availability of cheaper labor in Bangladesh, which is another barrier for quicker automation in the manufacturing companies in Bangladesh and another significant issue against the adoption of Industry 4.0. The last barrier is that the installation of Industry 4.0 technologies is very expensive, so companies don’t apply them in factories(Jantan et al., 2018).

Industry 4.0 can help industries to integrate environmental protection, control initiatives and process safety measures in supply chains to develop sustainable supply chains. However, this is not easy as there are many challenges in the adoption of Industry 4.0 initiatives. Luthra and Mangla attempted to evaluate the challenges to Industry 4.0 initiatives for supply chain sustainability in India based on literature review that they tried to confirm through interviews. Where they identified four challenges; organizational, technological, strategic and legal and ethical. Organizational constraints were considered the most important and include; financial constraints particularly for small and medium enterprises, low management support and involvement which is necessary for diffusion of Industry 4.0 sustainability practices. Also, poor digital operations vision, low understanding on Industry 4.0 implications, reluctant behaviour towards Industry 4.0 and lack of competency in adopting/applying new business models. While technological challenges were related to lack of global standards, data sharing protocols, infrastructure and internet-based networks. In addition, the need to improve internet connectivity in in Indian rural regions, lack of integration of technology platforms that is required to support heterogenous cyber physical components and poor quality of existing data. Furthermore, they identified that strategic challenges are related to insufficient governmental support and policies and unclear economic benefits of digital investments for effective Industry 4.0 adoption. Also, poor research and development on Industry 4.0 adoption and lack of digital culture. As for legal and ethical issues these were classified as those related to security issues, profiling and complexity issues, legal issues and collaboration and coordination problems.

In another study that attempted to understand the barriers to the adoption of Industry 4.0 in India twelve barriers were obtained from other literature and then verified. They include:

- High implementation cost of Industry 4.0 which makes it difficult for small and medium size industries to adopt it due to their lack of funds.
- Investment in emerging technologies such as IoT may include a threat for organizations as they may be a potential for financial loss and the company may not be able to recover their investment.
- Adoption of Industry 4.0 will result in process changes due to advent of CPS and smart factories. Also changes in organization functions giving rise to decentralized organizations and decision making will be made at the shop floor level. However, even though IoT is beneficial across industries, it carries significant challenges which are related to the internal and external integration of vertical, heterogeneous, and closed systems. Which are significant concerns for most of the enterprises.

- Adoption of IoT in new businesses is related to potential financial gains. However, several IoT applications and technologies are still in the initial development stages. Thus, there is uncertainty in the potential cost-benefit expectations that may be obtained from the adoption of IoT.
- Selection and design of Industry 4.0 architecture for different applications is a significant challenge specially when considering wireless sensory networks. Moreover, there is a lack of standards and reference architecture since Industry 4.0 is a new concept.
- The huge amounts of information flow in Industry 4.0 platform pose cybersecurity threat and data privacy issues. Cybersecurity threats are related to privacy, authorization, verification and access to the system, applications, network, and data represent significant challenges for organizations.
- Establishment of seamless integration and interoperability between different technologies and network systems is one of the biggest barriers to the adoption of IoT solutions to create a cyber-physical infrastructure of IoT ecosystems.
- Organizations should have stricter rules for IT security, as well as working with the machines and working hours.
- Jobs in the manufacturing sector are prone to be automated resulting in human job losses and those that remain will comprise more knowledge work as well as more short-term and hard-to-plan tasks.
- There is a need for enhanced skills in order to implement Industry 4.0.
- Lack of knowledge management systems.
- Lack of IT infrastructure that is needed to support the Industry 4.0 implementation.
- Legal and Contractual Uncertainty

2.5 Supporting the United Nation Sustainable Development Goals for 2030

In 2015, leaders from 193 countries created and agreed to adopt the United Nations Sustainable Development Agenda for 2030, a shared blueprint for peace and welfare of the present and future people and planet. The agenda consists of 17 Sustainable Development Goals (SDGs) that necessitate a call for action and a global partnership by both developed and developing countries, see appendix 6.1. Furthermore, the SDGs perceive that the ending of poverty and other deprivations must be accomplished parallelly with strategies aiming at improving health, education, reduce inequality and boost economic growth. Also, at the same time addressing climate changes and preserving oceans and forests. The SDGs have been localized since 2016 all over the world in organizations, institutions, governments, universities and individuals in all sectors and they work on implementing several goals at the same time.

For each SGD the UN specified the targets to achieve it and indicators. SDG 9 is related to industry, innovation and infrastructure. Its goal is to build resilient infrastructure, promote inclusive and sustainable industrialization and to foster innovation. Seven targets have been set for goal 9, which are:

- Boosting of scientific research and updating industrial technologies in all sectors and countries, especially developing ones by 2030. Also, to encourage sustainability and innovation.
- Encourage inclusive and sustainable industrialization by 2030 and increasing the share of employment in manufacturing and gross domestic product. While doubling share in developing countries.
- Increase accessibility to ICT and providing universal and affordable internet in least developed countries by 2020.
- Increase access to financial services including affordable credit for small scale industries and other enterprises, particularly in developing countries. Also, to increase their inclusion in value chains and markets.
- Assist the development of local technology, research and innovation in developing countries.
- Upgrading of infrastructure and retrofit industry so they become sustainable by 2030. While improving resource use efficiency and increasing the adoption of clean and environmentally friendly technology.
- Developing infrastructure that is resilient, sustainable, reliable and of quality in order to support economic development and wellbeing of humans(“Sustainable Development Goals,” n.d.).

Moreover, there are numerous interlinkages between the SDGs and therefore they should not be approached separately. Also, they support each other's implementation. For instance, achieving the second and third target by using ICT and increasing internet access this can assist in tackling SDG 7 and 13 in an integrated manner (Were SDG 7 encourages affordable and clean energy and SDG 13 is related to increasing actions to mitigate climate change and adapting to its impact). This can contribute in a significant manner to sustainability and decarbonization in industrial and economic development.

According to the United Nations Industrial Development Organization (UNIDO) report (Accelerating clean energy through Industry 4.0, 2017) Industry 4.0 zero can help foster and achieve SDGs 9,7 and 13. Moreover, developing countries now have access to energy technologies that current industrialized countries did not have at their similar stage of growth. This means that by adopting Industry 4.0 developing countries can leapfrog and the opportunities provided by Industry 4.0 technologies can provide them with sustainable industrialization and new business models. In addition, ICT and advanced technologies in general can help solve some of the biggest issues such as access to energy and connectivity while preventing carbon lock-ins (Nagasawa et al., 2017).

Chapter 3 Methodology

3.1 Research Question and Hypothesis

Industry 4.0 and its technologies have gained significant and increasing interest over the last few years all over the world. It has been adopted in some industries and have become an important area of discussion and research in organizations and universities. Despite this great interest, the topic of Industry 4.0 is relatively new and there is a lack of literature about it, both from a theoretical and empirical point of view. Furthermore, it is important to showcase successful practical applications of Industry 4.0 technologies in different countries and to assess their impact on various beneficial effects. However, very few studies have investigated Industry 4.0 technologies in developing and least developed countries. Beside that the current literature lacks information regarding Industry 4.0 in Sudan. Particularly, there is no literature investigating the barriers to Industry 4.0 technologies in Sudan and their ranking. Also, the literature lacks an explanation of how the utilization of Industry 4.0 technologies can support Sudan and countries like it in meeting the United Nation sustainability goals and which technologies are more important for Sudan. Moreover, understanding the potential opportunities and challenges that Industry 4.0 may pose on countries with different levels of industrialization is necessary to outline the limits, barriers and risks it may pose to inclusive and sustainable industrial development(Nagasawa et al., 2017).

In light of the aforementioned gaps with regards to Industry 4.0 technologies in literature the aim of this dissertation is to answer the following research questions:

What are the barriers faced in Sudan in implementing Industry 4.0 technologies?

How can Industry 4.0 technologies support Sudan in achieving the UN Sustainable Development Goal 9 by 2030?

Which of Industry 4.0 technologies are currently more important for Sudan?

Therefore, from these research questions three main objectives will be deployed. The first objective is to develop a clear ranking of the most important barriers that are preventing Sudan from adopting Industry 4.0 technologies. Then to explain how the adopted and to be adopted Industry 4.0 technologies can support Sudan in achieving the United Nations sustainable development goal 9, however focusing only on the part of building resilient infrastructure, inclusive and sustainable industrialization and fostering innovation. Finally, the research will aim at identifying the most critical technologies for Sudan considering its current infrastructures and industries operating in it.

3.2 Research Philosophy and Approach

When embarking on a research the aim of the researcher is to develop knowledge in a specific field. The researcher should adopt a research philosophy that contains assumptions regarding the researchers view of the world, that will underpin their research strategy and the methods to choose.

Saunders et al. (2007) developed a research onion Figure 3.1, consisting of six layers to describe the stages that a researcher must follow when formulating an effective methodology. In the first layer it is important to define the research philosophy and it should be noted that there in no one good philosophy. In fact, each one is better at doing different things and selecting one depends on the researcher's question. The four research philosophies positivism, realism, interpretivism and pragmatism are described in terms of ontology, epistemology, axiology and data collection techniques. Were ontology regards the nature of reality and raises questions about how the researcher assume the world operate and their commitment to their point of view. Were as epistemology regards what constitutes acceptable knowledge for the researcher and axiology is related to the role played by the researcher's value in all stages of the research and is important for the research to be credible(Saunders, Lewis, & Thornhill, 2009).

