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TESI DI LAUREA

"CHALLENGES AND OPPORTUNITIES OF INDUSTRY 4.0: A STUDY CASE"

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Firma dello studente

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Acknowledgments

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Abstract

Many fears have arisen regarding the probable situations that employees may confront because of employment disruption and technological change caused by Industry 4.0. While the pace of technical breakthroughs is increasing, the adoption of Industry 4.0 must follow the appropriate path based on well-defined plans to safeguard employees' positions and create improved working conditions at the organization.

This thesis will discuss the potential challenges and opportunities of implementing Industry 4.0 for managers by conducting a case study in steel making industry. The goal of the research was to help managers understand how to successfully deploy Industry 4.0 technology in their companies. With the fastest rate of adoption, CPS and IoT technologies are considered the fundamental elements of Industry 4.0. Various sources are apprehensive about the impact of Industry 4.0 on businesses, particularly on employees as the potential disruption to skills and employment as a result of these technologies. On the other side, many people are positive about the implications of the latest technologies. They expected an increased efficiency and flexibility among employees. Skills may be disrupted because of Industry 4.0 technology applications. However, many businesses are not fully prepared for implementing Industry 4.0. To shed light on the effects of Industry 4.0, the present thesis analyses the case study of an Italian firm operating in the steelmaking and nonferrous metals industries. This firm integrated CPS and IoT technologies into their traditional Roller Guide machineries, thus transforming them into smart Roller Guides. The findings of this case study showed that the biggest hurdles that companies encounter were different for managers and employees: whereas the latter mostly struggled with technological issues, the former were more concerned with cultural issues. Employees observed a disruption in job characteristics as a result of the introduction of CPS and IoT. Nonetheless, the smart guide systems reduced injuries rate at manufacturers' facilities as the workers are not required anymore to enter the rolling mill room which implies an enhanced safety condition. In addition, an increased productivity has been witnessed among employees in the shopfloor due to the smart Roller Guides. On a management level, know-how expertise is currently altering leadership techniques. Aside from being more open to the shift of embracing Industry 4.0, training programs are required.

The keywords used while searching are “Industry 4.0”,” Employees”, “Automation”, “Smart Factories”,” Shopfloor”, ” SRG”,” IoT”, “CPS” “Employment”, and “Manufacturing”. These mentioned keywords are matched within others in the Google system specifically Google Scholar.

Introduction

Industry plays a key role in the nation's economy; this term refers to a group of businesses and manufacturing activities that produce goods or offer services. Industrialization, or the so-called first industrial revolutions has begun in the 18th century but at that time it was limited to Great Britain, it later spread throughout the world, where the use of a new basic material like iron and steel has begun. From the late 19th to early 20th centuries the second industrial revolution took place, this era was characterized by mass production of steel, chemicals and weapons (NIILER, 2019). This second industrial revolution was a tremendous transformation of people's lives according to Joshua-B (2018). The third industrial revolution began in the 1940's. This revolution era is defined as the digital revolution and it's characterized by the spread of automation and digitization through the use of electronics and computers, the invention of the Internet, and the discovery of nuclear energy (Ward, 2019).

Now and at the dawn of the 21st century the world is encountering the fourth industrial revolution that we refer to Industry 4.0. This Industrial Revolution stemmed from new and advanced technologies that can lead to a new era of developments at all levels, together with several disruptions for humans and industries. The new advanced technologies like Industrial Internet of Things (IIoT), Autonomous Robots, Cyber Physical Systems (CPS), and Artificial Intelligence (AI) are shaping the future of the Industries and its Employees. Workers like shopfloor employees are expected to handle a big share of these advancements and disruptions as they did in the past industrial revolutions which brings critical questions and concerns about the potential effect on this workforce.

Many concerns evolved about the possible scenarios that employees will face in terms of jobs disruption and technical transformation occurring as a result of Industry 4.0. While the pace of the technological advancements of Industry 4.0 is growing it is known that the implementation of the Smart Factories should follow the right path based on well-defined strategies in order to secure the position of Employees and implement better conditions at the at the company.

This thesis identifies and analyses the social and technical impact of Industry 4.0 on employees and examines the challenges and opportunities presented by adopting Industry 4.0 technologies for the companies' managers. The purpose of the research is to contribute to exploring and presenting a guidance for companies' managers in how to successfully embrace Industry 4.0 while maintaining the harmoniously human-machine interaction the smart factory.

The Thesis will be guided by following these research questions:

1. What are the challenges for implementing Industry 4.0 in manufacturing processes?
2. How will Industry 4.0 technologies impact the Employees?
3. How can managers successfully implement Industry 4.0 technologies at the shopfloor?

Through rigorous research and analysis, the following key findings were obtained:

- **Finding 1:** The main challenges for Industry 4.0 are technical and cultural in nature. The author found that the technological issues are related to the complexity of Industry 4.0, which many firms are currently not prepared to confront like data security and employee's preparations. The cultural problems stem from the mindset of many company executives, who are unwilling to take steps toward Industry 4.0 due to a lack of awareness and comprehension of Industry 4.0, as well as a fear of risk and uncertainty.
- **Finding 2:** The impact of Industry 4.0 technology on employees has been positive and negative. Companies may improve shopfloor safety by separating personnel from hostile environments in production facilities. Furthermore, employees will have greater control and understanding of the manufacturing process and will perform less physical activities. The negative impact is from the possibility of skill disruption that new technologies might generate, requiring more technical and digital abilities.
- **Finding 3:** To successfully implement Industry 4.0, managers must put first training and determine suitable application cases, validate vertical, horizontal, and end-to-end integration, and leverage internal capabilities, such as cultivating an innovative culture, investing in developing staff members, and encouraging cross-functional collaboration.

In the first chapter, the thesis discussed the phrase Industry 4.0 and presented the past Industrial revolutions and how they transformed the world of industries, which aids in uncovering the origins of the current industrial revolutions and the notion of a new industrial period. The author has identified the main technologies in Industry 4.0 and their role, as well as explored the major obstacles that Industry 4.0 may encounter. These technologies are the main drivers behind Industry 4.0 and can be described as Industry 4.0 components such as CPS and IoT. This Chapter explored Industry 4.0 elements and application by presenting RAMI4.0 that is a three-dimensional map that explains the key aspects and integration of Industry 4.0's physical and virtual members. This will help in analyzing the functionality of all components that may be integrated in implementing Industry 4.0.

Chapter 2 provides a definition of the shopfloor and displays the elements inside the production line. This chapter examined the potential concerns on the shopfloor as a result of Industry 4.0 adoption after analyzing two studies that investigate the potential implications of Industry 4.0 on workers. These problems include skill disruption, job relocation, and the absence of company preparedness for implementing Industry 4.0. What is interesting is that each research studied the consequences using a different technique and came up with different results.

In Chapter 3, the author conducted qualitative research by setting a case study following a semi-structured interview. The case study in this chapter was a supplier of smart Roller Guides to the steel-making industry. These roller guides are composed of up of two Industry 4.0 technologies: CPS and IoT. The study contributes to understanding the influence of these two technologies on employees and management. It looks at the challenges that managers encounter as well as the planning for establishing these technologies inside the adopter facility.

Chapter 4 offered recommendations for future developments. Which contribute to managers effectively implementing Industry 4.0. Following chapter 4, the author attained the overall goal of the research.

The keywords used while searching are “Industry 4.0”,” Employees”, “Automation”, “Smart Factories”,” Shopfloor”,” SRG”,” IoT”, “CPS” “Employment”, and “Manufacturing”. These mentioned keywords are matched within others in the Google system specifically Google Scholar.

Chapter 1

Introduction to Industry 4.0

The manner in which industries work and engage with technology has undergone a remarkable transition in the past few years. This industrial revolution is a watershed moment in the growth of manufacturing and industrial processes. It combines cutting-edge technology, networking, and data-driven decision-making to allow smart, agile, and long-term operations. Some scholars said that it is a result of the previous industrial revolution, particularly the Third Industrial Revolution, which shifted industries from mechanical to electronic processes.

The first chapter defines Industry 4.0 and provide an outline of previous industrial revolutions. It is well known that previous industrial revolutions had an impact on industrial operations, and a review of these revolutions will aid in having a better grasp of the industries' transformation for decades now. This chapter will examine the major technologies driving Industry 4.0 and their applications. These technologies are the primary drivers of Industry 4.0, and they have a variety of applications and concepts that aid in giving several benefits to businesses. These advantages are accompanied with challenges, which will be explored in order to identify the barriers of this industrial revolution.

Industry 4.0 is an emerging concept that has the potential to elevate businesses and shop floors to new level. This level is distinguished by automated procedures and digital activities inside the organization's divisions and facilities. It comprises of many efforts that can assist the organization in evolving and staff members in communicating more effectively. This chapter will help in better comprehending all of the topics raised in order to better observe Industry 4.0.

1. What is Industry 4.0?

Industry 4.0 is an overarching concept characterizing business applications of a wide range of technologies related to digitization, connectivity and automation, such as Internet of Things (IoT), cloud computing, big data and artificial intelligence, new generation robotics, blockchain, etc.. The German government identified Smart-Factory as one of the important related activities in the last decade as it set the concept Industry 4.0 in 2011 (Xu et al., Industry 4.0 and Industry 5.0—Inception, conception and perception, 2021; Vogel-Heuser et al., 2016).

This high paced revolution as a consequence of progressive digital transformation inside factories, the fusion of Internet tech and prospective technologies in the field of "intelligent" machines and products will cause a new fundamental criterion development in industrial production (Lasi et al., 2014). It is defined as a new level of organization and control over the entire value chain of the product life cycle, more aligned than ever to individual customer demands. Its paradigm facilitates the interconnection and connectivity of physical objects such as sensors, devices, and corporate assets with the Internet. A sequence of process steps likely to increase flexibility and reduce coordination complexity (Vaidya et al., 2018).

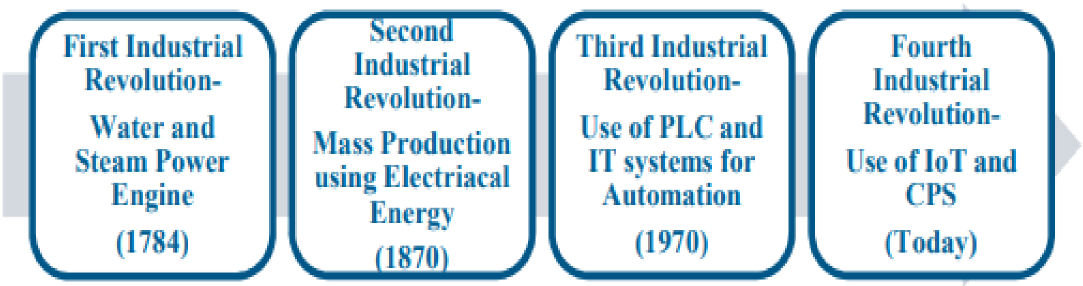

Figure 1. The Four Industrial Revolutions

Source: Vaidya et al., 2018

One side of Industry 4.0 is to convert the regular objects to self-aware ones, which mean self-learning, using different kinds of smart algorithms and artificial intelligence with the aim to improve the machine overall performance and implement more efficient interaction with the users. Figure 1 shows the first three industrial revolutions with their key uses and primary engines of each period, one can see that IoT and CPS are the main drivers for Industry 4.0 and the designing of smart factories. IoT, stands for the "Internet of Things," a network of physical "things" that are integrated with sensors, software, and other technologies with the purpose of communicating and sharing data with other devices and systems through the internet (Oracle, 2020). On the other hand, Cyber Physical Systems, or CPS, are comparable to IoT. Cyber-Physical Systems (CPS) combine computing, networking, and physical processes. Computers and networks are used to monitor and regulate the physical processes, and there exist feedback loops in which the physical processes influence the calculations and vice versa (Greer et al., 2019).

Many governments started to adopt Industry 4.0 with its wide range of concepts in the last decade, seeking a new industrial phase that leads to a higher flexibility in the production process. It started in Germany, the country of origin when the program "High-Tech Strategy

2014" has established, followed by The United States with a program called "Advanced Manufacturing Partnership", then France that implemented "La Nouvelle France Industrielle" and Italy "Industria 4.0" (Dalenogare et al., 2018; Xu et al., Industry 4.0 and Industry 5.0—Inception, conception and perception, 2021; DAS, 2011) . These adoptions are not limited to developed countries but also some of the developing countries have announced their own programs like Brazil under the name "Towards Industry 4.0" and China that established "Made in China 2025" with a strict vision for enhanced development (Xu et al., Industry 4.0 and Industry 5.0—Inception, conception and perception, 2021; Dalenogare et al., 2018).

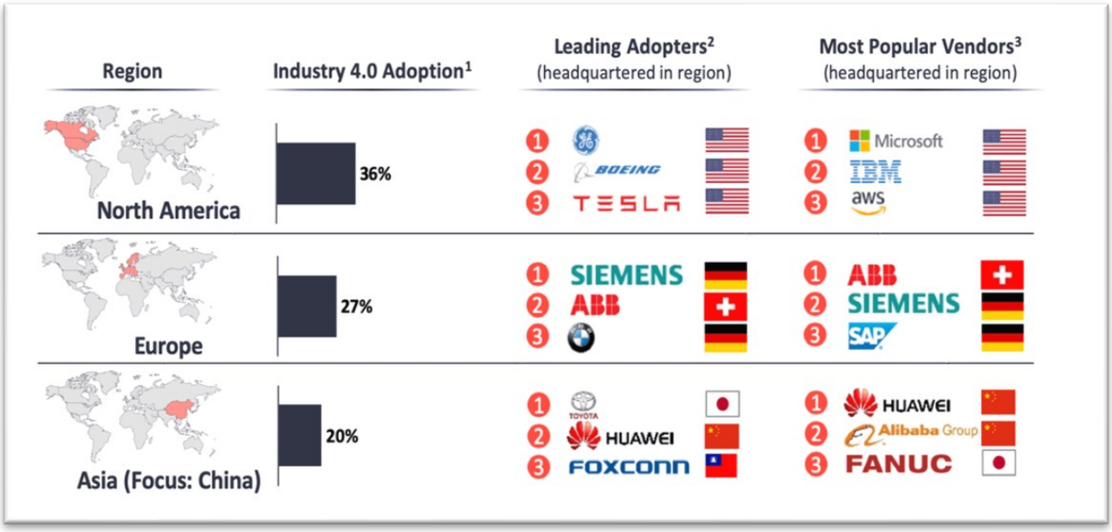

Figure 2. Industry 4.0 Technology Adoption, Adopters and Vendors, by Region

Source: Wopata (2020)

Figure 2 shows the overall adoption rate of Industry 4.0 by region, to the left besides the leading adopters among countries and the most popular vendors internationally. One can see that North America is the leading region in embracing Industry 4.0 with 36% followed by Europe with 27% and then Asia with a focus on China with 20% which is eye-opening knowing that many European countries already established more public initiatives than any other elsewhere. In the middle and to the right, for leading adopters and the most popular vendors among each region which should not be surprising that North American producers were more certain to have introduced cloud, IoT, and IoT platform technologies due to the fact that the three most well-known North American vendors (Microsoft, Amazon, and IBM) all offer cloud and IoT products. Additionally, General Electric and Boeing, two of the top three companies that were deemed to be "principal adopters," are based in the country. In Europe, the manufacturers exhibited more than average adoption of cloud, but also in other technologies like collaborative robots (cobots)[1]and edge computing[2]. Asian manufacturers adopted collaborative robots more frequently than the average but far less so cloud and IoT technology (Wopata, 2020).

2. The Past Industrializations

The change from being a consumer to becoming a producer by working in the land with the settlement of the nomadic communities that were engaged in harvesting and fishing is the initial transition that may be regarded as the turning point in humanity's evolution. Humans began to alter their lifestyles to control animals, farm the land, and build a number of social organizations to increase their productivity by the beginning of the first industrial revolution (Kurt, 2019). Shop floor employment has been a cornerstone of that era. During that time, industrial jobs increased dramatically, and significant changes occurred in how things were manufactured. Prior, the majority of families settled in tiny, rural towns, and their life centered over cultivation. This production line employment began about 1760 in England, during a time marked by a population migration from rural to urban regions (Salem, 2022).