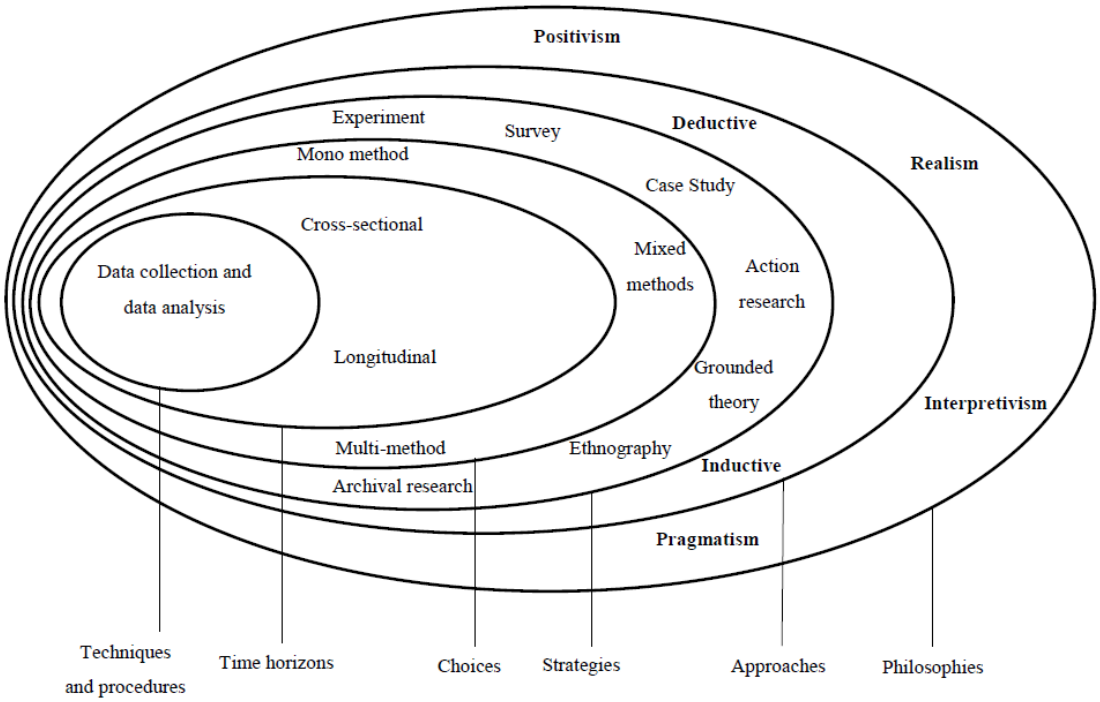

Figure 3.1.1 Research Onion

Source: © Mark Saunders, Philip Lewis and Adrian Thornhill 2008

As can be seen from Table 3.1, briefly reporting the philosophies classification, the philosophy that reflects the approach used is positivism: it was aimed to work with an observable social reality in order to generate conclusions that can be generalized, just like physical and natural scientists do (Remenyi et al., 1998). Also, it is believed that only phenomena that can be observed will lead to the production of credible data and, before collecting these data, existing theory was used to develop hypotheses. The objective is to test these hypotheses and contribute to the further development of a theory.

Table 3.1 Research Philosophies in Management Research (Saunders et al., 2009)

	Positivism	**Realism**	**Interpretivism**	**Pragmatism**
Ontology	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
Epistemology	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations. Alternatively, phenomena create sensations which are open to misinterpretation. Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

After defining the research philosophy, the next inner layer of the onion which is the research approach can be explored. The research approach involves determining whether to use a deductive approach in which the researcher develops theory and hypothesis and subsequently design a strategy to test the hypothesis or an inductive approach were data is collected and theory is develop by analysing the data. Based on this it was decided to follow a deductive approach. In addition, positivism usually matches a deductive approach. To conduct a deductive research Robson (2002) suggested five sequential stages for a deductive research:

1) Deducting a hypothesis (a testable proposition about the relationship between two or more concepts or variables) from theory;
2) Conveying the hypothesis in operational terms by showing how the concepts or variables are to be measure. This proposes a relationship between two specific concepts or variables;
3) Using one or more strategy to test the operational hypothesis;
4) Examining the outcome of the inquiry. This will either confirm the theory or indicate the need for its modification;
5) Modifying the theory if necessary, according to the findings.

In case of a revised theory it necessary to go back to the first step and repeat the steps in order to verify the theory. Moreover, the deductive approach poses certain characteristics that make it preferable than an inductive approach for the research. It allows to search and explain the casual relationships between variables and then to apply controls to test the hypothesis by collecting quantitative or qualitative data. Also, the research will use a highly structured methodology to support replication which ensures reliability. Deduction requires the researcher to be independent of what is being observed in order to pursue principles of scientific rigour. Furthermore, concepts should be operationalised in a manner that allows facts to measured quantitatively and the principle of reductionism should be followed, that is reducing the problem to the simplest element in order to be better understood. The last characteristic of deduction is generalisation, that requires selecting a sample that is of sufficient size and representative of the population in order to generalise statistically.

On the other hand, an inductive approach is concerned with building theory rather than confirming or testing it and thereby theory will follow data rather than the opposite as with deduction. For this reason, it is not possible to talk about a hypothesis testing phase and the approach does not allow for approval or disapproval of theories. Thus, theory verification is limited and requires further research to be integrated. Unlike deduction, it allows to understand the way in which people interpret the social world(Saunders et al., 2009). The table below summarizes the main differences between the deductive and inductive approaches:

Table 3.2 Deductive Vs Inductive Research Approach (Saunders et al., 2009)

Deduction emphasises	**Induction emphasises**
• scientific principles • moving from theory to data • the need to explain causal relationships between variables • the collection of quantitative data • the application of controls to ensur validity of data • the operationalisation of concepts to ensure clarity of definition • a highly structured approach • researcher independence of what is being researched • the necessity to select samples of sufficient size in order to generalis conclusions	• gaining an understanding of the meanings humans attach to events • a close understanding of the research context • the collection of qualitative data • a more flexible structure to permit changes of research emphasis as the research progresses • a realisation that the researcher is part of the research process • less concern with the need to generalise

According to the above-mentioned characteristics of the two approaches, it is clear that the deductive approach better suits the research objectives, since the research doesn't aim at developing new theories but rather to test theories.

3.2 Research Strategy

After the research philosophy and approach were selected the next three layers of the onion were determined that is; research strategies, research choice and time horizons. These represent the research design and involved converting the research question into a research project. According to Saunders (2002) the most common strategies that are employed are; experiment, survey, case study, action research, grounded theory, ethnography and archival research. A brief description will be provided below for each strategy in order to justify the choice for this research.

An experiment is used to understand whether a change in one or more independent variable(s) produces a change in a dependent variable. They tend to be used in exploratory and explanatory research to answer 'how' and 'why' questions. In a classic experiment two groups are formed and are similar in all aspects related to the research. In the first group (experimental group) a planned intervention or manipulation is made, while in the second group (control group) no intervention is made. The dependent variable is then measured before and after the manipulation of the independent variable for both groups. Then the dependent variable is compared in the two cases and any differences is attributed to the intervention. Experiments are usually performed in laboratories allowing greater control over aspects of the research process such as the sample selection and the context. However, laboratory settings are unlikely to be related to the real world of organisations. Therefore, the ability to generalise their findings to all organisations is lower than a field-based experiment.

A survey is usually associated with the deductive approach and is frequently used to answer who, what, where, how much and how many questions. Thus, it is normally used for exploratory and descriptive research and are popular as they allow to collect large amounts of information from a sizeable population in an economical manner. Standardised data is usually obtained using a questionnaire administered to a sample and it allows easy comparison. Furthermore, surveys allow collection and analysis of quantitative data using statistics. The data collected can be used to explain the relationship between variables and to produce a model of the relationship. Moreover, they provide more control over the research process and it allows to generate findings that are representative of the whole population at a lower cost than collecting data for the whole population. Two data collection techniques are used for surveys, which are structured observations that is often associated with organizations and methods research and interviews(Saunders et al., 2009).

A case study is defined as "a strategy for doing research that involves empirical investigation of a particular contemporary phenomenon within its real life context, using multiple sources of evidence"(Robson, 2002). Within a case study the boundaries between the phenomenon being studied and the context in which it is being studied are not clear. Case studies are of interest if the researcher wants to gain a rich understanding of the context of the research and the process being followed. They also allow to answer why, what, how questions and is used in explanatory and exploratory research. Moreover, various data collection techniques such as interviews, questionnaires, observation and documentary analysis are used. Thus, it likely that multiple sources of data are triangulated i.e. several data collection techniques are used in a single study to ensure that the data is telling you what you think it is telling(Saunders et al., 2009). Yin (2003) identifies four case study strategies that are differentiated based on two discrete dimensions; single vs multiple case and holistic vs embedded case. A single case provides an opportunity to observe and analyse a phenomenon that few have considered before and allows to define the actual case which is usually an organization in which the researcher works. While multiple cases are used to determine if the findings of the first case occur in the other cases and as a result the need to generalise from the findings. Furthermore, if the research is concerned with an organization as a whole then the organization is treated as a holistic case study. While if within an organization a number of logical sub-units are examined, then the case study is called an embedded case study(Yin, 1994). Although using a case study may sometimes give an unscientific feel it could be argued that it can be a very worthwhile way of exploring existing theory. Moreover, a well-constructed case study can enable challenging of existing theory and provides a source of new research questions.

Action research is distinguished from other researches strategies as it attempts to focus on action, in particular promoting change within an organisation and is therefore useful for how questions. Moreover, the researcher would be involved in the action for change and to apply the knowledge gained somewhere else. Its strength is that it focuses on change, recognizes that time needs to be devoted to diagnosing, planning, taking action, evaluating and the involvement of employees in the whole process. Employees engagement is necessary as they are more likely to implement a change they helped in creating. Thus, an action research combines both data gathering and facilitation of change.

Grounded theory should be though of as a combination of induction and deduction and is beneficial to predict and explain behaviour with emphasis being upon developing and building theory. Data collection begins without the formation of an initial theoretical framework and then theory is developed from data generated by a series of observations. This data leads to the development of predictions that are then tested in further observations that may or may not confirm the predictions. The main drawback of grounded theory is that it could lead to the over-simplification or to completely ignore the existing literature.

Ethnography is rooted to the inductive approach and stems from the field of anthropology. Its aim is to describe and explain the social world the research subjects inhabit in a manner that they would describe and explain it. Ethnography takes place over an extended time period as the researcher must immerse himself in the social world being researched. Since the researcher will constantly be developing new toughs regarding what is explored, the research process should be flexible and responsive to change. Moreover, ethnography is naturalistic so a phenomenon will be researched in the context that it occurs in and wont employee data collection techniques that oversimplify complexities of daily life(Saunders et al., 2009).

The last strategy is the archival research which uses administrative records and recent and historical documents as the main source of data (Bryman, 1989). It allows research questions that focus upon the past and changes over time to be answered whether they are explanatory, exploratory or descriptive. The ability to answer these questions will be constrained by the nature of the administrative records and documents as they may not contain the information needed to answer the research question(s) or meet the researcher’s objectives. Moreover, data can be missing or access to data may be refused or the data may be censored for confidentiality(Saunders et al., 2009).

Based on the above characteristics of strategies and the research objective, time and knowledge constrains it was decided that using a multiple and embedded case study is the best strategy to answer the research question. Moreover, as stated by Yin, case studies allow for studying a certain phenomenon in a real-life context, especially when the boundaries between a phenomenon and its context are not clearly evident. Also, as it will allow to cover contextual conditions that are relevant to the phenomenon under study. Finally, since the focus of the study is to answer "how" and "what" questions(Yin, 1994).

3.3 Description of the Case

The selected case is Sudan's largest and most diverse food company, in particular it produces, process, manufacture, sell and serve dairy, pasta, flour and grains, agricultural products and is the producer of international carbonated soft drinks company in Sudan. Moreover, it has always been labeled as a pioneer in Sudan's food industry and a demonstration of its commitment to excellence is its investment in high-tech and modern technology and facilities. Also, it has some of the most advanced plants in the region as international quality standards are hallmarks of its approach. The company also provides consultancy services, support and training to locals to support them improving quality and yield. Finally, the company is committed to the contribution to sustainable development and improvement of the community wellbeing through discretionary and responsible business practices. As it has won several Corporate Social Responsibility awards and is committed to the UN Sustainable Development Goals of 2030.

3.4 Research Choice and Time Horizon

Research choice refers to the choice of quantitative or/and qualitative data. In the first case, data are collected through a questionnaire and analysed through graph or statistics, while in the second case, data are collected through interviews and analysed through categorization (Saunders et al., 2009). It is possible to distinguish between a mono method technique in which a single data technique and the corresponding analysis procedures are used, or a multiple method were more than one data collection technique and analysis procedures are used to answer the research question. As for a multiple method it is possible to distinguish between multi-method quantitative studies and multi-method qualitative studies. Also, mixed methods were both qualitative and quantitative data collection techniques and relative analysis procedures are used. Mixed methods may be further subdivided into mixed method research or mixed model research. Were the former uses quantitative and qualitative data collection and analysis techniques and procedures at the same time or one after the other. While the lateral combines quantitative and qualitative data collection techniques, analysis procedures and approaches at other phases of the research such as research question generation.

As for the research time horizon it is possible to distinguish between cross-sectional and longitudinal studies. In cross-sectional studies a particular phenomenon is studied at a precise time and often they employ the survey strategy with interviews conducted over a short period of time. Due to their timeliness, they are the most used approach in academic dissertations which are necessarily time constrained. They may be used to describe the effect of a phenomenon or how different variables relate to each other. While in longitudinal studies people and events are observed over a long-time period, allowing the researcher to control the variables being studied. Their main strength is the capability to study change and development over time(Saunders et al., 2009).

Considering the previous choices about the approach and the strategy, as well as the constraints especially in terms of time, it was decided to follow a mixed method, cross-sectional study.

3.5 Data Collection Techniques and Coding

Data collection was based on structured interviews that consisted of a set of identical questions and were interviewer-administered. One of the most important aspects to consider carefully was the type of respondents to address and the number of responses that were needed in order to produce reliable and generalizable results. It was initially aimed at interviewing ten managers from the leadership team, executive and senior managers, who were selected as they were the most knowledgeable and experienced regarding the research topic and the various companies. Also, the managers were of different nationalities which allows to eliminate bias towards the country. Three of the interviewees, were too busy and apologized for turning down the interview so overall 7 interviews were conducted. Moreover, all respondents had an engineering background and their knowledgeability of technical aspects were ensured. The interviews were conducted in English at the managers offices and consisted of a set of open-ended questions that were sent to the interviewees a week ahead, along with a briefing of the research topic (refer to appendix 6.2 and 6.3). Moreover, a set of probing questions and examples for each question were set ahead based on literature to probe the interviewees if necessary. Audio recordings and notes were taken during the interview in order to control bias and produce reliable data analysis.

Interviewer Number	Position	Interview Duration (min)
1	Head of Agriculture	41
2	Head of Manufacturing	86
3	Group Head of IT	55
4	Head of Strategy	98
5	Dairy Plant Manager	44
6	Spray Dryer Plant Manager	34
7	Head of Human Resources	30

Figure 3.2 Case company interviewees

The evidence from the case companies was then integrated around the research objective, as suggested by Yin (1994), and coded into themes. Codifying is the process of arranging things in a systematic order, to make something part of a system or classification, to categorize. It involves applying and reapplying codes to qualitative data – it is a process that allows data to be "segregated, grouped, regrouped and relinked in order to consolidate meaning and explanation" (Grbich, 2007, p. 21). Bernard (2011) succinctly states that analysis is "the search for patterns in data and for ideas that help explain why those patterns are there in the first place". Therefore, coding is a method that enables the organization and grouping of similarly coded data into categories or "families" because they share some characteristic – the beginning of a pattern. Since the number or respondents was not large the data was analysed manually, without utilising any specific software package according to recommendations by Salanda. The manual coding process was guided by the research objective, with special attention to the following aspects: peoples' responsibilities and motivations, specific means and strategies being used, as well as understanding of processes. According to Saldana the researcher must believe in the necessity and payoff of coding for selected qualitative studies and should stay open during initial data collection and review before determining which coding method(s) will be most appropriate and most likely to yield a substantive analysis(Saldana, 2013).

Coding into themes was a four-step process; raw data, first cycle coding, second cycle coding, categorization. Were, first a transcript was written for each interview and read 3 times before starting the coding to get familiar with information and simplify the choice of the coding methods. During coding and recoding it was strived to ensure that the codes and categories became more refined, conceptual and abstract as proposed by Salanda. Below are the First cycle coding methods that were used, moreover it was decided to code all of the interviews data;

- Simultaneous coding involves the application of two or more codes to a single qualitative datum or overlapping occurrence of two or more codes applied to a sequential unit of qualitative data. It is useful to use it when the data content suggests various meanings, which necessitate and justify more than one code since complex social interaction does not occur in neat isolated units. Moreover, simultaneous coding should be used if a segment is descriptively and inferentially meaningful.
- Descriptive coding, also called topic coding summarize in a short phrase or a word usually a noun, the topic of a passage. It is necessary to ensure that they identify what is being talked about or written (topic) not the substance of the message (content). Descriptive coding is suitable for most qualitative studies, particularly for beginners in data coding, ethnographies and studies with a wide variety of data forms e.g. interview transcripts and field note. The primary goal of description is to allow the reader to see and hear what the interviewer saw and heard in general. In addition, descriptive codes from data collected across time can be charted to assess longitudinal participant change.
- Process coding or action coding use gerunds or words that end with "ing" to signify action in data. It includes coding of simple observable activity e.g. playing or reading and general conceptual actions such as negotiating or surviving. Processes also includes actions intertwined with time such as things that change, emerge or occur at a certain sequence or are strategically implemented through time. Process coding is suitable for almost all qualitative studies especially those that search for ongoing action, emotion or

interaction in response to situations or issues, in order to achieve a goal or handle a problem. For grounded theory, process coding occurs concurrently with initial, focused and axial coding and finding the consequences of the action or interaction is part of the process. Also, it is not necessary to use process coding as the sole coding approach to data.

- Value coding involves the application of codes to data that reflects the participant's values, belief and attitudes that represents his/her perspective of the worldview. Each construct has its own meaning, however value coding as a term subsumes them all. Were value being the importance attributed to a thing or idea by another person or yourself. The greater the person's meaning, the greater the personal payoff and therefore the personal value. While attitude is the way people think and feel regarding things or ideas. They are a part of "a relatively enduring system of evaluative, affective reactions based upon reflecting the evaluative concepts or beliefs, which have been learned" (Shaw & Wright, 1967). Finally, beliefs are part of a system which includes values and attitudes, in addition people's personal opinions, experience, morals, knowledge and other interpretive perceptions of the social world. "Beliefs are embedded in the values attached to them" (Wolcott, 1999) and may be considered "rules for action" (Stern & Porr, 2011). Moreover, value coding may be used for almost all qualitative studies particularly those exploring intrapersonal and interpersonal experiences of the participant, cultural values, identity and actions in a case study, oral history, critical ethnography and appreciative inquiry(Saldana, 2013).

Then a second cycle of coding was performed, were the first cycle codes and their coded data were recognized and reconfigured to develop a smaller and refined list of broader categories, themes, concepts and assertions. In the second cycle coding, focused coding was used which involved searching for the most frequent/significant codes in order to develop salient categories in the data corpus. Moreover, focused coding was selected as it allows to compare the newly constructed codes with other participants data to assess comparability and transferability. According the Charmaz (2006) doing so "Your study fits the empirical world when you have constructed codes and developed them into categories that crystallize participants' experience".

Moreover, a questionnaire (refer to appendix 64) was made in order to confirm the validity, rank and rate the severity of each of the identified barriers to the spread of industry 4.0 in Sudan. As stated by Sunders et al (2009) questionnaires are particularly useful in explanatory and confirmatory research, as they allow to examine and explain relationships between variables highlighting cause-effect relationships. Self-administered questionnaires were used and were administer electronically using the internet. The questionnaires and the instructions for filling them were emailed to each of the interviewees along with eight other managers. However only from the additional respondents 4 replied, Table 3.3.

Table 3.3 Additional respondents for the questionnaires

Interviewer Number	Position
1	Strategic Planning Manager
2	Senior Business Analyst
3	Project Manager
4	Supply Chain Manager

Were the respondents were asked to confirm each barrier by assigning a value between 1-10 where 1 indicates low agreement with the statement and 10 strongly agreeing with the statement. Then to rank the barriers from 1-18 in terms of preventing the spread of the technologies 1 being the highest and 18 the lowest.

Furthermore, since qualitative research as such are often criticised for their tendency to become biased and lacking scientific rigor. Integrity of the research process was ensured through the following aspects:

- Sampling: Interviewees were selected based on their ability to provide reliable contribution.
- Reliability of analysis: Interviews transcripts, coding, data collected directly rather than depending on secondary data.
- Validation: Interviewees testimonies combined with the questionnaires.

Chapter 4 Data and Analysis

4.1 From transcript to categories

From the transcript a first cycle coding was conducted using simultaneous, descriptive process and value coding as explained in section 3.5. Similar codes were applied to the text whenever possible, otherwise new codes were generated. In total 129 codes were initially generated from the first cycle coding. Then the irrelevant codes were removed, and a second cycle coding was carried out in which some statements were quoted directly, and some were summarized or paraphrased with the interviewee’s own words. In order to enhance the coding process as some statements were big. Then the most significant codes were used to create categories. Table 4.1 below shows a sample coding that was done according to the process explained above.

Table 4.1 Sample coding

Raw data	**1st Cycle Coding**	**2nd Cycle Coding**
“We already started working on big data analytics with companies that provide customers with points for using certain items, so this gives you an idea of which products are purchased and by which consumers from an external data source. Also, we implemented a mobile application for house wives that allows to determine their purchasing habits, every time they purchase something whether it is our product or a competitor one, they specify it in the app and receive points in return and then they can receive free products. The idea is to also understand on what products and quantities the consumers budget is spent.”	Data analytics - Consumer behavior	Big data benefits

From the second cycle coding some statements were quoted directly, but most were summarized or paraphrased in the researchers own words. A total of 55 codes were generated, form which 8 sub categories and two main categories were developed as seen in Table 4.2.