2.1. The First Industrial Revolution

The factories were a new form of producing goods that emerged during the first industrial revolution, when automation and technical sophistication had advanced enough to make it desirable to put employees together below one structure (Mokyr, 2001). The spinning jenny, water frame, and spinning mule were the first advancements that took place in cottage industry the first industry to advance in that era. The spinning jenny, for example, was created in 1764 in Stanhill, England by James Hargreaves. The mechanism lowered the amount of effort required to create fabric, allowing a person to operate on 8 or more cylinders at the same time (Beck, 'Cottage Industry vs. Factory System During the Industrial Revolution', 2017). On the other hand, Thomas Newcomen's creation of the steam engine in 1712 is considered to be one of the major momentous occurrences of the historical context. Conventional approaches of extracting water from mines were time-consuming and labor-intensive. As a result, steam engines aided in the powering of Industrialization, allowing turbines to substitute formerly extremely laborious labor (Beck, 'First Industrial Revolution vs. Second Industrial Revolution', 2016).

[1] Collaborative Robot is a robot that is capable of learning multiple tasks so it can assist human beings.
[2] Edge computing is an emerging computing paradigm which refers to a range of networks and devices at or near the user.

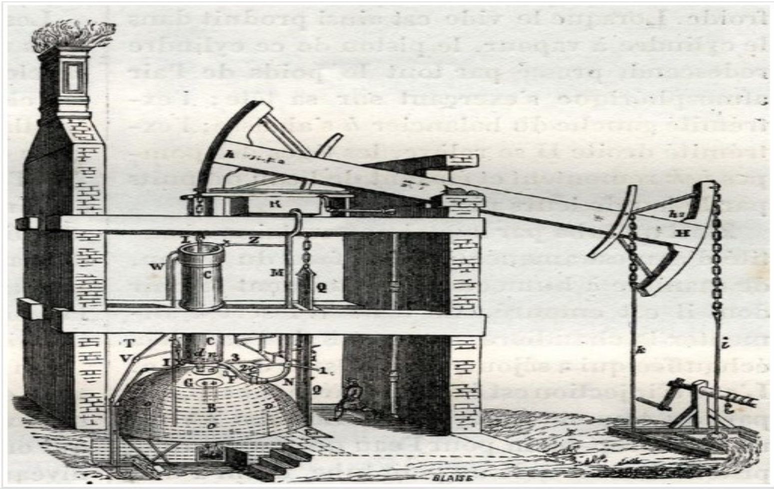

Figure 3. The Water Steam Engine

Source: Beck (2017)

The First Industrial Revolution's factory structure provided new methods of producing goods and the shopfloor division was as follows[3]:

4. Centralized workplace: The factory, rather than having individual employees scattered in their residences and crafts, was a huge central location where numerous people came together to manufacture items. The machines were expensive, huge, required a lot of electricity, and were controlled by a huge number of employees.
5. Division of labor: This is when several individuals each have a distinct role in the production of the product. Each employee can have expertise in a single tiny activity and is not required to know how to create the full product.
6. Unskilled workers: Employees may be "unskilled." They might be assigned a basic job which they would repeatedly do.
7. Standardized parts: Various components of a product were harmonized. This means they were manufactured in the same manner and to the same specifications. This idea later evolved to convertible components, which allowed individual pieces to be readily changed and maintained.

E.P. Thompson's "The Making of the English Working Class" examines the developments in the employment market throughout the initial industrial revolution. The

[3] https://www.ducksters.com/history/us_1800s/factory_system_industrial_revolution.php

transition from a cottage industry to a factory-based manufacturing systems resulted in the creation of new professions and vocations, such as factory workers and machine operators. As a consequence, a new class of industrial capitalists emerged, controlling the manufacturing processes and amassing vast riches while the workers battled with poor conditions at work, low salaries, and long shifts. As a result, the first industrial revolution exacerbated social class and inequality in England. It is worth noting that it also had many bad aspects, such as poor living circumstances, child labor, and toxicity (Beck, 'Industrial Revolution Overview' , 2017). Twelve-hour work schedules were common in the new industries and pay was pitiful. Employee accommodation was frequently dismal, with inadequate sanitation and adequate drinking water. Schooling was not widely available. Nevertheless, the innovations were not lucrative in France, Egypt, or other nations, which is why the Industrial Revolution occurred in the United Kingdom.

2.2. The Second Industrial Revolution

Numerous new technologies, notably electricity, were created during the Second Industrial Revolution, which lasted from 1840 to 1917. By that period over that era, there was a progressive rise in the rate of productivity—output per hour—in US production, as well as a steady distribution of electric power in US factories (Atkeson&Kehoe, 2001). Low salaries, hazardous working environment, heavy workloads, child labor, salary discrimination, and other factors have contributed to worker unhappiness that occurred that period. According to Sukkoo Kimhas[4] skilled employees were in short supply to manage the industries, where around 33 million of unskilled laborers immigrated to the United States during second industrial revolution period. On the other hand, efficient machines did more laborious works (Mohajan, 2019). The introduction of large - scale production, in which employees were kept immobile while jobs were transferred to them, was also significant. In this manner, the operator could manage the pace at which procedures were conducted while also minimizing the time labor spent among functions (Mokyr&Strotz, The Second Industrial Revolution, 1870-1914, 1998).

At the time, the modern company was starting to emerge, with work, typically in a manufacturing environment, becoming industrialized and managed by managers (Bright et al., 2019). By I 2.0 the cost of telegraph and railroads became less expensive which impact

[4] Associate Professor of Economics PHD, UCLA

positively the industrial system and built a wide network with efficient connection and this resulted in the establishment of the first structured institutional framework with professional management within the train corporations. This concept of more adequate and decisive business is called scientific management. The approach centered on decreasing the number of physical movements necessary in the workplace. Knowledge management influenced other subjects such as industrial engineering, and manufacturing engineering (Botti, 2019).

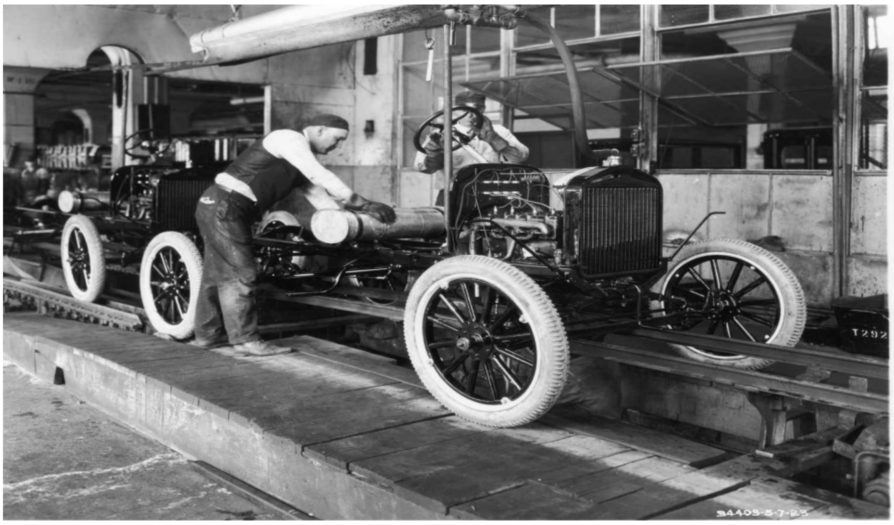

Figure 4. Moving Assembly Line by Henry Ford

Source: Goss (2020)

At the end of this revolution Assembly Line was invented by Henry Ford in 1913. The mobility element was what set this production line apart. Henry Ford famously stated that the utilization of a conveyor belt allowed work to be brought to the workers rather than the employees travelling to and around the vehicle. The car started down the line and produced gradually. It was first dragged by a rope, but it eventually evolved into a simple moving chain system. This Assembly Line helped in increasing productivity and replacing several tasks were done by the employees and reduced working hours. Despite the fact that the labor of building a vehicle had been simplified, employees began to depart Ford Motor Company to work for rivals. Shopfloor employees considered assembly line labor uninteresting since they were now just executing one or two tasks rather than working on a complete car. Furthermore, the employees disliked the stringent time constraints imposed by the moving assembly line. It was tough to ensure that you finished all of your job before the car went on to the next station. Vehicles might be missing pieces, or employees would trip over each other while assembling the vehicle. Not only did Henry Ford raise his employees' compensation, but he also reduced the number of hours they had to work (FordMotor, 2020).

2.3. The Third Industrial Revolution

The third industrial revolution was accompanied by the advent of computer (and IT) technology on factory floors (Haidegger, 2017). It demonstrated the transition from mechanical and analogy electrical technologies to digital electronics with the introduction and growth of digital computers and digital record keeping, which is still ongoing today (Schoenherr, 2004). Digital electronics is the mechatronics technologies as for example: computerized machine tools, flexible production cells, and computer-integrated shop floor. In the digital revolution different tasks started to be done on computers. Novel storage devices enabled the total of human knowledge to be kept in electronic information, while ARPANET[5], the forerunner to the Internet, was gradually developed to enable electronics to connect and conduct work with one another. The impact cannot be understated; the invention of the computer enabled a single individual to combine the labor of formerly disparate technical occupations into a single instrument. Data could be saved and modified simultaneously, and equipment could be mechanized by adding software and programming so that an employee could supply inputs for a system to conduct a repetitive operation (Islam et al., 2020).

[5] The Advanced Research Projects Agency Network

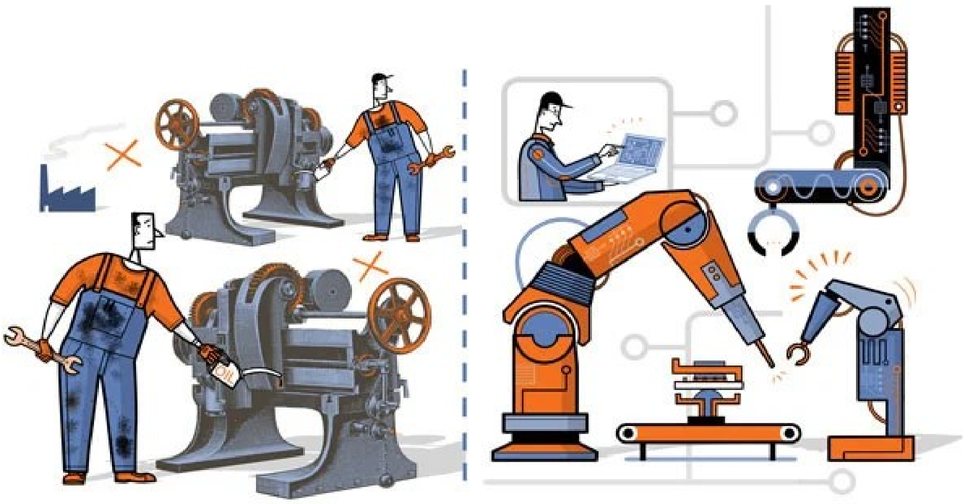

Figure 5. The Third Industrial Revolution Shop Floor Evolution

Source: The Economist (2012)

The introduction of Programmable Logic Controllers (PLCs) allowed manufacturing industries to develop repeatable, consistent and controlled manufacturing processes that did not rely solely on human interaction, and which allowed manufacturing capacity to expand beyond previous limitations of the workforce (Jeffs, 2019). Machine control design is a distinct field of engineering that necessitates understanding specific and distinct modeling techniques known as hierarchy mapping. Although there are some links among management and electrical layouts, many element identifiers and layout standards differ (Hackworth& Hackworth, 2003). A series of significant shifts in the structure of tasks at the manufacturing site are at the heart of the third industrial revolution. Such organizational forms turn the shop floor into a driver of continual and continuous development in both products and systems, resulting in a potent new source of innovation, efficiency, value creation, and capital formation. The third industrial revolution shop floor comprises the production as well as the R&D lab. According to Konosuke Matsushita, the founder of the Japanese electronics company and one of those who designed the new shop floor of I3.0 “A company will get nowhere if all the thinking is left to management. Everybody in the company must contribute, and for the lower-level employees their contribution must be more than just manual labor. We insist that all our employees contribute their minds”. Japanese companies are perhaps the best examples of the new shop floor, while similar arrangements can be observed in a number of 'progressive' corporations in the United States—for example, 3M, Hewlett Packard and Xerox—as well as in Europe—for example, Pirelli—and Scandanavia—for example, Volvo (Florida, 1991). The Japanese corporation’s approach is that engineers and scientists lead the charge in planning, industrial workers and technicians are continually advised on the technology's potential to be produced (Imai et al., 1985). After the software is built and deployed, industrial workers give ongoing ideas on how to enhance and optimize the technology's quality as well as the production process. This results in constant development of product quality and usefulness, as well as ongoing process enhancements. The intellect of scientists and engineers is utilized in advance and contained in new technologies in this approach. The fundamental production line is then designed by these and other engineers in a supervised laboratory or small research plant setup. Following that, new technology is applied, almost unaltered in factory settings. Employees in the workplace do their production jobs but provide little, if anything, for the advancement or improvement of this technological advances or its manufacturing process (Florida, 1991).

Last but not least, the digital technology evolution in the third industrial revolution led to a rise in the demand for new academic specializations. The design of the factory has changed, and a new era of shop floor activities started with high connectivity among assemblies where the history of automated factories began. Narrow job classifications gave space to more multiskilled jobs, and remuneration mechanisms modified to pay off employees for expanding their knowledge bases. Hourly workers achieved more control over their work and further executive power. Engagement and job scope growth became increasingly important as the number of fully autonomous plants increases (HELFGOTT, 1986). The third industrial revolution is the nucleus of Industry 4.0 and the shop floor of the future with its complexity.

3. The Pushing Forces of Industry 4.0 - Technology Push

Advanced factory is the key basis for industry 4.0 that is recognized as a technology-driven revolution to improve productivity and efficiency. These new technologies, combined with massive amounts of real-time data, will reshape production and support operations across a global supply chain, as well as alter human-machine interactions, also customers and supply chain partners (Tang&Veelenturf, 2019). Thus, Automated manufacturing systems are being integrated into whole supply chains and product life cycles as part of the industry 4.0 by emphasizing the environment of interactions and communication between people, places, things, and equipment, which is made possible by CPS and CPPS (Büchi et al., 2018).

CPPS refers to Cyber Physical Production System. Industry 4.0 is defined by The German Federal Government as a new formation known as the Cyber Physical Production System

(CPPS) that integrates manufacturing and logistics systems that make major use of the universally available information and communications network for a highly automated exchange of data and in which business and manufacturing processes are synchronized (Bahrin et al., 2016). As a result of CPPS, manufacturing systems are able to make smart decisions through coordination and actual communication between production things (Lu et al., 2020), allowing for efficient mass manufacture of high-quality, customized items (Wang et al., Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination, 2016). These systems strive to monitor and operate the machines, modules, and outputs via a feedback loop that collects a large amount of data (big data) and update the digital models with physical process facts, resulted in a smart factory (Wang et al., Current status and advancement of cyber-physical systems in manufacturing, 2015). Therefore, industry 4.0 technologies can be categorized into physical and digital technologies. Physical technologies mostly describe production methods like additive manufacturing (Bai et al., 2020), or sensors and drones (Morrar et al., 2017). Modern information and communication technologies including cloud computing, blockchain, big data analytics, and simulation are examples of digital technology (Liao et al., 2017).

The emergence of new digital industrial technology known as Industry 4.0; is a shift that fueled by nine underlying technological developments as shown in figure 6 by Romero et al., (2021) and Boston Consulting Group (BCG). Numerous of these nine technological developments that serve as the basis for Industry 4.0 are currently in use in manufacturing. They will, however, reshape manufacturing because detached, optimum cells will emerge together as a properly integrated, digitalized, and improved workflow, resulting in increased efficiencies and modifying conventional manufacturing interactions among suppliers, manufacturers, and consumers well as amongst both human and machine (Rüßmann et al., 2015).

Figure 6. Nine technologies of Industry 4.0

Source: Romero et al., 2021

The nine pillars of Industry 4.0 has been defined by many of scientists, consulting firms, literatures (Vaidya et al., 2018; Rüßmann et al., 2015; Bahrin et al., 2016; Romero et al., 2021; Bagheri et al., 2015; Neugebauer et al., 2016) and (Boston Consulting Group[6]-BCG):

i. **Big Data and Analytics:** As per Forrester, Big Data has four dimensions: volume of data, range of data, velocity of creation of new data and analysis, and scale which is the worth of data. To enable real-time decision making, the gathering and complete evaluation of data from various sources, including manufacturing machines and systems, together with corporate and customer-management systems, are becoming routine. The data analysis of prerecorded data serves to determine the dangers that existed in various steps of production previously in the industry, in addition to anticipating the new challenges that may emerge, as well as numerous solutions to prevent it from happening once more in the industry.

ii. **Autonomous Robots (Industrial Automation):** The incorporation of artificial intelligence (AI) into software is referred to as industrial automation. It has machine learning skills for systematically and on a wide scale doing repetitive activities formerly performed by people. They utilized to undertake more accurate autonomous production methods and to work in areas where human workers are constrained. They also prioritize safety, adaptability, versatility, and collaboration.

[6] Boston Consulting Group is an American global management consulting firm and one of the Big Three — the world's three largest management consulting firms by revenue.

iii. **Simulation:** 3-D simulations of goods, materials, and manufacturing processes are already employed throughout the engineering phase. But, with industry 4.0 they will be widely utilized in production plant to harness real-time data to mimic the physical environment in a virtual model that can incorporate machinery, items, and people, reducing machine installation time and enhancing quality, also decrease the problems in production during the setup stage. In addition, improving the decision-making quality.

iv. **System Integration: Horizontal and Vertical System Integration:**
Enterprises, suppliers, and customers are rarely in close connection to one another even engineering, manufacture, and servicing are not included. Also, the corporate and shop floor functions are not completely linked. System integration refers to three dimensions used to offer the connections needed to connect real and virtual system objects. Vertical integration, the process of connecting system components. Horizontal integration, by connecting two or more systems. The third dimension is end-to-end engineering among the whole product life cycle.

v. **The Industrial Internet of Things:** In the Industrial Internet of Things, various items, including incomplete goods, will be incorporated with computing and will be connected via proper protocols. Engineering solutions that are linked through the Internet of Things are defined as Cyber-Physical-System (CPS). That enables field equipment to communicate and engage each other as well as with more central controller as needed. It also decentralizes analysis and taking decisions, allows for real-time reactions.

vi. **Cybersecurity and Cyber Physical Systems (CPS):** Secure, dependable communications, as well as advanced machine and user identity and access control, are critical. Cybersecurity refers to measures taken in advance to prevent data from being lost, hacked, or destroyed. On the other hand, CPS systems are those in which physical and man-made systems (physical space) are strongly linked with computing, networking, and control systems (cyber space). CPS's key attributes are decentralization and independent manufacturing activity. The use of appropriate sensors in CPS should detect failures in machinery and immediately prepare for defect repair activities on CPS. Additionally, the effective usage of each workstation is determined using the cycle time necessary for the activity done on that station.

vii. **The Cloud:** More manufacturing endeavors will necessitate increasing data exchange across sites and business boundaries with Industry 4.0. Cloud computing is a digitized system that provides internet access to computational and processing engines hosted on remote servers. This cloud helps in connecting multiple devices to a single cloud to exchange intelligence and can be expanded to a collection of devices from a shop floor together with the complete plant.

viii. **Additive Manufacturing:** Is a manufacturing process that uses a number of additive or overlaid tools and methodologies to construct three-dimensional (3D) solid items. With Industry 4.0, additive manufacturing processes will be extensively employed to make small volumes of personalized items with construction benefits such as complicated, lightweight designs. Shipping distances and inventory levels will be reduced by high-performance, decentralized additive manufacturing technologies. With the use of additive manufacturing technologies such as fused deposition method (FDM) and selective laser melting (SLM), manufacturing must be more efficient and less costly.

ix. **Augmented Reality:** A range of services are supported by augmented-reality-based systems, including the selection of materials in a storehouse and the transmission of restoration instructions via mobile devices. Augmented reality can be used in industry to offer labor with genuine data to enhance strategic planning and work routines. Staff may obtain maintenance guidance on how to substitute a specific item while inspecting the damaged system.

4. Industry 4.0 Challenges

The Industry 4.0 digital revolution is a verge that will radically alter how we live, perform, and interact with one another. The progression will be beyond anything humanity has ever seen in terms of scale, scope, and ambiguity (Schwab, 2016). According to Schwab, the fourth industrial revolution uses connectivity and communication among billions of devices, which makes it fundamentally different from previous ones. It is developing exponentially rather than linearly when compared to earlier ones. Additionally, the intensity and complexity of these changes portend a complete overhaul of the management, governance, and manufacturing activities.

Due to the fact that Industry 4.0 technologies are still in their infancy, little is known about their true significance and contributions. These technologies must be consolidated with conventional manufacturing systems, causing wellness and compatibility concerns even more critical (Bai et al., 2020). This rapid evolution of Industry 4.0 technologies combined with unclear perceptions of 4.0 methodologies imply different challenges that could be managerial, technical, social, organizational etc.:

4.1. Technical Concerns

The smart factory is a subset of CPS that relies on the broad and comprehensive application of information technologies to production. Thus, to build smart factories, we require smart hardware and software. Intelligent system controllers, high bandwidth IWN devices, industrial production big data analytics software, and integrated data mechanisms are examples of these. Multiple tech-challenges are embedded in these systems and had been recognized based on theoretical analysis and development experience (Wang et al., Implementing Smart Factory of Industrie 4.0: An Outlook, 2016)

a. **Intelligent Decision-Making and Negotiation Mechanism:** Smart artifacts are critical elements of a digital workplace. Whereas today's computer numerical control (CNC) machines typically have 3C capabilities, intelligent machines should also have independence and affability. This implies that intelligent objects can decide for themselves rather than being told what to do, and they are able to negotiate with one another and with smart outputs. However, the lack of autonomy in the systems is a key challenge for the whole process.

b. **Data Management and Resource Allocation:** Resource distribution is a crucial requirement in cloud computing data centers. The significance of this concept is defined by the huge number of resources available in cloud-based environments. Resource distribution barriers are divided into three categories: data center network resources, data center application usage, and efficient information center allocation of resources.
Improving virtual environment provision while maximizing profitability is the most difficult problem in data center network resources. Additionally, the procedure for choosing the best virtual network with IP over a cloud-based network is a serious problem that has been taken into account with respect to transmission, latency, and diffusion transformation factor (Moghaddam et al., 2015)

c. **Cybersecurity:** Future developments of CPS in the workplace may succeed or fail depending on the sub-domain of privacy. The incorporation of cloud computing only increases the significance of this component and will require harmonizing rules and cybersecurity levels. Security cannot be an add-on, and that is the main problem at hand. We must safeguard numerous pieces of information regarding clients, vendors, business tactics, and expertise. Rather than in an organization's dedicated data center, these types of data are often saved on the public cloud. For instance, hackers might reveal these secret documents, which could result in significant financial loss or perhaps legal issues. On the contrary, humans, machines, and other tangible items are all linked to the cloud. When the control system malfunctions, these items could act destructively and result in immediate property damage (Wang et al., Implementing Smart Factory of Industrie 4.0: An Outlook, 2016). Therefore, starting with the outline phase, it must be thoroughly constructed and embedded into the standards and systems (Wang et al., Current status and advancement of cyber-physical systems in manufacturing, 2015).

d. **System Modeling and Analysis:** According to the basic self-organized hypothesis, the self-organized process could result in unforeseen circumstances like disaster (Merry&Kassavin, 1995). Consequently, we must simulate the self-organized manufacturing system, determine its dynamical equations, and draw conclusions about suitable control strategies. Nevertheless, complex series research remains a hot field, and the theories on self-organized systems have not yet developed (Wang et al., Implementing Smart Factory of Industrie 4.0: An Outlook, 2016).

4.2. Organizational and Managerial Concerns

In fact, there is ample proof that industries are being significantly impacted by the technology driving the Industry 4.0 within all sectors. Still, the pace of change and the velocity of innovation, according to some worldwide Chief executives and top business leaders, are difficult to understand or predict and are a source of ongoing wonder for even the best connected and most knowledgeable people (Schwab, 2016). This implies that several organizational challenges do exist:

a. Legal issues: Data release may occur accidentally or on purpose when data is uploaded to a cloud service or sent over wireless connections. The uploading and downloading of a 3D model must be covered by copyright legislation, which varies from nation to nation. The formula may need to be altered in order to move the treatment of an order to another plant with sufficient capacity, increasing the danger of technological secrets being revealed. For the majority of enterprises, data security, safety, and anonymity are top priorities (Chen&Tsai, 2017).

b. **Privacy issues:** Numerous sensors capture the noises and images of various individuals in various locations. However, there are serious privacy concerns regarding this extensive public data collection. In order to guarantee firms to acquire and preserve this data correctly for public safety, governments must create legal provisions (Tang&Veelenturf, 2019).

c. **Investment Issues:** For the vast majority of new technology-based projects in production, the problem of investing is rather universal. A Company must make a sizable initial expenditure to deploy industry 4.0. Indeed, a significant level of expenditure is necessary for an industry to execute all of industry 4.0's pillars (Valdeza et at., 2015).

d. **Servitization Business Models:** In the industrial sector, BMs have often concentrated on the creation or construction of physically tailored goods that are more or less personalized, and they have made money from their sales. The lowering of tariff barriers and the harmonization of technological standards throughout the world have placed strain on these conventional BMs. In order to avoid having to compete exclusively on manufacturing costs, several scholars have advised that manufacturing companies in developed nations can increase their involvement in the value chain by adding services to their existing product lines (Thoben et al., 2017).

e. **Managerial challenges:** According to a cybersecurity director in industrial goods, nobody is able to identify cybersecurity today; while many still think it just refers to information security, it actually encompasses much more. The lack of interest in cybersecurity is partly a result of conventional manufacturing organizations viewing it as a purely financial burden rather than a tool for value development. Thus, a vision for the future must be the foundation of CPS. Organizational change will enable this goal to become a reality (Culot et al., 2019).

4.3. Social Concerns

The Fourth Industrial Revolution is expected to increase global GDP levels and enhance the standard of living for people all around the world, much like the revolutions that came before it. Future technology advancements will result in a procurement miracle with long-term increases in productivity and efficiency. Costs associated with transportation and communication will decrease, even as the effectiveness of global supply chains and logistics. However, like the previous revolutions, the fourth one may also result in increased inequality, as economists Erik Brynjolfsson and Andrew McAfee have noted (Schwab, 2016) While the existing manufacturing fundamentals need attention and are not sustainable (Alkaya et al., 2015). Therefore, this fourth industrial revolution can provide a number of difficulties and restrictions for society:

A. **Social inequality:** The biggest social issue raised by the Fourth Industrial Era is inequality. The inventors, stockholders, and investors who contribute the intellectual and physical capital are typically the biggest benefactors of innovation, which explains the widening income disparity between those who rely on capital vs labor. Therefore, one of the primary causes of income stagnation or even decline for the bulk of the people in high-income nations is due to technology (Schwab, 2016).
B. **Environmental doubts:** Industry 4.0 has mostly concentrated on productivity and attaining high profits. Whereas there are constraints in the manufacturing process to guarantee that natural resources are utilized at a predictable velocity that does not surpass the pace of regeneration of these resources, and the ecological capability to receive these emissions must not be overlooked in the context of environmental sustainability. On the other hand, natural environmental destruction, adverse effects on the environment, and unsuitable working conditions, all of which may probably result in an environmentally unsustainable consumption habit (Oláh et al., 2020).
C. **Information security issues:** Novel technologies and platforms will make it easier for Governments to be given new technical capabilities that will allow them to have more control over the populace through the use of widespread monitoring systems and the capacity to manage infrastructural facilities. Overall, though, as novel sources of competition and the transfer and decentralization of power that

new technologies enable will lead legislatures to face pressure to implement policies to change their existing strategy for public participation and policy making (Schwab, 2016).

D. **Labor market:** The need for highly trained individuals has grown in high-income nations, while the need for people with lower levels of education and training has declined. Consequently, the center of the employment market is being scooped out while demand is strong at the upper and lower ends. The substitution of employees by machines as a result of automation's replacement of labor across the whole economy might widen the disparity between capital returns. and returns on labor. In addition, it's also possible that, overall, the technological substitution of occupations may lead to a net gain in secure and satisfying employment (Schwab, 2016).

Nobody can deny the numerous benefits provided to various industries and businesses that use Industry 4.0 technology. Clearly, this fast-paced industrial evolution aids in increased profitability, cost reduction, greater living quality, and better market understanding, which leads to better competition. However, in this new age, one of the most significant topics to consider is the condition of the workers within smart factories and the potential situations that may arise in the future. For now, researchers, managers, and engineers are still arguing the position of shop floor employees in the future where various scenarios may apply.

5. Understanding Industry 4.0 Application with RAMI4.0 Architecture

The race towards a progressive adoption of Industry 4.0 among several governments and its companies is not only inspired by the automated manufacturing process with its general concept but also by other factors. One of the main factors is the big data and the high capacity of the Industry 4.0 system to gather huge amounts of this data. The data itself is an added value through sophisticated analysis algorithms that can assess and foresee mechanical faults, loads, and other issues in machines by analyzing data collected through sensors with an ultimate goal of serving the customer needs. Factories can utilize the data gathered from product tracking to customer segmentation and develop novel products. These features increase the functionality of items for consumers, providing new opportunities for manufacturers (Frank et al., 2019). Furthermore, Industry 4.0 supports new socio-technical infrastructures by revolutionizing various areas of the workplace, including well controlled work structure, continuous learning and professional career models, multi-team system, and knowledge management. This is said to be a socio-technical approach of the Industry 4.0 program that will cause a fundamental change in how individuals utilize technology and their surroundings (Kagermann et al., 2013).

Clearly, the term Industry 4.0 touches extended notions, each of which cannot be precisely classified in terms of a discipline or distinguished in individual cases (Lasi et al., 2014). Yet, what we can say that it doesn't only confine in the technical aspects of the business, but it exceeds that to the organizational body and to corporate social responsibility at the same time.

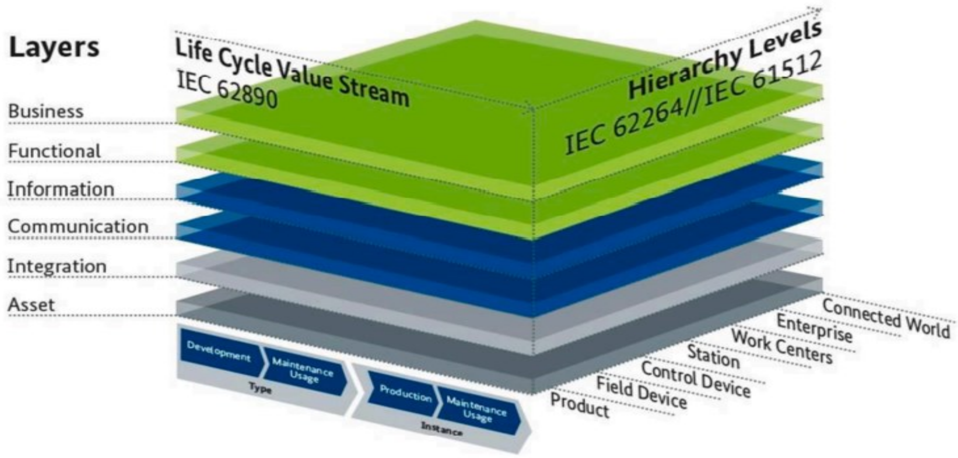

Figure 7. Reference Aarchitecture Model Industrie 4.0 (RAMI4.0)

Source: (PlattformIndustrie4.0, Architecture model Industry 4.0 (RAMI4.0), 2016)

The RAMI 4.0 architecture model in figure 7 was created by the German Electrical and Electronic Manufacturers Association (ZVEI) (Xu et al., Industry 4.0 and Industry 5.0—Inception, conception and perception, 2021). RAMI 4.0 is a three-dimensional map explaining the vital facets and the integration among digital and physical members of Industry 4.0 (PlattformIndustrie4.0, Architecture model Industry 4.0 (RAMI4.0), 2016)RAMI 4.0 assures that all respondents have an identical view of the issue and build mutual comprehension. These dimensions are the:

- **Life cycle and Value Stream:** This is the first dimension located in the middle of the architecture. This dimension is based on IEC 62890, a proposed standard for managing the life cycle (Pisching et al., 2018). It considers the product life cycle from conception to decommissioning. Hence, it covers the whole stages of product life cycle and value stream together, starting with the ideation, development, production then to the sales and the services related after (Schweichhart, 2016). It takes in consideration also the process of recycling or ditching of the product.

Figure 8. Product Life Cycle
Source: Derived from figure 3.

Left side of figure 8. one can see the type that is formed along with the initial concept, or when a product is being developed which involves putting layout orders, creating and evaluating products, producing initial samples and prototypes (Gayko et al., 2018). While the development part consists of the construction plan that contains the development, construction, computer simulation and prototyping of the product. In the maintenance usage side, which is also related to the construction plan, we can find the software updates, instruction manuals and maintenance cycles etc. (Schweichhart, 2016).