Table 4.2 Categories and sub categories developed from 2nd cycle coding

Barriers	**Advantages**
• Economic • Political (Sanctions) • Technology • Cultural • Human	• IoT benefits • Big Data Analytics benefits • Industry 4.0 benefits

4.2 Barriers to Industry 4.0

To understand what barriers are faced by Sudan in implementing Industry 4.0 technologies, the managers were asked directly to speak about the various barriers faced by the company when trying to implement any of Industry 4.0 technologies to obtain an understanding of the internal barriers. Also, to talk about the barriers faced in implementing them in Sudan being a least developed country. This is important in order to enable generalization of the results and to eliminate bias from the case study. Also, some barriers were mentioned by the managers alone before being asked. The 7 respondents made 31 statements regarding the barriers which are distributed in the 5 categories of barrier as shown in Figure 4.2 below. From the five categories of barriers Economic barriers were the most stated 36% followed by Political 21%. For confidentiality reasons in case of quoted text it will not be possible to specify the names or positions of the respondents.

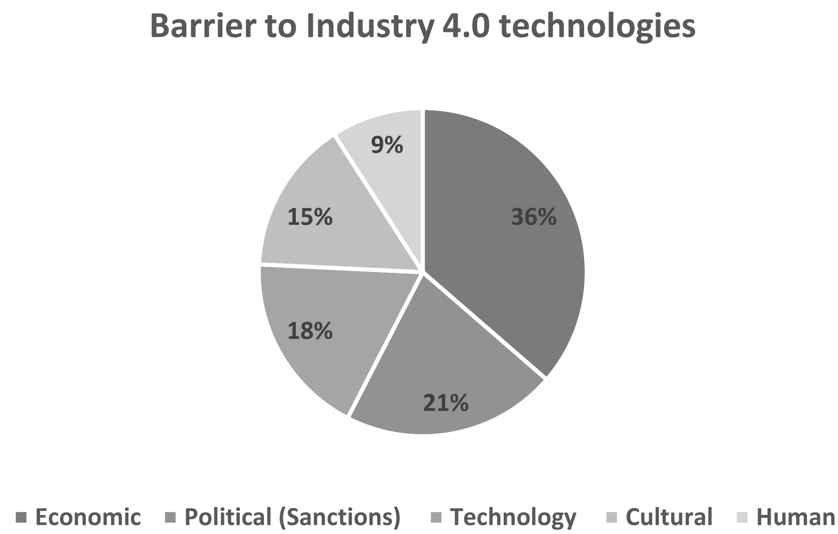

Figure 4.1 Categories of barrier to Industry 4.0 technologies

4.2.1 Economic barriers

Analyzing the coded data 4 out of the 7 respondents have mentioned Economic barriers as one of the barriers faced by Sudan in implementing industry 4.0 technologies. Some managers mentioned the same Economic barriers, however overall five different types of Economic barrier were mentioned. Competition between companies is perceived as an encourager to change, however Sudan is viewed as a country that lacks competition and entrance of technologies that shake up the industry by displacing established technology. Also, the country's currency and unavailability of CAPEX are seen as an issue as the government does not provide loans to support those who want to invest in bringing new technologies. Some added that the country can provide loans however it is the government corruption that is preventing that.

"*Economy is protected there is not much competition or entrance of disruptive technology."*

"The currency and CAPEX are an issue in other countries if you are bringing new technology the government gives you loans but it is not happening."

"The problem is not the lack of loans but rather it is the government that is corrupted."

Also, the low income of the population discourages companies from investing in these technologies due to its high cost and it increases the cost for the final consumers whom cannot afford a lot. For example one of the respondent believes that using 3D printing in food industry as in pasta is a method that allows to differentiate products from competitors, adding value and building market share but it would be of no interest to the country for the next five years as consumers of low income resemble a big portion of the population and they can care about the shape of the food. Other related statements to low income are specified below

"Since a big percentage of the population has a low income it is not possible to use technologies such as 3D printing to differentiate products as it will increase products cost. So, given the nature of our economy low cost provision is the crucial thing."

"Many farmers can't afford using RFID for cows due to their low income."

"For manufacturing and food management RFID can be used for batch management however there is a high initial cost which prevented us from implementing it as you need all batches to be RFID and this increases the cost which is not good in the current Financial situation. However at least we will implement them in pallets to know how many have been entered or exited from the warehouse"

"In Sudan our job is to get food to people that is good to them and they can afford, and the consumers cannot afford much, and labor is cheap and as a result of those 2 we will always be behind Western countries."

In addition, the availability low cost labor is viewed as another barrier since sometimes no justification is seen in replacing labor with Industry 4.0 technologies.

"Robots whether in industry or agriculture tend to come in economies where labor is expensive but that is not the case in Sudan so the return you will get in replacing people with a robot is not existent but in the US & UK the model is different as labor is expensive so using robots in agriculture and manufacturing is ok.

4.2.2 Political barriers

Of the 7 interviewees 5 have mentioned Political barriers as one of the barriers for countries like Sudan in implementing industry 4.0 technologies. The 5 interviewees mentioned sanctions imposed on the country as the only political barrier, however its limitation was described in different ways. For instance, one manager mentioned that even though the company has purchased several farm software for farm data analytics they faced problems in using it due to the sanctions as parts of them were from the US.

"As for analytics any of these readings must go through a farm software, however this is an issue for us due to the sanctions imposed on Sudan every time we pay for a new system and when we have to do a renewal or upgrade we cannot as the provider says that it requires inclusion of parts which they can't provide due to sanctions."

Another problem mentioned regarding sanctions is that it discourages foreign companies from operating in the sanctioned country and the local companies cannot purchase from some foreign companies abroad even if they want to. Therefore, it is not possible to operate Cloud technology in Sudan and companies may not be able to purchase any technology they want.

"*As for Cloud computing it is not implemented because of the sanctions imposed on Sudan. Usually cloud is owned by big companies such as HP, Microsoft but they do not operate in Sudan because from here it is not possible to proceed with payments as you cannot do a bank transaction."*

"The current sanctions are actually a barrier to technology and one of the big problems to link to other countries is that it is not possible to do financial transactions, and this is what discourages companies like Apple from opening in Sudan."

"Regarding cloud computing its automatic the more you consume the more you are charged. So, the problem becomes is how can the companies owning the cloud charge you? Unless you are able to pay from outside Sudan."

"The modern trend is to have sales data from the market on a cloud but because of the sanctions most of these technologies are very nascent in Sudan when we wanted to get the ERP it was not possible to have it on a cloud we had to put it on a server, so that was a bottle neck but by 2030 hopefully this will not be an issue."

"There are external pressures on the company lifting certain import bans will enables us to move forward."

Furthermore, when asked to specify the challenges faced in implementation of Industry 4.0 technologies in Sudan being a least developed country one manager stated that with sanctions no knowledge is transferred to the country.

"With sanctions and foreign currency also we have to start developing indigenous capabilities because with sanctions there in no knowledge transferred to us if you want to know something you have to work hard to get it."

4.2.3 Technology barriers

As for technology barriers 3 out of the 7 respondents have mentioned them and overall 5 statements were made regarding technologies being a potential barrier themselves. For instance, one manager mentioned that drones are being used to test soil by taking readings from the soil with respect to the soil composition (chemical properties), however they still must compare its results with lab tests. For example, if a reading of magnesium is obtained by the drone and lab test that says that it not equal to the amount obtained then a correction factor is applied between the actual and the drone to get more reliable data from the drone. Then, consequently either materials are added to the soil or it is kept as it is, but you can't remove material, however you must dilute it somehow. Also, the same manager mentioned that in terms of agriculture they are using IoT based probes that contains moisture sensors connected to the internet and provides readings of the soil moisture to manage irrigation. However, they cannot rely a 100% on them as irrigation is critical for crops.

"Currently we are using probes, however we do not fully rely on them. They are actually helping but we do not take its readings for granted we perform our manual readings as it is very dangerous because one of the things that really affects the quality of the crops is the irrigation."

According to another manager a barrier to Industry 4.0 technologies is the available technologies in the company. For instance, the current ERP in the company called SAGE does not support quality batch management to track and withdraw from the market batches with quality issues. Moreover, as stated before due to sanctions they are not able to install SAP which is capable of doing so.

" RFID tracking in terms of quality batch management is important because if you can have a problem in a batch you can quickly track and withdraw it from the market in particular for dairy as the shelf life is very short by the time you get a complaint it might all be expired or consumed so it is almost impossible. Also, ERP is driving this however our current system Sage doesn't have this capability, but the new SAP does and its required to do it however"

Moreover, it is not possible wo work with cloud in Sudan as the internet is not reliable and connecting from another country is expensive.

"We considered to connect to a cloud in Dubai to have a special line similar to fibre cables for 20 MB and the company had to pay 30,000-40,000 dollars/month, in order to have connectivity to SAP in Dubai."

4.2.4 Cultural barriers

Regarding culture 4 out of 7 managers consider it a barrier to Industry 4.0 technologies and overall 4 statements were made about the cultural barriers. First, since Sudan is a developing country the population consists of a greater number of young people unlike in developing countries so there is more access to labor which causes the cost of labor to be low, so there is no need for autonomous robots now.

"In addition, in developed countries there is more of an ageing population but in developing countries we have more young people so at least for the next 50 years that is not an issue. We will only use robots when there is precise manufacturing like making a chip that needs high precision".

Another problem in Sudan is that data regarding locals on the internet is not enough which limits the use of big data analytics when analysing marketing campaigns and searching for local suppliers through the internet whom are not familiar with providing digital information.

"As for big data we have the BI department, to get big data reports you have to combine your day to day reports with those available on the internet (social media etc…). Regarding Sudan the

data available on the internet is not that much outside Sudan a campaign can be based on a hashtag however it is not the case in Sudan."

"Since we are dealing with the local suppliers we lack the ability of using big data analytics for suppliers selection as there is no supplier data base to give you the information about them for example the quality of gum relates to the soil characteristics and the area of growth but local suppliers are not familiar with providing digital information."

Finally, one manager stated that change is not a common a thing for people in Sudan and therefore people resist change. Therefore, not many people introduce new technologies and resistance will be found when new technologies are being introduced.

"One of the barriers is the psychological resistance to change and here it is a little bit bold within Sudan because change is not very common."

4.2.5 Human barriers

As for humans 3 out of the 7 managers stated that humans can be barriers to the introduction or usage of industry 4.0 technologies. According to two of the respondent's people need time to adapt to new technologies because even if the technology is available and they are not convinced and believe in its capability, then they will not consider using it. So, this slows down the process of using these technologies.