Right side of figure 8. There is the instance where industrial production of goods is happening based on general category. Each produced item, for instance, has a special serial number, and thus each one serves as an instance of that type. Customers purchase and receive the instances and the transition from type to instance may happen more than once and this goes under the maintenance usage that also considers the recycling and scrapping of the product (Gayko et al., 2018). For example: As a motor manufacturer I can take two perspectives:

1. My product and service offer to my clients
2. My internal processes and workflows

In this part of RAMI 4.0 The digitization and linking of value streams in Industry 4.0 offer enormous opportunities for advancement. Logistic data plays a big role, and they can methodize themselves depending on the order stockpile. Procurement has real-time inventory visibility and recognizes where portions from suppliers are located at any particular time. On the other hand, during production, the client can view the product's updated status. This integration of purchasing, shipment planning, manufacturing, supply chain, servicing, customers and suppliers, and so on, offers significant efficiency for the enterprise (Gayko et al., 2018).

- **The Layers Axis:** It is the second dimension of RAMI 4.0. The six layers on the vertical axis define the dissolution of an equipment into a company's properties, which are organized layer by layer (Henkel&Rexroth, 2015). They are utilized to reflect viewpoints like data maps, operational specifications, communication patterns, hardware/assets, and business functions (Adolphs et al., 2015) i.e., they identify a structure of ICT representing the Industry 4.0. These six layers are from up to bottom as shown in figure 9. (PlattformIndustrie4.0, RAMI4.0 – a reference framework for digitalisation, 2018):

Figure 9. The Six Layers of RAMI 4.0
Source: Derived from figure 3

1- **'Business'**: Organizational and operational procedures, i.e., What is the client willing to pay for?
2- **'Functions'**: The asset's serves, i.e., What is the purpose of my product?
3- **'Information'**: Important Data, i.e., What data must my product focus on providing?
4- **'Communication':** Information accessibility, i.e., How do I or my client reach the data?
5- **'Integration':** Transformation from the Physical to the Digital World, i.e., Which components of my good or service are digitally accessible on the network?

6- **'Asset':** "Things" which are the physical ones in the real world, i.e., How do I assemble my good or service into the procedures so that it can be used in the actual world?

- **Hierarchy levels:** The third dimension as a horizontal axis. Following the research purpose, this is the most important level as it mostly touches the Shop Floor. It is formulated on the basis of IEC 62264//IEC 61512, an international standard that introduced four surfaces that you can see in the middle of the hierarchy standards on figure.3 to the right [from top to bottom] and they are called (Pisching et al., 2018; Schweichhart, 2016):

1- **'Enterprise'** that is consisting of adaptable systems and machines
2- **'Work Centers'** in which operations are transferred across the network
3- **'Station'** where entrants communicate throughout hierarchy levels, and
4- **'Control Device'** where the communication among all participants and the manufacturing process progressing is controlled.

In the first four elements of the hierarchy levels, you can see the old concept. While, to support the smart factory, three additional levels were appended to RAMI 4.0. These levels are: At the bottom,

5- The **'Field Device'** to make it possible for machines or systems to be controlled smartly, using devices like smart sensors (Pisching et al., 2018)
6- **'Product or Workpieces'** It considers the consistency of the production line and the interdependence of the manufacturing plants (Adolphs et al., 2015)**.**

At the top:

7- The **'Connected World'**, by which the factory can use cooperative connectivity to approach partners outside its walls.

For the Industry 4.0 organization, these pieces represent the essential components (Pisching et al., 2018).

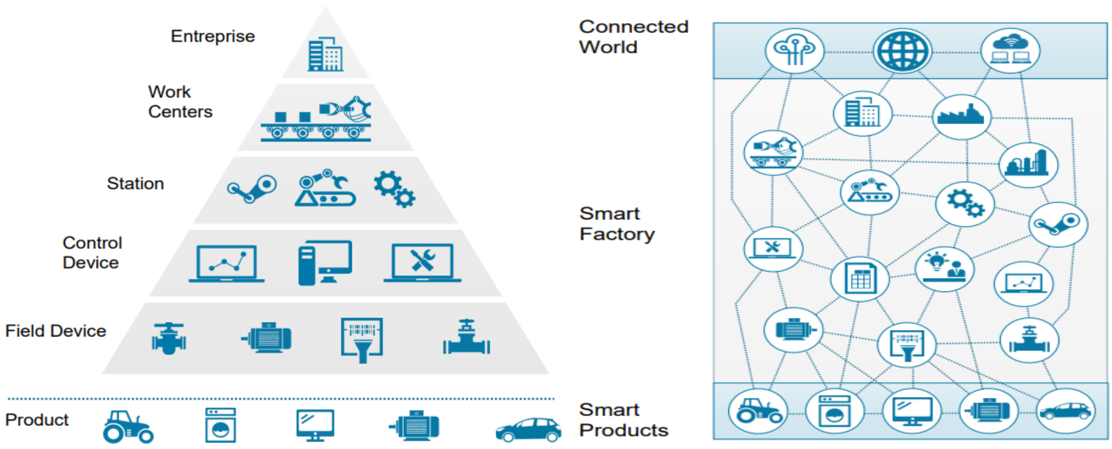

Figure 10. (a) The Old World: Industry 3.0 (b) The New World: Industry 4.

Source: (Salari,2016)

Figure 10 (a) & (b) are graphics designed by freepik[7] that helps to understand better the hierarchy levels of RAMI 4.0. Figure 10. (a) refers to Industry 3.0 as the old world and according to Martin Hankel[8] (2016) the factory and process is a hardware-based structure where many of the functions are compelled to hardware. At the same time, communication is hierarchy based and one can see that in Industry 3.0 the product is totally isolated from the other components while the enterprise is not efficiently connected to the external world.

On the other hand, figure 10. (b) shows Industry 4.0 as the "new world" the whole process with its all components is interconnected which represents the Smart Factory. It shows that the enterprise is open to the external environment that is connected to the whole components inside the factory and the management so the network can spread out of the company boundaries. It consists of systems and equipment that are adaptable; functions that are scattered through the network. In addition, it is possible for everyone to communicate with one another (PlattformIndustrie4.0, RAMI4.0 – a reference framework for digitalisation, 2018).

The main difference, which is vital, is that the products are interconnected to other functionalities which cover the product life cycle. This progressed model with the high interconnectedness of the tangible, service, and digital worlds can enhance the quality

[7] Graphic RAMI 4.0 © Plattform Industrie 4.0 and ZVEI, pictogram: © Anna Salari, designed by freepik

[8] Martin Hankel is the Head of Digital Business, Bosch Rexroth Hydraulics

of information needed for industrial production system planning, utilization, and function (Landherr et al., 2016).

RAMI 4.0 incorporates various implications and gives a shared understanding of Industry 4.0 technology integration. This 3D map view of Industry 4.0 technologies allows industry associations and standard - setting committees to identify sector requirements ranging from automated production and mechanical engineering to process engineering (Henkel&Rexroth, 2015). Hence, Industry 4.0 concept is about linking business operations inside and throughout the company boundaries where the internet is anywhere, and things are becoming smart which will lead for a new era of services and functions. Moreover, data from vendors, clients and inside the enterprise is linked and transparently accessible, and devices and equipment's organize production autonomously, allowing for greater flexibility, efficiency, and resource conservation (PlattformIndustrie4.0, RAMI4.0 – a reference framework for digitalisation, 2018).

Chapter 2

Shopfloor Employees in Industry 4.0 Era

Over the last two decades, there has been a surge in interest in automation and digital technologies, as well as their implications for our society. The development of innovative technologies, and growing access to some of them, have raised questions about their effect on production processes and on various elements of effective structures once they are adopted (Anzolin, 2021). Since the first industrial revolution, the shopfloor has played an important role in providing advantages to businesses.

The second chapter aims to help in understanding the shopfloor mechanism and the important components of this structure by outlining the operations within the production line. The previous industrial revolutions, particularly the third, transformed the way workers worked, and machines supplanted certain employees' tasks. In this manner, researchers and scholars are divided on the influence of Industry 4.0 on businesses, particularly on the shopfloor and its workforce.

Two studies will be analyzed in this chapter that help in identifying potential challenges for the employees and the shopfloor. Employees are constantly effected by new technologies application. They are regarded as the most impacted party in each change. It is critical to describe any potential challenges that employees may experience as a consequence of Industry 4.0 in order to provide the best guidance for implementing Industry technologies and keeping employees in the proper position.

1. Shopfloor and Shopfloor Employees

The production area or as referred to in factory line is also called the shopfloor. A shop floor is a location where arrangement or manufacturing takes place. This might be performed manually by the labor or automatically by automated technology (Gruber, 2020). Equipment, machines and other means of production are involved. For instance, a shopfloor of food industry may include mixing and packaging equipment while for an automotive factory it can be assembly lines, robotics, painting tools etc. Thus, the shopfloor employees are those who work in this area providing different activities in operations, productions, and logistics (Point, 2022). The precise divisions or departments of a shopfloor might differ based on the kind of industry and the plant's organization. Nonetheless, the following are some of the most prevalent departments on a traditional shopfloor:

- **Production Department:** The manufacturing department is in charge of transforming raw materials and other resources into completed items or services. In between manufacturing phases, the department strives to increase the efficiency of the manufacturing assembly process so that it can reach the output objectives established by firm management and ensuring final goods provide the highest value and quality to buyers. Some duties that take place in this department are identifying the input, scheduling production, minimizing production costs, ensuring product quality, and improving existing products. This department can be the biggest one inside the company and it may include employee mechanics, machine setup specialists, maintenance employees, machine operators, cleaning staff, and engineers (Kossman, 2018).
- **Operations Department:** The Operations and Supply Chains Department emphasizes the theory that underpins the discipline of operations management, which includes the planning and operation of manufacturing transformation processes. Much of the work in operations concentrated on tactical concerns including line balance, timing, production management, stock management, and batch allocation. It also involves output and input logistics. Some of other duties that the employees in this department are responsible for are cleanings, shipping, simplifying staff communication and guaranteeing regulatory compliance with government agencies (Chopra et al., 2004).
- **Quality Control Department:** This department ensures the process by which a company strives to enhance quality standards. Quality control necessitates that the organization fosters an atmosphere in which managers and staff seek perfection. This is accomplished through educating workers, developing output quality norms, and testing products for statistically relevant deviations. Quality investigators, analyzers, controllers, supervisors, and laboratory staff are examples of employees who worked in this department (Hayes, 2022).
- **Engineering Unit:** A shop floor engineer unit is a group of engineers that collaborate to design, develop, and enhance manufacturing processes and systems. As problems develop, they can also participate in troubleshooting and problem solving. An engineer unit's particular tasks vary based on the industry and firm, but they often seek to ensure

that manufacturing processes are efficient, cost-effective, and fulfill quality requirements (Zoberis, 2017).

- **Maintenance Department:** The maintenance department on the shop floor is in charge of ensuring that all equipment and machines are operating properly and effectively in order to satisfy production goals. It involves normal equipment, machinery, and system maintenance, repairs, and troubleshooting (Reliabilityweb, 2023).
- **Warehouse/Inventory:** It serves an important purpose in the industrial business. The inventory department is in charge of storing and moving raw materials, work in progress, and finished commodities. It is critical to have an effective inventory management system in place to guarantee that the manufacturing process is not disrupted due to a lack of raw materials or completed items (Rheude, 2018).
- **Safety Unit:** A safety unit on the shop floor is in charge of ensuring that all workers operate in a safe environment. They create and execute safety policies, procedures, and training programs to limit the risk of workplace accidents and injuries. They do frequent inspections and audits to detect any dangers and resolve them as soon as possible. They also examine accidents and near-misses to establish the core reason and put corrective measures in place to avoid such situations in the future (Walsh, 2021).

Since the commencement of industrialization, technological developments have resulted in breakthroughs and have had a major influence on the functional domains of shop floor employees' systems; these transformations may be categorized under industrial revolutions in hindsight (Wilkesmann&Wilkesmann, 2017). Prior to that people produced things on a relatively small scale and most people were working as farmers. Ever since the beginning of the industrialization factory line employees always played an important role in the industries. Through which there was a paradigm shift marking the transition of shop floor employee's work crossing by the first and second industrial revolution and the implementation of mechanical technology crossing the third industrial revolution where the digital technology took place, reaching the era of the fourth industrial revolution or the so-called Industry 4.0.

2. Industry 4.0 Jobs

While the transition to Industry 4.0 provides potential for enterprises to boost their efficiency and competitiveness, it also prompts worries about the impact on employment, with some fearing massive job disruption and unemployment. Robotics technologies have advanced significantly over the recent two decades, and ongoing growth is expected to be exceptional

(Brynjolfsson&McAfee, 2015). Hence, the concern of massive labor substitution by robotics has resurfaced, owing mostly to accelerating developments in industrial automation (Skrbiš&Laughland-Booÿ, 2019). However, it is interesting to point out that there are only a few studies and institutional approaches on how the future of employment and skills would look like.

In this part, the purpose is to highlight recent studies that contribute to increasing the doubts about the implementation of Industry 4.0 technologies. This will help in investigating the possible challenges and disruption that may occur as a result of this Industrial Revolution. The Author has selected some empirical data from two different studies to show how automation is affecting or may affect employees and which factors play a big role in changing the world of Industries. We will discuss two of the most important and well cited studies that studied this particular topic in the last decade. Each one of the studies is based on a different approach which opens the door to understanding the digitalization effect based on two different approaches.

2.1. The Future of Employment (Frey&Osborne, 2017)

In this study, Frey and Osborne followed an occupation-based approach in which they look at how sensitive occupations are to digitalization. In doing so, they designed the current literature in 2 directions. Firstly, they establish a unique approach for categorizing jobs based on their vulnerability to computerization, leveraging on recent breakthroughs in Machine Learning (ML) and Mobile Robotics (MR). Second, they use this model to predict the likelihood of automation for 702 specified occupations and assess the projected effects of future digitalization on us labor market results. The occupation data for the study are collected from O*NET and covers the whole states in the USA.

Although the task model predicts that machines would be limited to routine activities for labor replacement, Frey and Osborne (2017) analysis shows that digitalization may be broadened to any non-routine work that does not have any technical obstacles to automation. As for tasks requiring awareness and dexterity, machines have yet to approach the range and depth of human vision. Despite basic geometry recognition is rather advanced, because to the fast development of powerful detectors and scanners, more complicated perception tasks, such as detecting objects and their attributes in a crowded field of vision, still pose substantial hurdles. However, huge, motorized items have indeed been constructed into factories, warehouses, airports, and hospitals, making it simpler for robotics to traverse when doing non-routine manual activities.

Within the next years, industrial robots with machine learning and extremely precise agility will be accessible for 50,000 to 75,000 USD, with higher degrees of cognition and other capabilities. As robotic prices fall, more companies will be able to afford them as stated in The Future of Employment (2013). Machines will almost certainly keep taking up a growing number of manual duties in industries such as manufacturing, packaging, construction, repair, and agriculture. Furthermore, robotic systems are already executing numerous easy service activities such as vacuuming, washing, grass cutting, and maintenance services. Nevertheless, industrial automated systems may now execute increasingly sophisticated duties in areas such as food processing, health care, commercial cleaning, and geriatric care. activities, creative intellectual capacity, and social cognitive tasks are doubtful to be replaced by machine assets in the next decade or two.