"When it comes to technology you must move step by step gradually and not just jump over stages because even if the technology is there the most important thing is that the people must be convinced in using it and this takes them time and they must see it to believe it."

"I think the available RFIDs are currently not fully utilized. The systems are available, but it is all about applying them"

When one of the interviewees was asked whether he thinks that Industry 4.0 technologies can support integration one of the managers mentioned that it does however the only barrier is human's way of thinking and their fear of losing their control because of technologies.

"I think these technologies support integration the only limitation is the people's mindset for them to understand the potential, a lot of old school people have a fear of technology they think that they will lose their control."

4.3 Rating of barriers for Industry 4.0 technologies

Of the 15 questionnaires that were sent to the managers by e-mail only 11 questionnaires were completed and 4 obtained no reply. Table 4.3 contains the list of barriers and Tables 4.4 demonstrates the rating results obtained when the respondents were asked to confirm each of the barriers that were obtained from coding the interviews. The respondents assigned a value between 1-10 to each barrier with 1 indicating low agreement with the statement and 10 indicating strong agreement with the statement. Then the mean rating for each of the barriers was calculated along with its standard deviation in order to understand the strength of each barrier on its own in preventing the spread of Industry 4.0 technologies.

Here an assumption was made were all barriers with mean values from 10-6.6 are be consider as a strong barrier, those with values from 6.7-3.4 are considered moderate barrier and from 3.3-0 are considered low barriers. As can be seen from Figure 4.2 barriers number; 15, 3, 16, 14, 5, 4, 18 and 10 have mean values between 9.0 – 7.0 therefore they were considered that the respondents strongly agree with these barriers. While barriers number; 2, 8, 1, 13, 9, 7, 17, 12 and 11 have mean values between 6.4 – 6.3, so they were considered as moderate barriers. The strongly agreed with barriers are those related to government actions are the most agreed with followed by those regarding sanctions imposed on the country and then low the income of suppliers and low labour costs.

Table 4.3 Barriers to Industry 4.0 Technologies

Barrier #	Barrier description
1	Not enough data in social media to take advantage of big data analytics.
2	Economy is protected as there is not much competition or entrance of disruptive technology that causes companies to upgrade their technologies.
3	Lack of government loans to support introduction of new technology.
4	It is very costly to operate cloud from another country.
5	Low income of local suppliers to invest in technology and a larger availability of young people compared to developed countries causing the cost of labour to be low thus discouraging the introduction of technologies e.g. robots.
6	Some technologies can't be used as they increase the costs for consumers whom are mostly low-income people (E.g. using RFID for batch management or 3D printing for pasta).
7	Psychological resistance to change particularly that is not very common.
8	Humans take time to adapt to technology, so it takes time even for the available technology to be utilized.
9	A lot of old school people have a fear of technology as they think that they will lose their control and they don't see the potential of the technology.
10	No local suppliers' database so it is not possible to use big data analytics in procurement and lack of information sharing with the public regarding technologies.
11	IoT probes are not reliable for soil moisture testing.
12	Drones are not reliable for soil testing.
13	Farm analytics software can't be renewed or upgraded because of sanctions.
14	Sanctions act as a barrier to accesses foreign resources whether they are technologies or knowledge, particularly financial transactions are an issue. Thus, it's not possible to use for e.g. Cloud or to have SAP.
15	Access to foreign currency is becoming more difficult with the governmental policies.
16	Problems to link to other countries as it is not possible to do financial transactions, and this is what discourages foreign companies from opening in Sudan.
17	Available technology in the company can act as a barrier e.g. the current ERP system (Sage) does not support batch management to track and retrieve items from the market.
18	Internet services in Sudan are not reliable so it's not possible to use cloud and the internet providers don't receive penalties for poor services.

Table 4.4 Rating of the barriers for Industry 4.0 technologies

Barrier#	Respondent Number											Mean	STD
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th		
1	2	8	9	5	3	5	8	6	8	5	8	6.1	2.2
2	2	1	10	4	2	8	10	8	8	7	10	6.4	3.3
3	10	10	10	8	6	10	7	8	10	10	9	8.9	1.4
4	8	5	10	7	8	8	8	5	7	10	6	7.5	1.6
5	9	9	10	9	4	10	7	8	8	5	6	7.7	1.9
6	9	10	5	8	4	8	9	9	9	6	8	7.7	1.8
7	5	1	6	7	2	5	4	8	6	6	3	4.8	2
8	8	1	8	7	7	5	5	8	7	8	4	6.2	2.1
9	2	2	10	8	3	5	4	9	8	4	3	5.3	2.8
10	8	3	10	6	2	9	9	8	9	9	4	7	2.7
11	5	1	5	4	4	2	2	5	5	6	3	3.8	1.5
12	5	1	5	6	5	3	2	6	5	8	5	4.6	1.9
13	5	10	5	8	1	1	4	7	9	10	7	6.1	3.1
14	5	10	10	8	5	6	10	8	9	10	10	8.3	2
15	5	10	10	10	8	10	7	10	9	10	10	9	1.6
16	8	10	8	10	9	6	6	9	9	10	10	8.6	1.4
17	5	1	7	7	2	2	8	6	6	7	2	4.8	2.4
18	9	8	10	5	3	9	7	10	10	3	8	7.5	2.5

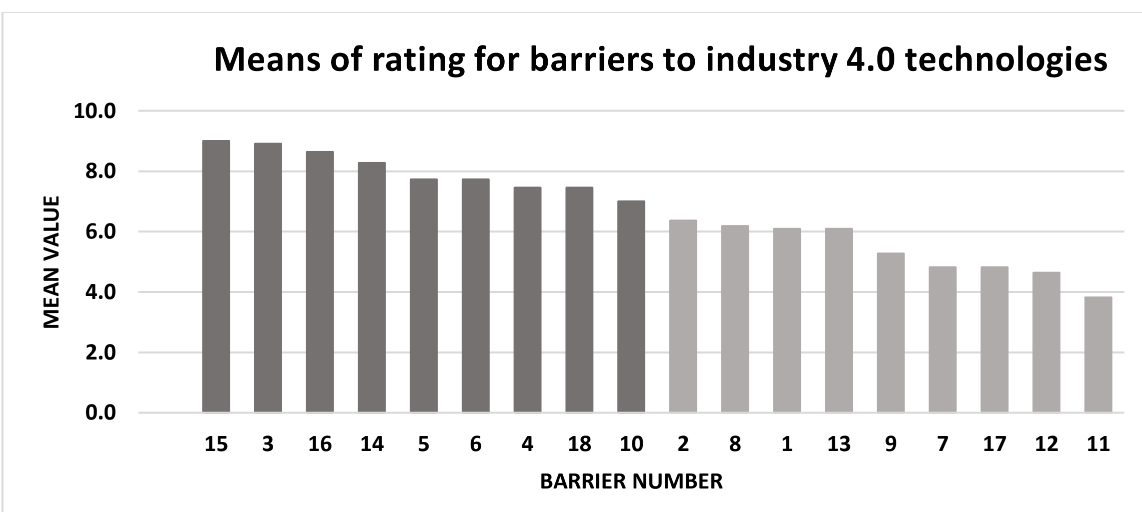

Figure 4.2 Means of rating for barriers to industry 4.0 technologies

4.4 Ranking of barriers for Industry 4.0 technologies

Table 4.5 contains the respondents ranking for each of the barriers from 1-18 in terms of preventing the spread of Industry 4.0 technologies, with 1 being the highest and 18 the lowest.

Table 4.5 Raking of the barriers for Industry 4.0 technologies

Barrier#	Respondent Number											Average ranking
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	
1	11	12	16	15	13	18	6	18	11	10	12	6.09
2	4	2	17	8	2	5	1	9	10	6	6	12.64
3	5	11	4	5	12	3	15	8	2	5	5	12.18
4	10	8	5	9	7	2	5	15	18	14	13	9.36
5	6	7	3	6	6	1	10	10	9	11	4	12.36
6	7	10	6	4	5	4	3	6	8	12	7	12.45
7	13	14	11	11	11	13	13	7	17	13	11	6.82
8	14	13	10	12	16	15	12	11	12	8	16	6.36
9	16	15	9	13	10	14	14	2	13	15	15	6.64
10	12	4	13	10	9	7	4	12	7	7	9	10.45
11	17	17	15	17	17	17	17	17	16	18	17	2.18
12	18	18	14	18	18	16	18	16	15	9	18	2.82
13	9	16	7	14	14	8	16	13	6	2	10	8.55
14	2	1	1	2	1	6	2	3	5	1	1	16.73
15	1	3	2	1	8	12	9	1	4	3	2	14.82
16	3	5	8	3	4	11	11	5	3	4	3	13.55
17	15	9	12	16	15	10	7	14	14	17	14	6
18	8	6	18	7	3	9	8	4	1	16	8	11

The average ranking for each barrier was calculated in order to determine which barriers are considered the most important by the respondents. The calculation of the average ranking was based on the equation below, where;

$$Average\ Ranking = \frac{x_1 w_1 + x_2 w_2 + x_3 w_3 + x_n w_n}{Total\ response\ count}$$

w = weight of ranked position

x = response count for answer choice

Were weights were applied in reverse i.e. the respondent's most preferred choice which they ranked as the 1st was given the largest weight of 18, and their least preferred choice which they ranked as 18th was given a weight of 1. Figure 4.4 shows the final ranking of the barriers to industry 4.0 technologies in Sudan. With the greatest barrier being sanctions as a barrier to foreign resources which was ranked as the 1st by 45% of the respondents and obtained an average ranking of 16.73. The 2nd most important barrier is difficulties in accessing to foreign currency due to government policies with a score of 14.82. While the 3rd is not being able to link to other countries as it is not possible to do financial transactions, is also related to sanctions imposed on the country. In fact, the top six barriers are all related to the economic and political category as mentioned in section 4.2.1.