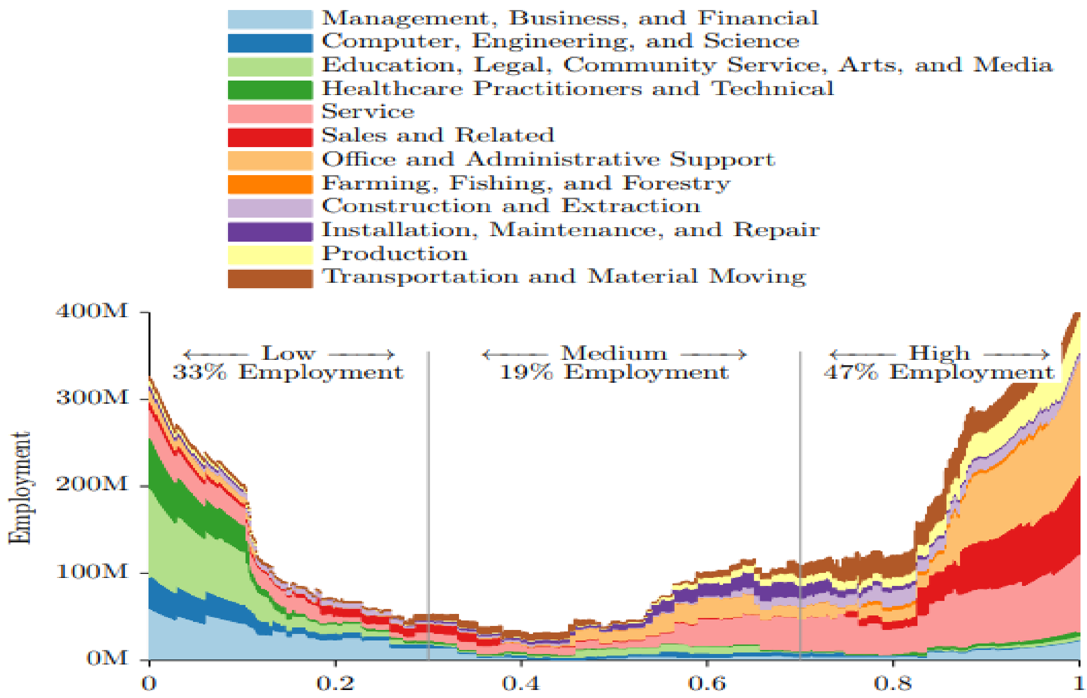

Figure 11. The Probability of Computerization

Source: The Future of Employment (2013)

Figure 11. shows the probability of computerization allocation of bls 2010 vocational employment, including the percentage in low, medium, and high probability groups. It is worth noting that the entire area under all slopes equals total US employment. Frey and Osborne (2017) estimate, 47 percent of total US labor is in the high-risk group, which means that connected vocations might be automated over an indeterminate number of

years, possibly a decade or two. According to them, the amount of automation over the next few decades would be decided by how quickly the above-mentioned engineering impediments to automation can be addressed. While the data may be understood as two phases of digitalization divided by a "technical plateau". In the initial phase, they discover that most employees in transportation and logistics, as well as labor in manufacturing, are likely to be replaced by digital technology. Automation of transportation and logistics jobs is in accordance with technical trends reported in the literature since computerized automobiles are currently being created and the lowering price of sensors allows equipping automobiles with advanced sensors more cost-effective.

In addition, the automation of factory vocations merely represents a prolongation of a pattern that has been witnessed over the last few generations, with industrial robots replacing up the everyday activities of most production employees. See Table 1. In the next page represents a classification of a selected shopfloor jobs by category and its contingency to be automated (from most to least for each category of jobs), where "SOC Code" is the occupation code under the US regulation and can be referred to on O*NET. As automated machines develop in terms of perceptions and agility, they will be able to undertake a broader range of non-routine manual activities. From the standpoint of technical capabilities, the great majority of remaining jobs in manufacturing vocations is thus anticipated to decline during the next few decades. Yet, engineering and science vocations are less susceptible to computerization due to the high level of creative thinking required according to Frey and Osborne (2017). However, it is important to emphasize that the literatures avoid making forecasts regarding the legislative process and popular acceptance although it appears that opposition to technical advancement has grown less widespread since the Industrial Revolution, knowing that there are current cases of technological change resistance. Furthermore, they didn't take in consideration the future salary rates, capital costs, or labor shortages. Although these variables will have an influence on the timing of the forecasts, labor is the rare element, meaning that compensation levels will improve compared to capital costs in the long term, making digitalization more economical.

Occupation	SOC Code	%
Engineer		
Petroleum Engineers	17-2171	16%
Industrial Engineers	17-2112	2.90%
Chemical Engineers	17-2041	1.70%
Mechanical Engineers	17-2141	1.10%
Technicians		
Engine and Other Machine Assemblers	51-2031	82%
Electro-Mechanical Technicians	17-3024	81%
Environmental Science and Protection Technicians, Including Health	19-4091	77%
Chemical Technicians	19-4031	57%
Electricians	47-2111	15%
Commercial and Industrial Designers	27-1021	3.70%
Installation and Repair		
Helpers–Installation, Maintenance, and Repair Workers	49-9098	79%
Maintenance and Repair Workers, General	49-9071	64%
Installation, Maintenance, and Repair Workers, All Other	49-9799	50%
Electrical and Electronics Repairers, Commercial and Industrial Equip.	49-2094	41%
Mobile Heavy Equipment Mechanics, Except Engineers	49-3042	40%
Telecommunications Equipment Installers and Repairers, Except Line Installers	49-2022	36%
Workers		
Production, Planning, and Expediting Clerks	43-5061	88%
Food Preparation Workers	35-2021	87%
Maintenance Workers, Machinery	49-9043	86%
Sheet Metal Workers	47-2211	82%
Roof Bolters, Mining	47-5061	49%
Cleaners of Vehicles and Equipment	53-7061	37%

Occupation	SOC Code	%
Engineer Technicians		
Electrical and Electronics Engineering Technicians	17-3023	84%
Aerospace Engineering and Operations Technicians	17-3021	48%
Mechanical Engineering Technicians	17-3027	38%
Environmental Engineering Technicians	17-3025	25%
Industrial Engineering Technicians	17-3026	3%
Operators		
Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders	51-6064	96%
Shoe Machine Operators and Tenders	51-6042	97%
Metal-Refining Furnace Operators and Tenders	51-4051	88%
Semiconductor Processors	51-9141	88%
Sawing Machine Setters, Operators, and Tenders, Wood	51-7041	86%
Plant and System Operators, All Other	51-8099	86%
Chemical Plant and System Operators	51-8091	85%
Cleaning, Washing, and Metal Pickling Equipment Operators and Tenders	51-9192	81%
Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	51-4031	78%
Chemical Equipment Operators and Tenders	51-9011	76%
Food Cooking Machine Operators and Tenders	51-3093	61%
Water and Wastewater Treatment Plant and System Operators	51-8031	61%
Managers		
Industrial Production Managers	11-3051	3%
Logisticians	13-1081	1%
First-Line Supervisors		
First-Line Supervisors of Food Preparation and Serving Workers	35-1012	63%
First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	53-1021	42%
First-Line Supervisors of Construction Trades and Extraction Workers	47-1011	17%

Table 1. Probability of Automation of a Selected Shopfloor Occupations

Source: Created by the Author depending on data derived from Frey and Osborne (2017)

2.2. The Future of Jobs (Th Future of Jobs, 2016)

The Future of Jobs report by World Economic Forum is a global challenge insight report speaking about employment, skills, and workforce strategy for the fourth industrial revolution. The dataset that forms the basis of this Report is the result of the "Employer Survey" that took place through the World Economic Forum's membership and with the significant support of three Employment, Skills and Human Capital Global Challenge Partners: Adecco Group, ManpowerGroup and Merce and other senior talent and strategy executives of leading global employers, representing more than 13 million employees across 9 broad industry sectors in 15 major developed and emerging economies and regional economic areas. The countries and economic areas covered in-depth by the Report are the Association of Southeast Asian Nations (ASEAN), Australia, Brazil, China, France, Germany, the Gulf Cooperation Council (GCC), India, Italy, Japan, Mexico, South Africa, Turkey, the United Kingdom, and the United States. The dataset is covering all occupations among the whole organizational levels. In contrary to Frey and Osborne (2017), the Study report has followed the task-based approach by asking the respondents to differentiate between large scale workplace jobs (i.e. work roles that are important to the company's activities in terms of the overall number of staff members because they make up the majority of its working population) and specialized careers (i.e. job groups, such as architecture and R&D, that are important to the company's activities essentially in terms of the total number of workers but because they provide specific services).

According to The Future of Jobs report business model disruption will have a significant influence on the job environment in the years ahead. One of the biggest technological drivers according to the survey respondents is Mobile Internet & Cloud Technology with 34% of the employees surveyed[9], while the mobile internet has uses in both industry and government, allowing for more effective service delivery and by using Cloud technology the transition of the activities can be done without a local software. These technologies are followed by Processing power & Big Data with 26% and then new energy supplies and technologies with 22% among different other technologies like Internet of Things, Robotics, Artificial Intelligence, and 3D Printing.

[9] The Report surveyed 13,549,000 Employees from all Industries. Over 2 million were blue-collar workers.

While these upcoming developments offer immense promise for future development and job growth, plenty of them also represent significant problems that will need deliberate adaption on the part of firms, governments, societies, and people. Many vocations will experience radical shift as entire sectors adapt and new ones emerge. New energy supplies and technology, for instance, will have a significant influence on the Energy, Basic and Infrastructure, and Mobility industries. While the significant influence of Artificial Intelligence will be on the Mobility Industry with 16% knowing that AI, Additive Manufacturing, and 3D Printing had a negative employment effect on all job types between 2015 and 2020 with -1.56% and -0.36% respectively according to The Future of Jobs survey (2016). Further dissecting the collection of technological progress factors in the pattern of the Fourth Industrial Revolution, on the other hand, gives a considerably more hopeful image of the employment generation prospects of technologies such as Big Data analytics, mobile internet, the Internet of Things, and robots as presented by The Future of Jobs (2016). It is important to mention that Frey and Osborne (2017) said that robots will have one of the most negative effects on employees, saying that robots will eliminate many occupations from existence.

Job Family	Drivers of Change							
	Mobile Internet & Cloud Technology	Robotics & Autonomous Transport	Internet of Things	Adv. Manufacturing & 3D Printing	Processing Power & Big Data	New Energy Supplies and Technologies	Geopolitical Volatility	Climate change, natural resources
Manufacturing and Production	-	−0.83%	-	−3.60%	-	−1.81%	−2.47%	−2.45%
Installation and Maintenance	−3.89%	-	−8.00%	-	-	-	-	3.00%
Computer and Mathematical	3.71%	-	4.54%	-	4.59%	-	3.89%	-
Sales and Related	0.43%	-	−0.89%	-	1.25%	−1.58%	−1.50%	-
Architecture and Engineering	-	4.49%	3.54%	3.33%	-	2.25%	1.33%	3.68%

Table 2. Employment Effect of Drivers of Change 2015-2020

Source: Created by the Author depending on data derived from The Future of Jobs Survey (2016)

The Future of Jobs survey (2016) participants anticipate high employment growth in the Architecture, Engineering, Computer and Mathematical job groups, a modest reduction in shopfloor positions, and a steep decrease in Office and Administrative employment between 2015 and 2020. In Table 2. The drop in overall Manufacturing and Production jobs is predicted to be fuelled by labour-substituting technologies such as additive manufacturing and 3D printing, as well as more resource-efficient sustainable product utilize, lower demand growth in aging population, and risks to world supply chains caused by volatility. In contrast, 3D printing, and robotics are all viewed as "powerful drivers of jobs growth in the Architecture and Engineering job category, due to a continuing and rapidly growing need for skilled technicians and experts to develop and oversee digitalized and automated manufacturing techniques. This is projected to result in a transition of production into a massively complex sector with a significant demand for trained and experienced engineers to contribute to making the industrial Internet of Things an actuality. On the other hand, some of the causes likely to contribute to a drop in demand for traditional professions in the Sales and Related job category include mechanization of checkout operations and intelligent supply chain management using sensors and other Internet of Thing's solutions. However, it is right that in their study Frey and Osborne (2017) predicted that there will be a very low risk on engineer occupations, but they predicted that most technicians' occupations in the shopfloor are in not less than 61% of automation risk. Yet, it is expected that the consumer industry roles in Manufacturing and production will decrease.

Radical developments in sectors and business models will influence the quality, required skills, and day-to-day content of practically every occupation, in addition to the number of jobs. Consequently, The Future of Jobs report (2016) anticipates a proportional gain in pay for in-demand occupations in all industries studied, in line with rising efficiency and skill demands. This disruption is reshaping sectors and business models, changing the capabilities that companies want and, in the meantime, lowering the shelf-life of employees' present specific skills. For example, instead of entirely substituting occupations and job categories, technological disruptions including robotics and machine learning are expected to replace various tasks previously performed as part of these occupations, liberating workers up to concentrate on new functions and resulting in quickly evolving fundamental skill sets in these professions. Other employment groups' fates have been varied as a result of these similar causes. Installation and maintenance jobs, for example, will see significant productivity gains and rapid expansion in green jobs such as the installation, retrofitting, repair, and maintenance of smart meters and renewable energy technologies in homes and commercial buildings, but will also be confronted with the Internet of Things' efficiency-saving and labour-substituting aspects. Referring that The future of Jobs (2016) indicated that net employment outlook by job family between 2015and 2020 is estimated at -1,609,000 jobs in Manufacturing and Production roles and -40,000 jobs in Installation and Maintenance.

By following a task-based approach study The Future of Jobs (2016) defines the risk of automation as a threat to a specific task in a in different occupations but not a threat for a whole occupation with what it present. From this point the researchers in this study are in contrary with Frey and Osborne (2017) that followed an occupation-based approach which considered one specific occupation as in the risk of automation which means being diminished with what it presents as tasks and roles. The World Economic Forum in its study The Future of Jobs (2017) is saying that each occupation is consisted of different tasks that could be related or not. On the other hand, a specific occupation in a country could differ in a different country from the tasks and roles, even the name which eliminated the idea in which if an occupation may be automated in one country means it will face the same fate in another country. Moreover, it presents that there a low probability for most of the occupations to be fully digitalized but a some or many tasks will be automated depending on the job considering the tasks that require contingency, human-interaction, socializing… Stemming from this approach the study predict a huge disruption in the business models of the companies and in the skills that will be required and skills set of the workers in the near future. Even more, figure 12 shows how some technologies are already affected the skill set of different jobs categories.

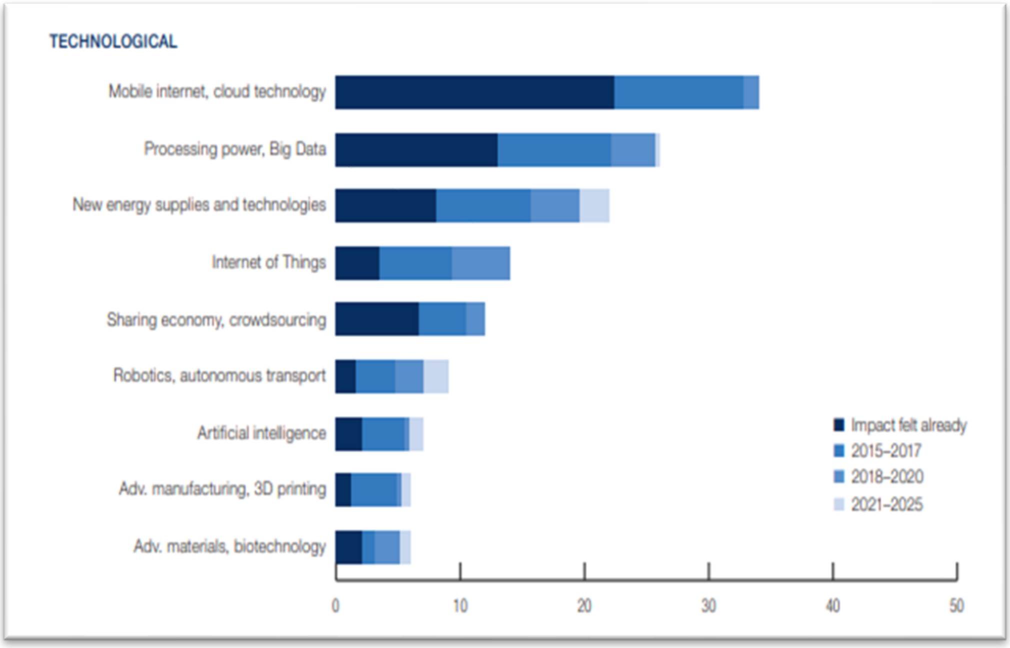

Figure 12. Drivers of Change Time to Impact Employee Skills (Share %)

Source: The Future of Jobs, World Economic Forum.

3. Challenges of Industry 4.0 for the Workforce: Skills Disruption and Job Displacement

The two studies have drawn attention to the possible impact of Industry 4.0 on the workforce. While perspectives differ on the magnitude of this influence, it is apparent that Industry 4.0 can bring significant challenges to employees.

Frey and Osborne's study (2017) stated that positions needing more education and training are far less likely to be replaced by robots, with just 0.5% of doctorate-level jobs at danger of automation, opposed to 69% of those involving only a high school diploma or less. The study did not focus on shopfloor employees particularly, but rather on the vulnerability of many vocations to automation. Researchers did, however, identify several areas that are particularly vulnerable to automation, such as manufacturing and transportation. Frey and Osborne (2017) predicted that 87% of industrial workers are at significant risk of being replaced by machines.

This comprises assembly line employees, machine operators, and other production-related occupations.

On the other hand, by following task-based approach 'The Future of Jobs' study by The World Economic Forum (2016) provided valuable insights into the changing landscape of employment, skills, and workforce strategy in the fourth industrial revolution. According to the research, business model disruption will have a substantial influence on the work market in the next years. The paper also emphasizes the employment impact of various technology breakthroughs on various work groups. Robots and additive manufacturing, for example, are projected to have a detrimental impact on Manufacturing and Production jobs by -0.83% and -3.6% respectively. The Internet of Things, Additive manufacturing & 3D Printing, and robotics, on the other hand, are seen as significant drivers of employment development in the shopfloor and mainly for Architecture and Engineering jobs by 3.54%, 3.33%, and 4.49% respectively. The study has focused in investigating the re-skilling process that is happening in the Industry 4.0 for a category of jobs and will most likely to cover a wide range of jobs and mainly in the shopfloor. It mentioned that the demand for new and high skills will surge in the next years due to the new technologies in the shopfloor and it intensified that the disruption occurring is a threat for specific tasks in specific occupations. However, the 'Future of Jobs 2016' study didn't ignore that jobs required routine tasks are at high risk of substitution.

In succession to the forgoing, we find that workforce is facing different challenges possibilities that should be deeply investigated all alone and this is something that we can rarely find so far in terms of the various previous studies specifically at the shopfloor level. The Author points here the disruption in the skills required and eliminating or substitution of a specific jobs.

3.1. Upskilling and Reskilling

The demand for new abilities among workers is one of the key challenges offered by Industry 4.0. With the introduction of new technology such as artificial intelligence, robots, and the internet of things, many employment functions will necessitate skills that were traditionally not essential. As a consequence, there is a growing demand for shopfloor labour to upskill and reskill in order to fulfil the expectations of this emerging era of business. The difficulty here is not only for staff, but also for companies, who must engage in training and development programs to guarantee that their staff is appropriately prepared for future occupations.

For more over two centuries, the manufacturing labour has been adopting new technologies; nevertheless, the Fourth Industrial Revolution is causing a disparity between eligible employees and the skills required for vacant employment. Furthermore, Deloitte and The Manufacturing Institute predict that the skills gap in American manufacturing over the next decade would be the biggest ever reported, exceeding prior forecasts of two million vacancies between 2015 and 2025. Portion of the industry's difficulty is figuring out how today's professions and related skills are changing into new employment and career paths that are evolving in tandem with modern technology. However, the sociotechnical systems framework allows researchers and stakeholders to understand the patterns of human-machine interfaces in the Industry 4.0 network, as well as the implications for shifting jobs and new skill sets (Kolade&Owoseni, 2022). They involve specific abilities for using technology to interact between employees, equipment, and goods; and the need for workers in Industry 4.0 to do more cerebral labour and less physical labour (Fareri et al., 2020; Morgan-Thomas et al., 2020). As digitalization and the Fourth Industrial Revolution proceed to reshape forthcoming factory jobs, executives and staff members alike must encompass a workplace culture that is anticipated to incorporate advanced technology and digital skills with uniquely human capabilities in order to generate the highest efficiency possible (Deloitte, 2019).

Given by Frey and Osborne (2017) perception and manipulation activities are considered at high-risk to be severely replaced. Tasks associated to creative and social cognition, on the opposite side, are less susceptible to substitution and displacement since they are non-routine and less adaptable to software programming. In this regard, many managers are considering training workforce as vital to maintain their position and increase their competitiveness.

Top 15 Skills for 2025					
1	Analytical thinking & innovation		9	Resilience, stress tolerance & flexibility
2	Active learning & learning strategies		10	Reasoning, problem-solving & ideation
3	Complex problem-solving		11	Emotional intelligence
4	Critical thinking & analysis		12	Troubleshooting & user experience
5	Creativity, originality, and initiative		13	Service orientation
6	Leadership & social influence		14	Systems analysis & evaluation
7	Technology use, monitoring & control		15	Persuasion & negotiation
8	Technology design & programming			

Table 3. Top Fifteen Skills for 2025

Source: Future of Jobs Survey 2020, World Economic Forum

Table 3 highlights the top competencies and skill categories that companies believe will become more important in the run-up to 2025. They include categories like analytical and critical thinking, as well as problem-solving, which remain on the summit of the list year after year. Lately, self-management skills such as active learning, perseverance, stress tolerance, and adaptability have emerged. Specialist talents in Product Marketing, Digital Marketing, and Human Machine Interface fall under the 'cross-cutting' skills that are a part of the new rising professions which make them the top skills demanded by employers (WorldEconomicForum, The Future of Jobs Report, 2020).

The Future of Jobs Report (2020) expected that by 2025, the hours utilized on current tasks by employees and machines will be identical. At the same time skill shortages may widen more over the next five years as in-demand talents shift throughout professions whereas expected 44% of the abilities required for individuals to execute their jobs successfully will shift. Firms believe that 40% of staff will require reskilling in six months or fewer, and 94% of company executives want employees to learn new skills on the workplace as a result of the new emerging occupations like Materials Engineers in the Automotive Sector, Renewable Energy Engineers in the Energy Sector, and Technicians in Mining and Metals. However, institutional upskilling tends to be more tightly focused on technology usage and architecture abilities, whereas emotional intelligence skills are less typically addressed.

3.2.Jobs Displacement

The ultimate goal for the key player manufacturers is to adopt Smart Factory. However, automation can be a serious risk to employment, and factory jobs that used to guarantee respectable remuneration, substantial advantages and a fulfilling career are indeed being removed by vulnerable jobs. Although the notion of a smart factory may appear beyond reach many readers, the core of it is that with the 4th IR, industrial processes may be more mechanized, lowering the amount of labour that must be done by people (Islam et al., 2020). In the last chapter we discussed jobs disruption as a result of Industry 4.0 with a focus on shopfloor occupations by analysing two of the most recent and specific studies ('Frey&Osborne' 2017 and 'Future of Jobs' 2016) about the debate in the last decade. In this section the Author will dive deeper in discussing the occupations that are at high risk of displacement and those already sought the effect of the technological progress by highlighting jobs at the edge of being diminished and the relation with key technologies that are threating these occupations.

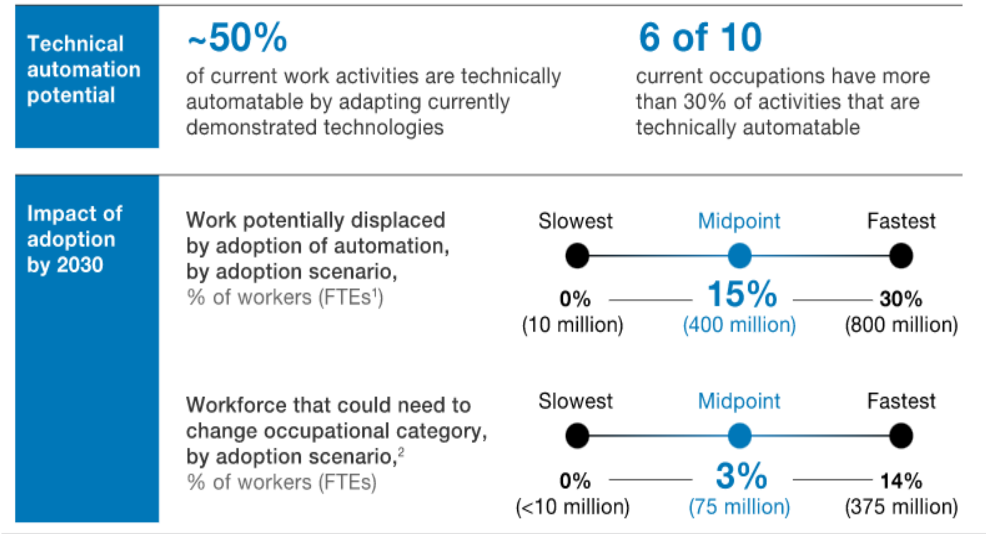

Figure 13. The Effect of Automation on the Workforce

Source: McKinsey Global Institute Analysis

The dual forces of technology and globalization have brought about major changes in labour markets (Hošman, 2020). These shifts may be seen explicitly in statistics monitoring job patterns in the United States between 2007 and 2018 where roughly 2.6 million jobs were lost over a decade (Ding&Molina, 2020). Based on a McKinsey Global Institute examination of 750 employment, "45% of paid tasks might be mechanized using "recently proven technology," and "60% of vocations might have 30% or more of their operations digitized.". After 2018, and by 2020 COVID-19 pandemic has increased the pace of the technological adoption by companies which led for additional lost in jobs at the shopfloor. For instance, Meatpacking plants, where butcher robots were employed to keep employees from being infected. This example can apply on the biggest meat processor in Europe 'Danish Crown'. It is still too early to say if the increased employment losses reported in automatable jobs will be sustained. Yet, the significant job cuts in these industries compounded the job-replacing worries about automation, since it is considerably simpler for employers (Molteni, 2025).

Case 1: At Danish Crown facilities in Denmark production the robotic initially scans the pig corpse before identifying its tail with machine vision. The feces-free corpse is then transferred to a cabinet-like bot, where a big, round cutter separates the pig from the breast to the bacon. The robot then advances to an automated, autonomous organ removal, muscle scissor, and spinal divider.

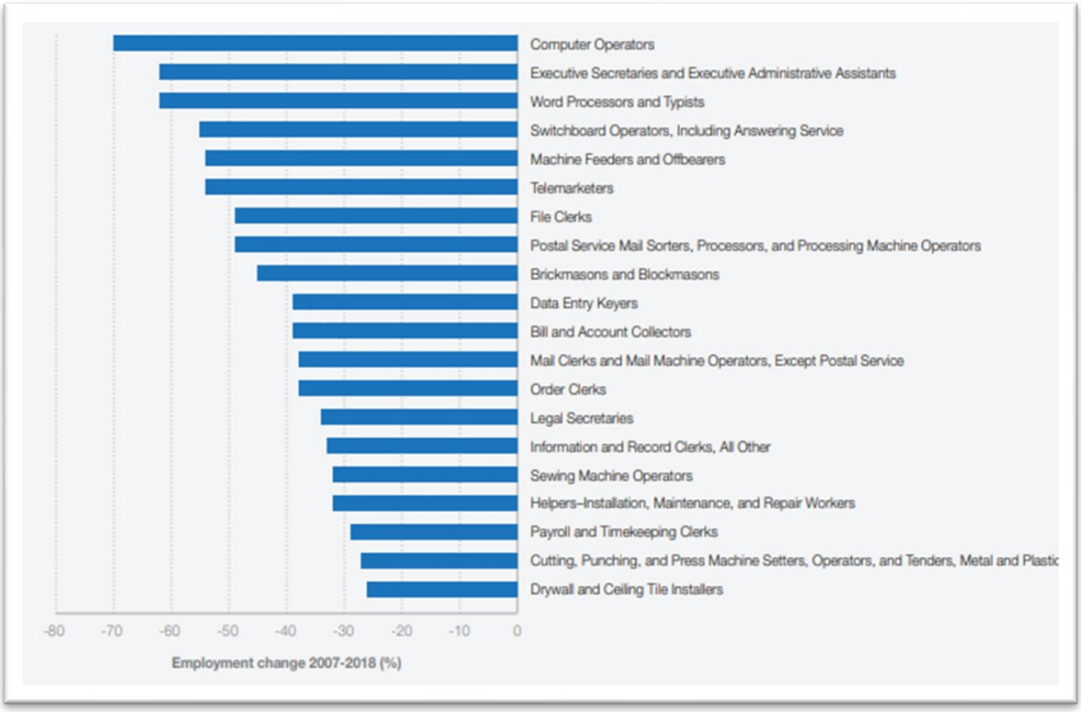

Figure 14. Workforce Patterns in the United States for Professions at High Risk of Automation, 2007-2018

Source: Ding, et al, 2020

Yet, forty-three percent of firms participated in the Future of Jobs Survey (2020) in polled plan to downsize their employees as a consequence of digital integration. On the other hand, and by 2025 6% of the workforce will be replaced by machines**.** Figure 14 depicts the positions that are being replaced, which include different shopfloor occupations such as Machine Feeders, Sewing Machine Operators, Maintenance and Repair workers, and other professions that rely on technology and work procedures that are rapidly becoming outdated. At the other end of the spectrum, the employment functions that are expected to become more obsolete by 2025 are essentially comparable with those highlighted in 2018 and in a variety of research articles on job automation. Among these occupations are the Assembly and Factory workers. These occupations as stated by Foote and Ryan (2015) are more vulnerable to automation and trade because they include more repetitive work than high- or low-skill professions as they consist of regular repetitive work. Given that, a considerable rise in the amount of companies planning to use non-humanoid robots and artificial intelligence, with both technologies gradually becoming a cornerstone of employment across industries (Ding&Molina, 2020; WorldEconomicForum, The Future of Jobs Report, 2020). While the two key technologies mentioned are a key stone in disrupting the shopfloor as per researchers who are apprehensive from the effects of the two advancements.

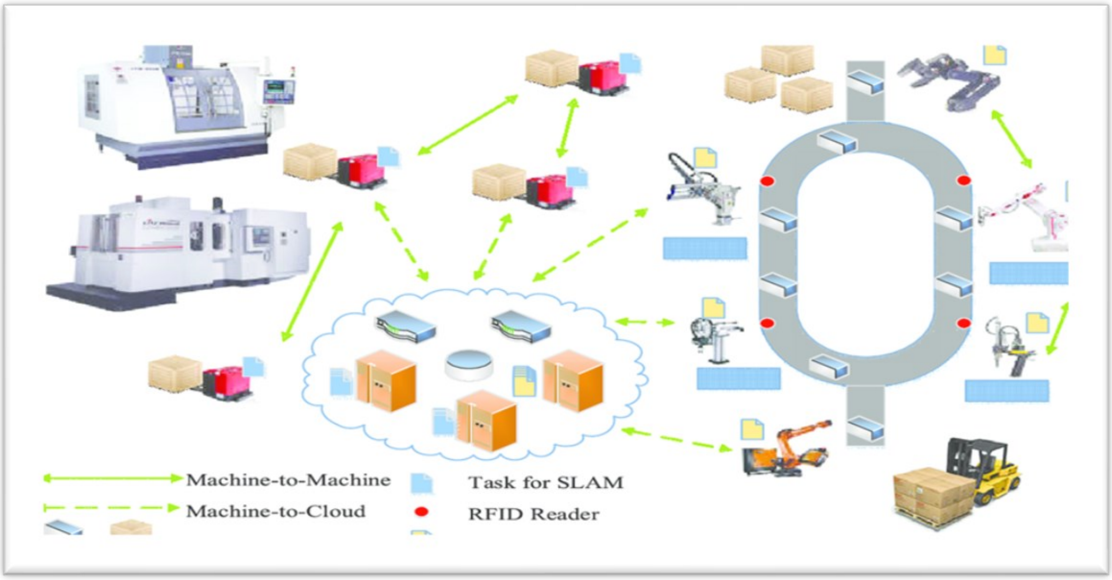

Figure 15. Cloud Robotics Application in Production

Source: Wan et al., (2016)

On the other hand, Özdenören (2020) and Brynjolfsson and McAfee (2014) have warned that technologies like 'Machine Learning', 'Machine Robotics', and 'Cloud Robotics' are capable of replacing jobs that lack clear algorithms. For them, what demonstrate that computerization is no longer limited to ordinary manufacturing operations. For example, Google's self-driving vehicles are one illustration of how manual work in transportation and logistics may eventually be mechanized. Moreover, several jobs among those with big chance of being replaced are interconnected with other occupations. This is a serious threat that around 10% of occupational boundaries would disappear, exacerbating the impact of automation. Nevertheless, Frey and Osborne (2017) have predicted that different shopfloor occupations have a probability of over 75% of being automated. Some to mention are 79% for Installers and Maintenance workers (SOC49-9098), 82% for Engine and machines assemblers (SOC51-2031), 93 % for Cooling and freezing equipment operators (SOC51-9193), 93% Industrial truck operators (SOC53-7051), 96% for Shoe & Textile machine operators and tenders (SOC51-6064). As mentioned before, there are some key technologies in disrupting these kinds of jobs for example Engine and machine assembling job is expected to fall by 6% between 2021 and 2031. Those who do roles such as using measuring devices like callipers, gauges, or micrometres, checking the compliance of items to stock lists or drawings. are being replace by Cloud Robotics.