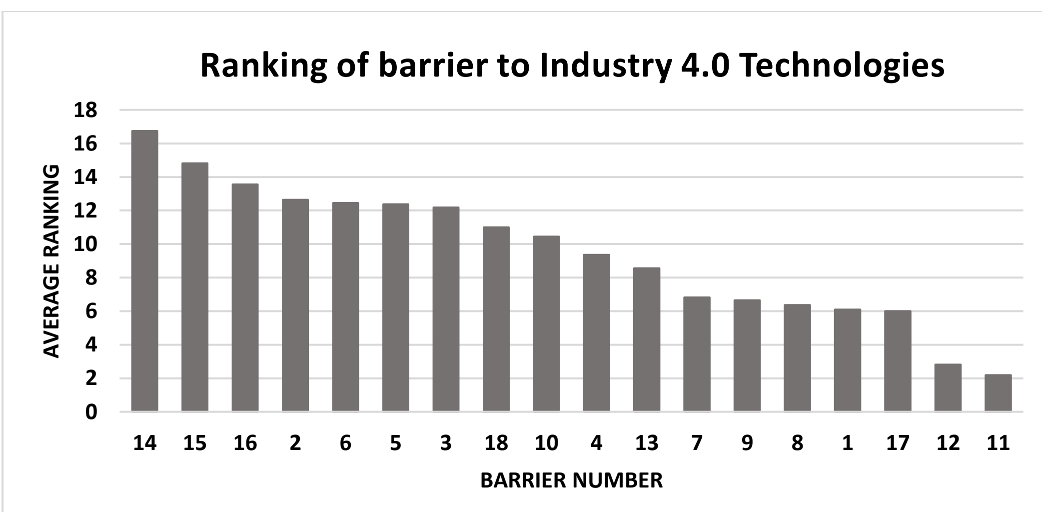

Figure 4.3 Ranking of barrier to Industry 4.0 Technologies in Sudan

4.5 Industry 4.0 technologies benefits

In order to understand how industry 4.0 technologies can support Sudan in achieving the United Nation Goal 9, in particular to promote inclusive and sustainable industrialization and foster innovation. Also, which of the technologies are currently more important for Sudan. It is necessary to first understand the opportunities that Industry 4.0 technologies can provide to it. These were determined by asking the interviewees direct question regarding these inquiries. Also, to determine which technologies are more applicable to the food and other industries and which KPIs are improved through application of these technologies. The 7 respondents made 30 statements regarding the benefits which are distributed in 3 categories as shown in Figure 4.4 below. From the 3 categories the most mentioned technology in terms of benefits is IoT 67%, followed by Big Data Analytics 27%.

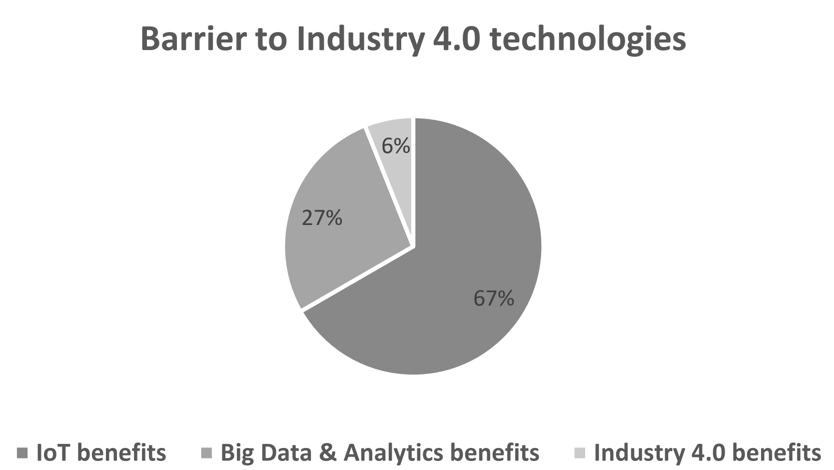

Figure 4.4 Categories of Industry 4.0 technologies whose benefits were mentioned by interviewees

4.5.1 IoT Benefits

Analyzing the coded data 4 out of the 7 respondents have mentioned IoT as one of the technologies the company is currently benefiting from. Overall the benefits of IoT was mentioned in 22 statements during the interviews. Four managers mentioned the use of IoT moisture sensors that connect to the internet to provide real time analysis of soil water content and allow management of irrigation. Also, a machine called SoilQuest that utilizes IoT and machine learning is used to create a soil map based on the soil properties to determine the areas in the farm to place the moisture sensors.

"With regards to the water now we have moisture sensors in the farm and are connected to the internet so you can get the readings from a computer as regard to what is the moisture content is to manage the irrigation. So as not to over irrigate or cause the crop to starve."

"The area that where mostly focused on is Agriculture where we can utilize new technologies to help the company to reduce costs"

Also, according to one of the managers IoT moisture sensors are used in greenhouses to provide irrigation according to their readings and they can be accessed online by the company who implemented them from outside Sudan to perform adjustments on them.

"There are a lot of IoT sensors that provide you with 2 things 1st the moisture and based on it you either increase the water irrigation or decrease it through valves and the same is used in the greenhouses of the managing director but to a smaller scale, even the company who implemented them is able to access them online to perform adjustment. The same thing can be applied to a large scale reducing both water and electricity consumption where the motors are only activated when needed. This also reduces the need for the engineers to move around the field."

Moreover, the company employs RFIDs in several areas for instance it is used in in fleet control for tiers since every now and then the tiers must be changed. Also, in order to track pallets and is combined with the ERP to see the ageing of material inside the warehouse in order to use them before their expiry date.

"Suppose you are getting raw material, so you know the production and expiry date and you know with the RFID the location of the pallet so then you have the ageing report which says this is the expiry date of these products, so the plan is to use them before the expiry."

One manger mentioned that the company is moving towards meat production and exportation and their plan is to employee RFID for livestock tracking as governments all around the world are moving towards enforcing it as part of their regulations.

"We are getting into meat production and as part of investing in such a business since we want to export value added agricultural commodities to industrialized markets and this is required as part of their quality management regulations to be able to track commodities back to source so we will need to conform to that. So clearly as far as animal products are concerned which could be meat, fish and poultry all of that we will need to use RFID trackers to allow the end users to trace them back."

Moreover, RFID tags are used for cows in the case study dairy farm to keep records of all their details and this assists the company to increase operational capabilities and reduce costs.

"All cows information is recorded using RFID; how much they eat, milk produced, medications etc."

Furthermore, all the manufacturing plants are connected to networks and it is possible for the producer of the factory to access the factory online to determine the faults and fix it or provide the company with guidance regarding the problems they see so they can fix it quickly reducing the time to repair. Also, it allows monitoring of performance and yield of the plants in real time.

"*Also, a good thing is that the producer of the factory can also access the factory online to determine the faults and fix it online from Europe sometimes. They can also inform us what problems they see and direct us in the right direction reducing time to fix an issue."*

"We are using advanced technology all the controls have in built systems to communicate among themselves so suppose I put 1 ton of wheat in the mills then I take X tons of flour, X tons of semolina etc… all the data from all the scales can talk to each other and calculate online and give you the yield that is part of the supply of Buller's the yield and performance of the plant is continuously monitored because the inherent nature of the scales can communicate with each other."

"As for factories each one has its system connected to a network and appears on computers however it is not connected to the maintenance system."

Also, the company is currently using drones in farms that takes readings from the soil to ensure certain elements are available in the soil to grow plants efficiently. The drones provide readings and then it is computed against the required and standard values. However, if there are variations then the drone has to calibrated to give the actual figures as its performance is affected by distance, speed and a lot of things.

"We have drones that fly and take readings from the soil with respect to the soil composition as certain elements must be available in the soil to grow plant efficiently"

4.5.2 Big data and analytics benefits

Of the 7 interviewees 4 have mentioned the benefits obtained from big data and its analytics benefits and overall 9 statements have been made regarding this. The company is building analytics with companies that provide customers with points for using certain items, so this allows them to have an idea of which products are purchased and by which consumers from an external data source. Also, the company is employing big data and analytics were consumers use a mobile app to specify what products they bought even if it is from a competitor and they are giving points every time they use the app and get free products in return. Then the data is analyzed to understand on what products and quantities the consumers budget is spent

"Yes, we are and that is why I separated between customer and consumer. When we go to consumer we are starting to invest in a much larger social media presence than we had we want to wrap up and get as many consumers involved in our social media spaces and the reason for that is a twofold; to grow and to collect data of their opinions and their views and of course sell them our products."

Moreover, the salesforce is equipped with hand held terminals (HTT) that allows data regarding sales to be either stored in an internal memory where it can be transferred then manually to the data base system or if there is good connectivity the data can be transferred directly online. The HTTs become a distribution demand when the salesmen are in the field collecting the demand it will be collected in the company's ERP.

"Big data from HTTs helps in better planning of production, raw materials, distribution based on orders and all sorts of planning."

Another application of big data and IoT regards the fleet were GPS is used to track the sales points and a historical map is analyzed allowing them to know in which areas the sales are high or low and how much time is required to reach a place and the fuel consumption, which in turn allows to optimize routes.

4.5.3 Other benefits of Industry 4.0 technologies

In addition to the above benefits all the seven managers stated that Industry 4.0 technologies can contribute to gender equality. Also, that even though the application of these technologies may replace labor work it will allow them to be trained improving their experience and lives.

"If you look at the factory we have gone from manual to automation and we worked on improving efficiencies by doing that we improved the experience of employees. So, we put a lot of effort on internal and external training to make the people more adaptable and improve their lives as well. We have lost a lot of staff to abroad as they have skills to market, but it also improved us as well and it is a good thing to see yourself training staff and giving them abilities, they didn't have before."

Chapter 5 Discussion and Conclusion

By reviewing the literature and evaluating the various themes, issues and frameworks in it, three gaps were identified in the literature from which the research questions were developed. Then based on that it was decided to perform a case study in Sudan, whose results were demonstrated in the previous chapter. Chapter 5 will provide a deep interpretation to these results and sum them up to provide clear answers to the research questions. Then a conclusion will be provided and the last subsection will be devoted to the illustration of the main limitations of the dissertation, as well as of some recommendations regarding how the research can be further improved in the future.

5.1 Discussion of results and answers to the research questions

Industry 4.0 technologies have a great potential to enhance humans lives and will provide benefits to each industry. As the world is moving towards more digitalization there will be more application and spread of these technologies. Although in some developing countries like India and China governments have set plans such as developing smart cities that will allow the diffusion of Industry 4.0 technologies. Currently in Sudan there is no governmental initiative regarding this, rather initiators are companies who realize and appreciate the potential of advanced technologies.