This industrial revolution is not solely technical in nature. Although the technological infrastructure at the organization changes, it has an impact on the social (or human) system, and conversely (Knutstad&Ravn, 2014). Indeed, work organization is regarded to be one of the most difficult obstacles to adopting Industry 4.0. Yet, the human dimensions of Industry 4.0 have received little attention (Kagermann et al., 2013). Their duties are becoming less conventional and need continual knowledge and ability improvement. Employees' skill portfolios, for instance, are likely to demand increased elevated thinking and decision-making abilities (Ras et al., 2017). As Industry 4.0 compels labor markets and manufacturing processes to evolve, traditional production techniques and industrial relations will be unable to resist this shift (Kurt, 2019).

According to one perspective, we are in a transitional stage, but, as with earlier technological revolutions, in the long horizon, the equilibrium of lost and generated employment will be favorable in terms of both volume and, more importantly, quality. There will be an influence on the abilities and capabilities needed of industrial employees. The tendency of digitizing simple and repetitive processes such as machinery loading and unloading will accelerate (wolf et al., 2018). Employees will be required to perform increasingly sophisticated and tangential activities, such as working with robots, for a greater proportion of their workday (Siemens, 2013). The primary responsibilities will include the monitoring and management of increasingly automated complicated operations, as well as the oversight and optimal use of devices (WorldEconomicForum, The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution., 2016; Frey&Osborne, The future of employment: How susceptible are jobs to computerisation? , 2017). As a result, interacting with material and large amounts of data, as well as interfacing with machines, will be fundamental parts of future job activities (Gehrke et al., 2015).

Chapter 3
A Case Study Analysis

In this chapter a single case study will be analyzed by conducting qualitative research using a semi-structured interview as the thesis attempts to perform a comprehensive investigation of the topic in its actual environment. The author has chosen this approach because it enables for a more in-depth knowledge of the participant's observations and viewpoints. While the semi-structured interview was selected because it takes the workplace setting into consideration. When an interviewee provides up a subject that might be significant for addressing the study challenges, a semi-structured interview allows for more extensive conversation. Based on the frame of reference, a series of questions will be prepared that may be tailored to the company industry and the interviewee's function in the business.

The thematic analysis method will be followed for data analysis by analyzing the interview transcript and discovering significant patterns in the data's themes. The author will take precautions to prevent multiple risks to feasibility and reliability. This includes, for example, the interviewer's intention to clarify the goal of the interview for the interviewee as well as taking into consideration any participant (error/bias), and research (error/bias). The interviewee's private data, such as name and address, as well as firm names, will likewise be confidential in the thesis. Furthermore, actual data will be securely preserved to guarantee that only the researcher has access to such private data.

The overall population includes all enterprises in the industrial sector. The target population is all manufacturers and technology providers that are in any phase of Industry 4.0. More specifically the thesis will employ self-selection sampling as a non-probability sample. This selection is appropriate for a study case and make a practical realization. The interviewee must be a manager who is overseeing the embracing of industry 4.0 in a company adopting or promoting specific or several Industry 4.0 technologies for manufacturers. The ideal interviewee will have knowledge of applying Industry 4.0 technologies, be able to discuss how they can impact shopfloor workers and offer guidance on how to harmoniously integrate humans and machines in the smart factory.

Research Methodology	Followed
Approach	Qualitative Research
Purpose	Exploratory
Method	Single case study
Sampling	Self-selection
Population	Non-probability
Data Collection Method	Semi-structured interview
Data Analysis Method	Thematic analysis
Research Quality	Explain the aim of the interview, select an appropriate atmosphere, validate data with participants,
Ethics	Information confidentiality

Table 4. Research Methodology Summary (Author's illustration)

1. Empirical Evidence

Around 1300 BC, intentional iron production started with the use of charcoal as a fuel and reduction in small furnaces that used cold air. Proof of such stoves has been discovered in Africa, Asia, and central Europe. The maximum temperature that could be reached in these burners was most likely lower than the melting point of iron. To be without rust and form wrought iron, the product had to be crushed. When improved blowing mechanisms were invented, the temperature could be boosted, resulting in the formation of liquid, high-carbon iron (Ottow et al., 1998). In our days, rolling is the process in steelmaking in which metal stock is run through pairs of rollers to reduce thickness, make thickness uniform, and/or impart a desired mechanical quality. The temperature of the metal rolled determines the classification of rolling. When the temperature of the metal exceeds its recrystallization temperature, the process is referred to as hot rolling. Cold rolling occurs when the temperature of the metal is lower than its recrystallization temperature. The gear responsible for processing the metal is the roll stands, which contain the pairs of rolls and are grouped together into rolling mills, the overall term for the factories. We can distinguish between hot and cold rolling mills based on the aforementioned rolling categorization.

In terms of employment and economic growth, the iron and steel sector is important to the world economy. The iron and steel industry directly or indirectly supports around 6 million jobs. After China, the European Union (EU) is the world's second largest steel manufacturer, accounting for over 11% of global steel production. In regard to value contributed and employment, it is one of the three major EU-28 subsectors. As a result, the state of the EU steel sector is critical for future chances of economic development, creativity, and wellbeing. (Vögele et al., 2020). Steelmakers can be grouped into two broad client divisions in terms of the market: intensive manufacturers and special steel producers. The former is distinguished by the manufacturing of high-demand items for a limited number of common applications. The development of innovations and the dissemination of novel technologies and procedures in the steel industry, combined with greater contact between steel maker as manufacturers vendors, and consumers, tends to support a deepening of the sectoral manufacturing and creativity system (Martins et al., 2021).

The case study company is an Italian multinational that specializes in the design, manufacturing, and supply of plants and machines for the steelmaking and nonferrous metals industries. To handle the company's diverse product lines, services, and functions, it has over twenty business units. The company is among the top manufacturers, suppliers, and designers of equipment for the production of steel and non-ferrous metals in the world. Thirty production facilities are used now by the business to operate globally with over 3 billion of revenues.

This case study focuses on the servitization unit. The firm offers own-brand and resell replacement parts and materials, engineering assistance and consultation, virtual condition tracking, maintenance, refurbishing and repairs, and training through this unit. The servitization unit also provides technological tools that are necessary for plant and equipment operation. Hence, the business unit under study consists of two sub-units:

1. A unit in charge of post-sale and client support for machinery and plants
2. A unit centered on the technology items to provide after-sales.

The latter is responsible for providing technology tools that help in increasing the efficiency and flexibility at the manufacturer facilities and enhance the factory conditions and the production process thanks to the engineering team that is working on implementing these solutions by exploiting Industry 4.0 technologies.

Following this, the study case will be specific as an Industry 4.0 technology provider for manufacturers within the steel industry. This will help in gaining insight about different adopters of the technology provided from the view of the supplier who plays a big role in implementing these technologies in its client's factory by handing over training, installation, maintenance, technical support, monitoring etc.

The interviewee is the sales director of the latter sub-unit in Servitization unit. He is in charge of directing the global application of Guide systems technology, having over 20 years of expertise at the firm and in the steel sector. He is in charge of the supply process of Roller guides for rolling mills to 20 clients worldwide, as well as the entire guide implementation process in the client plant, communication, and post-sales services. Considering his position and duties, he is well-suited to provide useful insights into the impact of Industry 4.0 technologies on employees and to help contribute to offering guidance to managers on how to apply these technologies in their companies. His knowledge and experience make him a valuable and appropriate contributor to reaching the thesis's aims and answering its research questions.

2. Industry 4.0 Technology Provider for Steel Making Industry

In light of its reliance on resources and the growing need for more sustainable manufacturing, the steel industry is always seeking innovative methods to increase resource efficiency and sustainability. Broad tools and procedures are available that may be used in a wide range of manufacturing processes. Nevertheless, remains an obvious need for integration, advancement, domain-specific modeling, and the use of Industry 4.0 technologies (Backman et al., 2019).

Relatively slight modifications in raw material and energy usage can drastically enhance process efficiency in large-scale production. Steelmaking systems of operation are complicated structures that involve raw materials, objects, energy, systems, automation systems, and personnel. Their effectiveness entails a variety of activities and duties. Planning, Scheduling, Real-time Improvement, and Monitoring are popular classifications for the process (Daoutidis et., 2018). The steel industry's major decision-making difficulties relating to unified manufacturing scheduling for the steelmaking ongoing casting-hot rolling process have been examined. A modeling idea called "order-set" is provided, as well as an optimization model with multiple objectives to maximize the efficiency of each process, the hot charge ratio of blocks, the tundish retention rate, and the added cost of technical operations (Lin et al., 2016).

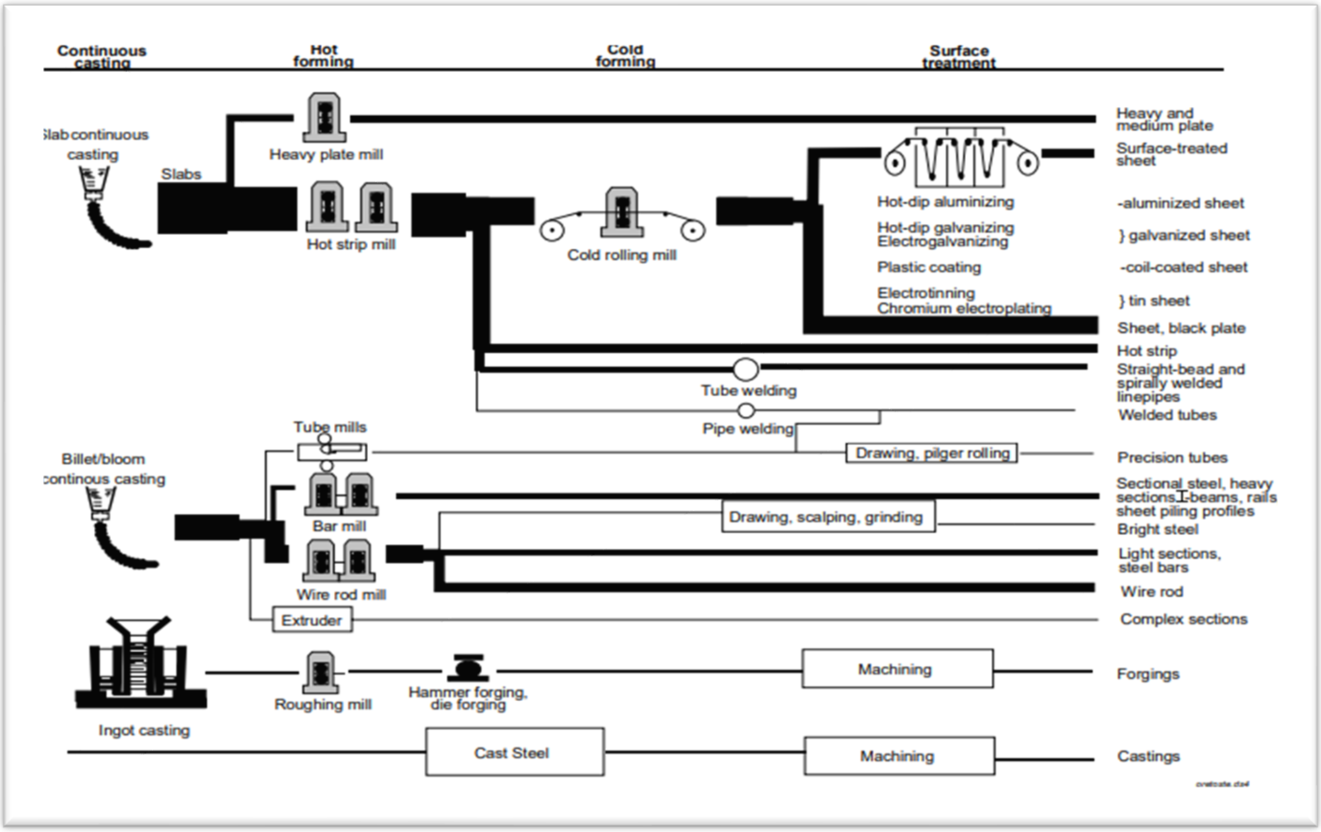

Figure 16. Circulation of Fluid Steel from Ongoing Casting to Final Output via Rolling Mills

Source: Schaubild - Vom Erz zum Stahl (1989)

The shape of finished goods and related continuously cast items are used to divide the steel industry into key manufacturing lines. In general, slabs are used to make flat items, whereas blooms and billets are utilized to make long (section) products. Figure 16 demonstrates several manufacturing lines for handling liquid steel from ongoing casting to finished products. The scope of the investigation includes two approaches that use constantly cast material as an input. Varied types of rolling mills are required for varied forms of rolled goods. The circulating fluid steel process entails the continuous transportation of the molten metal from the casting stage to the final product via rolling mills. During the casting step, molten steel is poured into molds to produce semi-finished products like billets, blooms, or slabs. These semi-finished goods are then moved to rolling mills, where they are mechanically shaped and refined into final products such as sheets, bars, or coils using methods like as hot or cold rolling. This continuous flow of molten steel from casting to rolling mills ensures a smooth and efficient production process, assuring cost-effective steel manufacture. This continuous flow of molten steel from casting to rolling mills ensures a smooth and efficient production process, assuring cost-effective steel manufacture. (Rentz et al., 1999).

The presented *Case* supplies steel manufacturers with *Roller Guides* technology. In rolling mills, *Guide Systems* are supplementary components for the manufacturing of lengthy goods. Because of the various dimensions, materials, forms, and operations they must manage, there is a vast range of them. *Roller guide* equipment directs the rolling stock at the entry and departure of the roll pass in hot rolling mills for long products, ensuring smooth rolling of the rolling stock. The guiding apparatus must be strong, precise, and steady. Rolling guide technology is critical in assuring the rolled product's surface quality. The guides must be constructed to accommodate the large range of stock sizes and shapes found in lengthy product rolling (Satyendra, 2015). The ambiguity that occurs between the guide's exit and the roll's groove results in poor output quality, uneven material flow, and higher wear on the equipment. Defaults might arise in the worst-case situation, which is not unheard of, resulting in costly downtime and repairs. Guide body sections may require repairs or replacement after long-term wear or rolling incidents. Because of Industry 4.0 advancements, the Engineering Team in Servitization unit was able to integrate two of the Industry 4.0 technologies in the Roller Guide they supply to steel manufacturers after years of continuous R&D. The technologies adopted were CPS and IoT that help in converting the conventional guide to a smart Roller Guide. Due to this, the sales manager claimed: *"Thanks to the sensor and to the motor that we apply on this other guide, we can drive the rolling mill on the first step for the industry 4.0."*

2.1. Adopted Technologies

The new enhancement by the engineering team transformed the conventional guides to a *Smart Roller Guides* (Will be abbreviated as SRG) by adapting:

A. **Cyber Physical System (CPS):** According to the International Society of Automation, cyber-physical systems are internet-enabled physical entity in the production while the notion of CPS is crucial to the execution of Industry 4.0 principles. The case adoption of CPS took place by integrating Smart Sensors into the Roller Guides. These sensors are IP address-assigned entity that are capable of self-monitoring, generating information on their own operation, and interacting with other linked entities or even the outside environment. It serves as an autonomous and self-sufficient process. The Smart Sensors implemented are also sufficient for enhancing the Human-Machine interaction where the operator can remotely monitor the process in a more flexible and efficient way.

B. **IoT Motors:** Prior to the broad deployment of IoT in manufacturing settings, specialists and operators of machinery would have to plan regular maintenance in order to detect what requires to be modified. Predictive maintenance is a means of averting expensive industrial equipment failure by evaluating data during production to identify odd behavior ahead of time, allowing suitable actions to be implemented to avoid lengthy periods of production downtime (Johson, 2020). The IoT Motors deployed by our case exchange data and offers predictive maintenance by applying an analytical method; employing real-time and historical data to show where a machine is not working as it should so that it may be corrected ahead of time. Each *Roller Guide* has two motors. The IoT Motors function by transferring data to enable the communications network to transfer safe information from the machinery to a data storage system. Then, the analytical data uses algorithms to the stored data in order to gain insight into how the system should perform and what it may be doing prior to breakdown. This information is then sent to the operator in the form of warnings and observations.