The analysis of the rankings obtained determines that the sanctions imposed on Sudan is the most significant barrier to Industry 4.0. Two sanctions were imposed on Sudan in 1997 and 2006 by the United States considering it as a state that sponsors terrorism and due conflicts in Darfur located in Western Sudan. The sanctions included embargoes on arms and trade and prohibiting financial services and transaction, which included import and export of goods, services and technology. However, the cost of complying with these sanctions caused US and global financial institutions to stop dealing with Sudanese banks. Particularly any violations or attempt of violation would result in criminal fines up to $1 million USD and custody that can go up to 20 years. Thus, access to foreign resources whether they are technology or knowledge and thus Industry 4.0 technologies became very difficult. This is because even if a part of the product is made in the US then it is not possible to purchase the product and purchasing products that are completely produced in other countries is also an issue due the difficulties in bank transfers. So, it is possible to say that the barrier ranked as the 3rd is linked to the sanctions barrier since foreign companies are discouraged from operating in Sudan due to their inability of carrying financial transactions to return their profits abroad. Another consequence of this is that all technologies that were purchased from outside Sudan faced difficulties whenever maintenance or updates were required specially if they contained any parts coming from the US. Thus, even though the utilization of cloud computing can enable IT services that don't exist and provide access to resources without the need of capital investment. It can not be utilized because of the sanctions.

The 2nd most critical barrier is the difficulty in accessing foreign currency and this is mainly due to two reasons the first is related to the independence of South Sudan which contained most of the oil reserves that contributed significantly to hard currency coming from exports. The second reason is government policies which led to shortages in foreign currency and is attributed by many as a result of corruption and lack of good governance. This in turn contributes significantly to difficulties in acquiring Industry 4.0 technologies as such technologies are imported. Moreover, Sudan's economy lacks competition and entrance of disruptive technologies which causes companies not to upgrade their technologies except in industries that are driven by technological advancement and some companies that realize the value of high-tech and modern technology. This is also related to the low income of many consumers which discourages companies in investing in some of Industry 4.0 technologies due to its high initial cost which intern leads to an increase in the price of the products and the consumers cannot afford a lot. Moreover, investing in Industry 4.0 technologies requires a lot of money whom its cost can be recovered by industrialized countries in the West as they can set higher prices that the growing middle class can afford but is not the case in countries like Sudan. Thus, it is not of current interest to invest in technologies such as 3D printing for producing pasta of various shapes, although it reduces waste and augmented reality for consumers in retail shops to view nutritious value or recipes involving various food products. In addition, as with other developing countries many of the local suppliers are of low income who cannot afford the capital required to procure Industry 4.0 technologies and the government does not provides loans to support introduction of new technologies although they can provide great value. So, although autonomous robots can provide great value is agriculture, they will not be utilized within the next 5 years in Sudan because of their high cost and the low labour cost.

Other barrier includes the unreliability of internet services in Sudan for long term use which is essential for proper operation of IoT technologies and cloud. Since the internet connection might work fine for one day but not the other and Internet Service Providers (ISP) do not sign any service level agreements (SLAs) with their customers, so there are no penalties for poor internet services. Another contributor to the unreliability of internet is the frequent power outages that can last several hours due to deficiencies in electric supply compared to the increasing demand, thus without backup UPS or generators these technologies will not be very effective. Also, the high cost of operating cloud from other countries does not make it appealing for companies though they demonstrate interest in it. Furthermore, local suppliers are not very familiar with providing digital information on the internet, so it is currently not possible for companies to utilize big data analytics for local procuring. At the same time this is worsened by the lack of interaction between the companies and the public to share information regarding technologies e.g. through exhibitions. Another area were big data analytics faces issues is that the social media data available on the internet is not that much as compared to outside Sudan were a marketing campaign can be based on a hashtag however it is not the case currently in Sudan.

As with all countries whether developing or developed humans also pose barriers to Industry 4.0 technologies. Resistance to change is due to several reasons the most important is related to the fact that change is not very common in Sudan, which makes tasks much of habits that are difficult to change. Beside that change causes fear to manifest in some people who believe that they will lose control by the introduction of these technologies and are not able to see the potential and value that will be provided from their employment. Also, by nature people need time to adapt and accept new technologies because even if the technology is available and they are not convinced about its potential and added value, then they will not consider using it. So, this in turn slows down the process of using these technologies. Finally, as with all modern technologies the lack of compatibility of previous technologies with those of Industry 4.0 for e.g.

as for the case study the company's ERP was not able to support batch management to enable tracking and retrieving items for the market. As for drones and probes the focus was only on their usage for soil testing for agricultural purposes however the limitation is due to the environment and the nature of soil as discussed previously.

The two other questions of this dissertation; *How Industry 4.0 technologies can support Sudan in developing inclusive and sustainable industrialization and fostering innovation? Which technologies are currently more important for Sudan?* will be answered together in the remaining part of this subsection based on findings.

Agriculture is considered as one of the most important economic sectors in Sudan, as it contributes to almost one-third of the country's national gross domestic product. Approximately two-third of Sudan's population live off agriculture, with almost 80% of the local labour force gaining jobs through the agricultural sector. Beside that it provides most of the inputs for transformative industries including edible oils, fibres and sugar. In agriculture there are three main important things soil, water irrigation and weather forecasting and they can greatly affect the quality of crops and this is where IoTs and big data can provide great benefits. First it would be beneficial to understand that soil is characterized by non-homogeneity i.e. two adjacent square meters may not be similar in terms of chemical and physical properties. The physical property is related to its texture which is composed of clay that are tiny particles and sand which is bigger particles. The physical properties are important because when you apply water there must be infiltration for the water to go down if the soil is solid the water will not go down. So, the texture must be in such a way that it allows infiltration for roots growth. Otherwise what happens is that if you have different layers and a layer is solid this will cause the water to be trapped in that layer leading to rotting. The trick is to monitor both the chemical and physical properties as you cannot only improve the soil by adding chemicals and each physical texture has a different chemical composition because if you have a high infiltration then the chemicals will move downwards quickly and vice versa if you have a low infiltration rate. So, you want to differentiate you want to use high infiltration with the harmful components to move down rapidly so as not affect the crops and the useful to remain or move slowly.

Using moisture sensors that connect to the internet will allow real time surface analysis of the soil moisture content at 10, 20, 30 cm etc... This is important to manage the irrigation of crops, in order to not starve or over irrigate crops as this will affect its quality and it helps in preventing water wastage. Also, it will reduce the time needed to check crops water level as they provide real time data and reduces fuel consumption in case of large-scale farming as the workers now do not have to move long distances around the farms to do those checks manually. Which, in turn assists in reducing operating costs and carbon dioxide emission. The moisture sensors are placed inside pivots which are circular areas in the farm. However, since the soil is characterized by non-homogeneity as explained above it is important first to determine the soil properties in the pivots since more than one probe may be needed in the same pivot area. This is also done through a machine called SoilQuest that employees both IoT and machine learning to take reading of the soil texture properties in order to determine which areas share the same properties and displays them in a soil map. It then provides different irrigation rates to the different areas of the soil according to the moisture readings that are previously determined in that area. Furthermore, another application of IoT in agriculture involves the use of drones for testing soil and crops. Were drones are currently utilized in farms to takes readings from the soil with respect to the soil composition i.e. the chemicals in it, as certain elements must be available in the soil to grow plants efficiently and this assist in optimizing the harvesting yield.

As with most developing countries the dairy industry has an important role in both urban and rural areas in Sudan and is considered as a consistent non-seasonal source of income with immediate cash returns. In 2015 Sudan was ranked as the 7th worldwide in terms of cattle population. RFID tags are used in the case dairy farms to keep records of all the cow details such as feeding, injection and how much milk is produced. So, if the production of a cow is decreasing then the cause is determined, and the corrective action is taken. Also, it reduces the time and possibility of mistakes when recording cow's data. All these allow the company to increase operational capabilities and reduce costs. It is also believed that RFID can be similarly employed for livestock identification as governments around the world are moving toward the enforcement of RFID for livestock identification. This provides authorities with an electronic means for tracing the livestock lifecycle particularly when there is a disease outbreak in a region.

Furthermore, manufacturing plants are connected to networks allowing the performance and yield to be monitored in real time, moreover big data from machines and sensors are analyzed to improve performance and make informed decisions. IoTs in manufacturing plants can help production managers in managing and tracing production processes and to define weak points and further strengthen their competitive advantage. Also, it is possible for the manufacturers of some plants to access the factory online thanks to IoT technology from Europe to determine the faults in machines and fix it or provide the company with guidance regarding the problems they see so they can fix it quickly reducing the time to repair. Moreover, as part of warehouse management RFIDs can be utilized for pallets tracking and can be combined with the company's ERP to track the ageing of material inside warehouses so as to ensure their utilization before their expiry date and thereby allowing for waste control. This is particularly important for companies that have many warehouses and various raw materials as the tracking of raw materials becomes more difficult. As well as the case of high cost materials as the losses will be high.

Moreover, when it comes to Fleet management in case many tucks are utilized by a company as with the group of companies in the case study which has 100's of trucks in order to distribute their products all over the country. Using RFIDs in fleet control for tiers helps in keeping track of the tier's conditions, enabling better management of tires throughout their lifecycle and replacing them whenever necessary. Which helps in preventing trucks stoppages because of tier related issues and particularly when travelling to ruler areas where streets along the way are quite empty and can be dangerous. Also, for sales teams as they must visit many shops hand held terminals serves as a distribution demand allowing them to collect sales data that can be stored internally or transferred directly to the company's ERP. For example if the company has 30 SKUs all its data will be included in the HTTs, consumer code, money limit and how much credit is available for the costumer so if their limit is 100,000 SDG and the salesman already provided him 50,000 SDG worth products so he can then have more products of worth 50,000 SDG but if he exceeds that he will have to pay the due money before receiving more products. This is based on big data and it helps in better planning of production, raw materials, distribution based on orders and all sort of planning. This advantage is that this is online, so it is not based on the gut feeling of the salesman or supply chain and it gets in a lot of things like just in time, more precise planning, more precise utilization of resources and can be shared with suppliers to assist them in planning their production and inventories. Thus, IoTs and big data and analytics can enable both horizontal and vertical integration making companies, functions and cross-company more cohesive.

Also, salesman use GPS for tracking the sales points and they have a historical map, using big data analytics allows them to know in which areas the sales are high or low and how much time is required to reach a place and the fuel consumption. Furthermore, by utilizing big data analytics, companies can analyze data from the social media, market and companies research organizations in order to understand the behavior of consumers, price elasticity and the amount and type of consumption in different parts of the country and their requirements which allows the companies to develop new and innovative products. This is where Sudan's consumer landscape does not necessarily have to differ from the way it needs to be managed it in developed countries in America and Europe.

Speaking of other social benefits, despite that the application of Industry 4.0 may replace several labor jobs companies in Sudan are willing continue to implement internal or external trainings to these employees to help them in improving their efficiencies and adapting to new requirements of the world. This will provide them with better experience and improve their lives and is particularly true for companies driven by corporate social responsibility. Also, new jobs will be created particularly in the areas of big data analytics, product development and technical jobs to maintain and operate these technologies. Also, it is believed that Industry 4.0 technologies can contribute to gender equality as well with the digitalization of industries.

Finally, it is believed that for Sudan in addition to the IoTs and big data and analytics and considering the economic barriers currently only cloud is needed as it will enable IT services that are currently not available in Sudan, reduce investment costs supporting particularly entrepreneurs and small companies. While augmented reality, simulation and autonomous robots are considered as technologies of great potential and value adding but cannot be employed now, however in the long term they will be considered due to the current barriers faced by the country particularly those related to economic category mentioned before.

5.2 Conclusion

Industry 4.0 technologies are impacting all industries and as the world is moving towards more digitization there will be more application and spread of these technologies all around the globe. Their benefits will not only be limited to manufacturing, but their application will be seen more in consumers products as they have a great potential in enhancing humans, daily lives. Both developed and developing countries have already developed plans to support the diffusion of these technologies including Germany, India and China. However even within developing countries the benefits and challenges that Industry 4.0 technologies may pose on each country are different.

This research demonstrated that digitization and the implementation of Industry 4.0 technologies have already begun in Sudan, although not as extensive as in developed countries. The case study presented applications of IoT technologies and big data and analytics in the food industry which demonstrated their capability in supporting inclusive and sustainable industrialization. They enable companies to optimize their production, enhance their operating efficiency, reduce cost, materials waste and their impact on the environment and supporting the development of their community. Also, they enable companies to develop innovate products that meet the needs of the changing pace of human's lives. Thus, these technologies can provide significant benefits towards meeting the UN SDG 9. Moreover, the study demonstrated that currently for Sudan IoTs, big data and cloud are the most important technologies. However, cloud is prevented by sanctions while autonomous systems, augmented reality and simulation are considered of value but not essential currently due to the economic barriers that are faced by the country.

Moreover, Sudan currently faces some significant challenges that affect the adoption of Industry 4.0 technologies, the most critical are related to political and economic reasons. Political barriers include sanctions and is the greatest barrier as they place embargo on financial transaction and technologies importation, that also act as a barrier that prevent foreign technology companies from operating in Sudan. Also, currently the country is faced with difficulties in obtaining foreign currency, lack of government support and poor governance. Which have left Sudan blocked out and not able to immerse into the substantial benefits offered by Industry 4.0 technologies. Other barriers include lack of competition and entrance of disruptive technologies which is supported by the low income of many local producers who rely on basics since they cannot afford the capital required for these technologies in several sectors. Thus, providing big manufacturing companies with no motive to upgrade their technologies since they are already ahead of local producers. Also, for large scale manufacturers the low income of many consumers does not allow them to raise their prices a lot in order to recover costs thus it is not possible to employ some technologies e.g. 3Dpriniting for food production. Other barriers include poor internet services, high operating costs, insufficient information regarding these technologies, human's resistance to change and fear of technology and lack of compatibility of some of Industry 4.0 technologies with previous technologies.

5.2 Recommendations

Application of Industry 4.0 technologies can significantly boost Sudan's industries and enhance its infrastructure. However, to support its diffusion both the private and public sector must work on spreading information through exhibitions and cases that demonstrate its potential across the value chain. Also, on building capabilities by training and developing the workforce to meet the new skills and knowledge needed to operate these technologies. Moreover, there is a need for the government to work on improving Sudan's infrastructure, particularly the telecommunication and power stations infrastructures as there are shortages in these areas nowadays and they are essential for proper operation of these technologies. Beside that good governance and government support in terms of financial loans is essential to enable small and medium size enterprises to acquire these technologies. Also, to release Sudan from sanctions that prohibit ease of access to these technologies. Beside that it is recommended to further explore the utilization of Industry 4.0 technologies in the mining industry which have become an important sector after the independence of South Sudan and is a flourishing sector that accounts for almost 4% of the country's GDP. Also, to identify the specific benefits they can provide in terms of improving the infrastructure in Sudan particularly for the water, electricity and telecommunication infrastructure.

Chapter 6 Appendix

6.1 United Nations Sustainable Development Goals for 2030

Figure 6.1United Nations Sustainable Development Goals for 2030(“UN Sustainable development goals 2030,” n.d.)

6.2 Interview Questions Breifing

Industry 4.0 refers to the 4th industrial revolution in which computers and automation will come together in an entirely new way, with robotics connected remotely to computer systems equipped with machine learning algorithms that can learn and control the robotics with very little input from human operators. Industry 4.0 introduces what has been called the “smart factory,” in which cyber-physical systems monitor the physical processes of the factory and make decentralized decisions. The physical systems become Internet of Things, communicating and cooperating both with each other and with humans in real time via the wireless web. Industry 4.0 includes the following technologies:

1) Additive manufacturing: Also referred to as 3D printing or Rapid prototyping Additive manufacturing uses data computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. As its name implies, additive manufacturing adds material to create an object.

2) Internet of things(IOT): The Internet of Things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded
with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data, creating opportunities for more direct integration of the physical world into computer-based systems. Key IoT technologies are Big Data management tools, predictive analytics, AI and machine learning, the cloud, and radio-frequency identification (RFID).
3) Big data analytics: Is the process of analyzing large volumes of data that traditional business systems would be unable to tackle. Data is gathered from a wide variety of sources, including social networks, videos, digital images, sensors, and sales transaction records. The aim in analyzing all this data is to uncover patterns and connections that might otherwise be invisible, and that might provide valuable insights about the users who created it.
4) Autonomous robots: These are intelligent machines capable of performing tasks in the world by themselves, without explicit human control
5) Augmented reality: is the integration of digital information with the user's environment in real time. Unlike virtual reality, which creates a totally artificial environment, augmented reality uses the existing environment and overlays new information on top of it.
6) Cloud Computing: Cloud computing refers to delivering on-demand computing services, originally storage, and now more recently processing power and apps, over the internet, with companies using this on a pay-as-you-go basis.

United Nations Sustainable Development Goals:

In 2015, leaders from 193 countries created and agreed to adopt the United Nations Sustainable Development Agenda for 2030, a shared blueprint for peace and welfare of the present and future people and planet. The agenda consists of 17 Sustainable Development Goals (SDGs) that necessitate a call for action and a global partnership by both developed and developing countries. Furthermore, the SDGs perceive that the ending of poverty and other deprivations must be accomplished parallelly with strategies aiming at improving health, education, reduce inequality and boost economic growth. Also, at the same time addressing climate changes and preserving oceans and forests. The SDGs have been localized since 2016 all over the world in organizations, institutions, governments, universities and individuals in all sectors and they work on implementing several goals at the same time.

For each SGD the UN specified the targets to achieve it and indicators. SDG 9 is related to industry, innovation and infrastructure. Its goal is to build resilient infrastructure, promote inclusive and sustainable industrialization and to foster innovation. Seven targets have been set for goal 9, which are:

- Boosting of scientific research and updating industrial technologies in all sectors and countries, especially developing ones by 2030. Also, to encourage sustainability and innovation.
- Encourage inclusive and sustainable industrialization by 2030 and increasing the share of employment in manufacturing and gross domestic product. While doubling share in developing countries.
- Increase accessibility to ICT and providing universal and affordable internet in least developed countries by 2020
- Increase access to financial services including affordable credit for small scale industries and other enterprises, particularly in developing countries. Also, to increase their inclusion in value chains and markets.
- Assist the development of local technology, research and innovation in developing countries.
- Upgrading of infrastructure and retrofit industry so they become sustainable by 2030. While improving resource use efficiency and increasing the adoption of clean and environmentally friendly technology.

6.2 Interview Questions

1) Which of these technologies are currently utilized in the company and across which areas of the value chain?
2) Which KPIs in particular those related to sustainability, have been significantly improved through application of those technologies?
3) Has there been significant/noticeable reduction in terms of environmental impact?

4) What is the impact on the employability of low skill labor and what opportunities would it provide them?
5) Do the implemented technologies or the implementation of other I4.0 technologies support the company in developing innovative methods/products along the value chain?
6) What are the barriers faced in implementing these technologies and what are your perceived benefits from implementing them and is there any actions from the company to support their implementation?
7) From your perspective which technologies/tools/software's/working practices are most applicable and effective to the food industry and other industries in Sudan?
8) What technologies in general contribute to gender equality and economic growth of companies?
9) How much does the implemented technologies support in achieving the UN goal to build resilient infrastructure, promote sustainable industrialization and foster innovation?
10) What are the challenges faced in implementation of those technologies in Sudan being a developing country?

6.4 Barriers Questionnaire

Barriers to Industry 4.0 Technologies

The table below contains a list of barriers to the spread of technologies in general and those related to Industry 4.0 in Sudan obtained from the interviews that where performed previously. Kindly confirm each barrier by assigning a value between 1-10 where 1 low agreement with the statement and 10 strongly agreeing with the statement. Then rank the barriers from 1-18 in terms of preventing the spread of technology 1 being the highest and 18 the lowest.

Table 6.1 Barriers to Industry 4.0 Technologies

Barrier	Rating	Ranking
1)Not enough data in social media to take advantage of big data analytics.		
2) Economy is protected as there is not much competition or entrance of disruptive technology that causes companies to upgrade their technologies.		
3) Lack of government loans to support introduction of new technology.		
4) It is very costly to operate cloud from another country.		
5) Low income of local suppliers to invest in technology and a larger availability of young people compared to developed countries causing the cost of labour to be low thus discouraging the introduction of technologies e.g. robots.		
6) Some technologies can't be used as they increase the costs for consumers whom are mostly low-income people (E.g. using RFID for batch management or 3D printing for pasta).		
7) Psychological resistance to change particularly that is not very common.		
8) Humans take time to adapt to technology, so it takes time even for the available technology to be utilized.		
9) A lot of old school people have a fear of technology as they think that they will lose their control and they don't see the potential of the technology.		
10) No local suppliers' database so it is not possible to use big data analytics in procurement and lack of information sharing with the public regarding technologies.		
11) IoT probes are not reliable for soil moisture testing.		
12) Drones are not reliable for soil testing.		
13) Farm analytics software can't be renewed or upgraded because of sanctions.		
14) Sanctions act as a barrier to accesses foreign resources whether they are technologies or knowledge, particularly financial transactions are an issue. Thus, it's not possible to use for e.g. Cloud or to have SAP.		
15) Access to foreign currency is becoming more difficult with the governmental policies.		
16) Problems to link to other countries as it is not possible to do financial transactions, and this is what discourages foreign companies from opening in Sudan.		
17) Available technology in the company can act as a barrier e.g. the current ERP system (Sage) does not support batch management to track and retrieve items from the market.		
18) Internet services in Sudan are not reliable so it's not possible to use cloud and the internet providers don't receive penalties for poor services.		

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