Based on the Industry 4.0 technologies adopted, the company is now able to provide its clients with two series of smart *Roller Guides*. Both *Guides* are motorized and function autonomously within the client plant. The intelligent *Guide* setting allows the configuration to be modified in seconds from a safe place. This will boost overall equipment efficiency greatly. The actual name of both guides will be changed in this thesis to preserve confidentiality.

i. **The X Guide:** It is a smart automatic guide with an online dimension. For more precise and accurate guidance control, strain sensors and motors are used to automatically adjust the roller width based on the dimension fluctuations of the circulating material during rolling. RX was developed to help change dimensions automatically from a current mill or control screen. The Intelligent Guide offers excellent guidance, autonomous, and it is user friendly.

ii. **The Y Guide:** It is a wire Guide that has smart sensors and motors to automatically adjust the position of the guide's exit with the channels of the rolls, which can shift up to 10% owing to cooling during spinning. The smart sensors operate under the 'Bearing Wear Monitoring System' and are installed in each cylinder chamber, detecting every time the crosshead passes the bottom dead center. These sensors compensate for cylinder velocity, chamber climate, and motor deviations caused by vessel maneuvering or cargo loading.

The integration of "CPS" and "IoT Motors" into the conventional *Roller Guides* transformed the whole rolling process of steel to be smoother and more flexible. According to the interviewee, the smart *Guides* are completely different from the conventional *Guides*,

"By adding sensors, we can receive feedback from the rolling mill and in the other side, having this feedback we can move with the remote monitoring because there is a circularity… Thanks to the motors".

I4.0 Technologies	Product	Function	Industry
CPS	Roll X Guide (RX)	Smart sensors for autonomous adjustments and control	Steel making
IoT Motors	Roll X Guide (RX)	Data transition and predictive maintenance	Steel making
CPS	Wire Smart Guide (WSG)	Smart sensors to compensate for cylinder velocity, chamber climate, and motor deviations	Steel making
IoT Motors	Wire Smart Guide (WSG)	Data transition and predictive maintenance	Steel making

Table 5. Industry 4.0 Roller Guides Provider Overview

(Author's illustration)

2.2. Smart Roller Guides Adopters

Eventually, the *Roller Guides* are being implemented in the plant and in the manufacturing process of the Smart guides adopter. Therefore, the operator and actual adopter are the manufacturers, being the clients of our study case. Twenty clients were using the conventional guides provided by our case study. At the time the interview was taken, 10 of these clients have transformed their conventional roller guides to Industry 4.0 roller guides developed by the provider. The 50% of the clients transformed their conventional rolling process to a digitalized process reflecting how the steel industry is seeking innovative ways to increase resource efficiency and sustainability because of its reliance on resources such as electricity, raw materials, and utilities.

The Sales manager stated that the level of maturity of implementing and using Industry 4.0 technologies embedded in the smart *Roller Guides* is at an advanced adoption level. This is because the technologies integrated with the roller guide transformed the whole functionality of the guide by converting it into an autonomous and smart guider. At the same time, this changed the whole manufacturing process in the steel industry and the way the rolling mill operates and the Human-Machine interaction which changed how the employees operate the plant.

Roller Guides Clients	SRG Implementers	Adoption Maturity Level	Location	Application
20	10	Advanced	Shopfloor (Production)	Rolling mill Plant

Table 6. Smart Roller Guides Adopters Overview

(Author's illustration)

2.3. Reasons for Adoption

As mentioned above, ambiguity may happen anytime during the production process. The reason is that *Roller Guides* are functioning under extreme circumstances, and pieces in touch with the substance are exposed to severe wear because the material guided by the *Guides* has a temperature of around 900°C and is rolled at speeds of up to 130m/s in the fast-finishing blocks. Before this enhancement, the Roller Guide was *"Just a piece of steel"* as stated by the interviewee. This is due to the fact that the former Roller Guide was left-out of tools that help increasing the lifetime of the *Guides* facing the conditions they deal with which leads to increased down-time and defaults in the production process.

Through the smart *Roller Guides* the company brought the rolling mill plants to the first step in Industry 4.0. The purpose behind this is to allow the manufacturers to understand better the production process behind the rolling mill by helping the rolling mills plants to become smart and digital. This is derived from the vision of the company to be a first mover in Industry 4.0 and gain a competitive advantage over the competitors by meeting the evolved requirements of the steel making sector due to the complex manufacturing process.

Considering the potential of the Industry 4.0 Roller Guide provided by our case study, 10 clients took the initiative to implement the smart Roller Guides in their plants to enhance the manufacturing by gaining:

A. **Know-How (Increased Efficiency):** The interviewee has mentioned: *"The adoption of smart roller guides has allowed the rolling mill specialist or the people that works in the rolling mill to understand better the production process taking place within their plants"*. By gaining awareness of the production process the adopters were able to increase efficiency and reduce the downtime of their plant. The manufacturers were able to gain know-how because of the constant feedback on rolling mill efficiency, ensuring that each cycle and billet is producing at maximum capacity. Analyze and develop novel procedures rules while taking into account all rolling mill characteristics such as climate, metal class, velocity, symmetry, wear, and so on.
B. **Competitive advantage:** The invention and adoption of new concepts place tremendous economic pressure on factories utilizing traditional technology, as new innovations offer major cost-related benefits in terms of investment. By gaining knowledge about their production process and a remote monitoring system the operator is able to increase productivity by having continuous feedback and updates in the operator screen, reducing the downtime and defects as a result of the machine learning algorithms function in the IoT motors, and improve the quality of their final product which leads the adopters to enhance their positions as steel manufacturers.

C. **Enhanced Safety:** According to the sales manager: *"Rolling mill is a very, very dangerous place because it operates with 1000 degrees".* Applying SRG inside the manufacturer factory means that there is no need for the operators to enter the mill floor; reassign experience in the pulpit and workshop. The reason is that the IoT motors through exchanging data and following predictive maintenance help in discovering any possible failures time ahead. While thanks to the *Smart Sensors* the operator is able now to remotely fix any defaults even before they take place.

It is worth noting that according to the participant, each manufacturer among the adopters implemented SRG seeking a specific advantage. This is also dependent on the nature of the market the manufacturer is operating within and the market regulations of the geographical region. For instance, manufacturers and clients from East Asia and countries like China focus on the economic competitive advantage and cost efficiency as priority over final product quality and safety. On the other hand, manufacturers in Europe mostly consider enhanced safety as the main driver for the adoption of the smart *Roller Guides* because of the strict safety policies in Europe.

3. Adoption Impact on Employees

It is perceived that current advancements in Industry 4.0 will have extensive effects not only on real production and applied manufacturing commodities, but also on the inner organization and external collaboration between enterprises and human employees. Cyber-physical systems (CPS) that are networked and pervasive, in addition to the integration of data, technology, and process-driven engineering shift cooperative activities (Ludwig et al., 2022).

The interconnectedness of the virtual and real-world surroundings in CPS enables new adaptive manufacturing processes that were not before possible (Spöttl&Windelband, 2021). As a result, Industry 4.0 might be considered the formal creation of the Internet of Things via CPS. However, Industry 4.0 adheres to a broader idea of interconnectedness that aims to examine and correlate all stages of the value creation process. The 'intellect of interconnection' is intended to envelop the entire production, with intelligent equipment organizing manufacturing processes on their own, also to the extent of having to cope with the practicalities associated like logistics (Bauernhansl et al., 2014; Brynjolfsson&McAfee, 2015). Although, within this contest, humans have significant roles in leading and controlling processes in Industry 4.0. Nevertheless, different, and new process interactions between the employees and the types of equipment's will take place, also, the shopfloors will demand highly qualified people to support a larger and more technologically advanced organization. (Baur&Wee, 2015; Spöttl&Windelband, 2021).

In this case, the respondent underlined that workers would continue to play an important part in the rolling system when the new technologies are installed. However, employees must be prepared to deal with the new methods, as human-machine interaction is essential for a more effective shopfloor.

3.1. Job Characteristics

As per our participant, when they implemented the smart Roller Guides, he stated: *"We passed from a piece of steel"* referring to the conventional edition. With the integration of the motors and sensors the new roller is now more complex. This means that new and evolved skills are required among the employees because the process is not anymore mechanical but electronical. Precisely, the sales manager defines the process as *"Mechatronic"* because they combined the mechanical part with the electrical part and automation. Nevertheless, the new skills or expertise required are varied which means all employees will have to play their role in the new process.

On the other hand, there will be less autonomy in the manufacturing process. Implementing the new technologies, requires less physical interaction from staff with the rolling mill by converting some manual work into automatic and monitored while operating. However, the operator is now required to work with smart systems of process monitoring and functioning through continuous data flow and remote control. The machine operator will receive real-time feedback on the manufacturing of each billet, which will indicate groove wear and stock variance. Operators might be proactive and question typical manufacturing. Hence, digital skills are more important now.

The impact of Industry 4.0 Roller Guides is more evident for blue-collar employees as mentioned by the participant. As the downtime will decrease, maintenance and replacement will reduce the manual work. Soft skills are now essential for this party of employees. Besides, white-collar employees will be able to receive and analyze data which may lead to a higher innovative environment at the company.

3.2. Benefits for Employees

There are several risks in the iron and steel sector that might result in injuries or disorders. Sound, heat, fire, toxins, and environmental risks are among these dangers as stated by Environmental Pollution (2023). One of the key characteristics of Industry 4.0 technologies is that they evidently enhance the safety conditions at the shopfloor.

For the case study, the safety enhancements are on the top of the benefits witnessed for the employees. Thanks to the new advancement workers don’t need to enter the rolling mill room. Hence, employees are facing less harsh conditions and risks. The smart guide systems reduced injuries rate at manufacturers' facilities.

In addition, by decreasing the amount of physical work, employees are now operating more flexible and participating in less exhausting duties. Productivity among employees increased on the other side, by receiving real-time data which helps them understand the manufacturing process and determine breakdowns before they happen and design products and shapes more efficiently within the rolling mill.

On the other side, white-collar employees are gaining know-how which help them enhance creativity and innovation. They are now able to design better product quality by having data base and digital analytical tools.

Technical Impact	New Skills Requirements	Impacts on Employees Jobs	Employees	Benefits
Less autonomy	Digital skills	Remote monitoring and process control	Blue-collar	Harsh conditions elimination and increased productivity
Reduced downtime	Soft skills	Less maintenance and replacement rounds	Blue-collar	Lower manual and exhausting duties
Higher Data-transition	Digital and soft skills	Gaining Know-How	White-collar	Creative and Innovative environment

Table 7. Employees Impact and Benefits Overview

(Author's illustration)

4. Management and Leadership

The incorporation of Industry 4.0 technology has resulted in an evolution in management and leadership approaches. Executives in Industry 4.0 must be adaptive and agile as they must be capable of leading their staff through the digitization process and leveraging technology to generate innovation (Tetik, 2020; FRANCKE, 2023). Leadership in the Fourth Industrial Revolution: Faces of Progress, Deloitte's second research on Industry 4.0 preparation, identifies four sorts of leaders who will prosper in Industry 4.0: talent champions, ecosystem orchestrators, social supers, and data-driven deciders.

- **Talent Champions:** are executives who are dedicated to acquiring, developing, and keeping great talent.
- **Ecosystem Orchestrators:** are leaders who emphasize forming alliances and ecosystems to generate creativity and development.
- **Social Supers:** These individuals are devoted to generating a good social effect and contributing to changes in society.
- **Data-Driven Decision-Makers:** These executives utilize data to take educated decisions and influence company results.

4.1. Employee Preparation for Industry

To prepare personnel for Industry 4.0, firms must examine their needs and determine how Industry 4.0 technology may satisfy those demands. Firms must provide straightforward and compelling value propositions for their workers in order to recognize the benefits of learning new skills and for organizations to recruit external talent to fill specialized areas for which there are inadequate internal applicants (Ellingrud et al., 2020).

Our participant said: *"As soon as our client decide to implement the new technology, we organize on-site training in order to learn and help both blue-collar and white-collar employees how the smart roller guide works"*. For him, this is the first and the main step they took in order to assure an excellent functionality of SRG in the factory floor. The preparation for employment takes place by giving a precise knowledge about the smart guide system and the technologies embedded in it. Furthermore, by bringing this insight to the employees the training helps them in understanding the skills they need to develop or acquire to successfully integrate with the digitalized system. A last important aspect is assigning people with the appropriate talents to the appropriate occupations to create, manage, and maintain their automated equipment and digital processes, as well as to perform tasks that machine cannot.

For the case, it is correct that the manufacturing process is now more complicated. However, the smart guide is user-friendly, and it is not difficult to operate. Hence, the employees will find it easier to adapt the new technology.

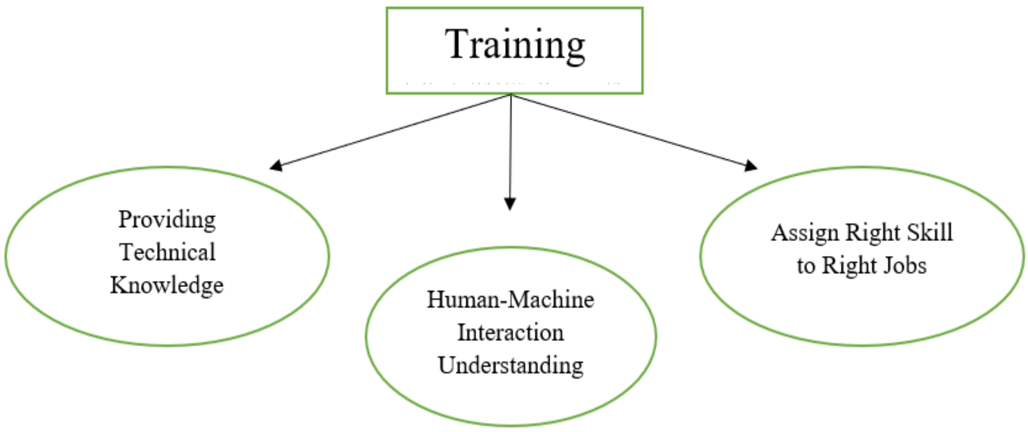

Figure 17. Training Activities in Employees Preparation for SRG

(Author's illustration)

4.2. SRG Impact on Management and Leadership

Industry 4.0 digital know-how management helps firms to break down data silos and link people, products, machinery, and processes from the factory floor to the executive officers to accomplish continuous and consistent management improvement (Chen&Zhou, 2018). Management and human resources should play a crucial role in this endeavor, locating high-potential personnel with the education and training required for higher-skilled roles, as well as those who are inclined to remain with the firm in the long term.

The provider in our case study didn't witness any significant change on the leadership and management level of his clients. Leadership approaches in the company are still the same in most of the aspects. Nevertheless, there is clear evidence on how the emerged data and the transition of it within the shopfloor and from the shopfloor to the whole organization changed the way leaders are approaching in some respects. The executives are now giving more importance to creativity and ideas flow at all organizational level. Managers are now setting plans and taking data-driven plans and decisions.

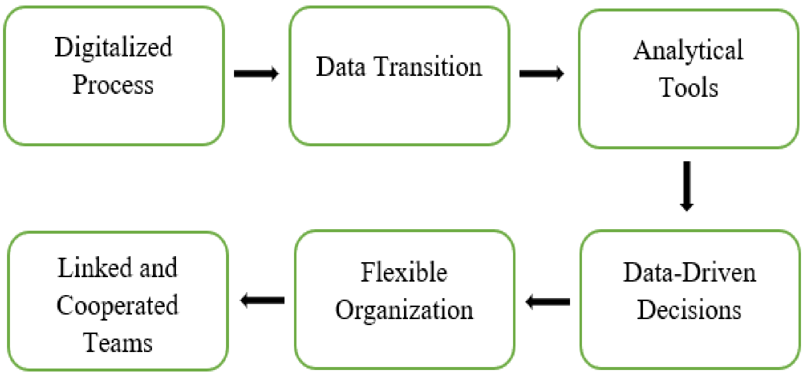

Figure 18. Digitalization and Data Flow Impact on Leadership at Clients Facility

(Author's illustration)

5. Challenges and Strategies for Adopting Industry 4.0 Roller Guides

Implementation of Industry 4.0 technology might be difficult for leaders in general, and especially in the steelmaking industry with one of the most complex manufacturing processes among all industries. Managers must evaluate the return on investment for Industry 4.0 technologies, execute complicated tools, and confront uncertainty about technology needs, advantages, and institutional implications (Alsaadi, 2022; Almeida et al., 2022).

Executives in the steel manufacturing business confront extra problems, such as integrating new technology with current systems and procedures. Despite these obstacles, numerous firms are investing in Industry 4.0 technology to increase manufacturing efficiency, asset utilization, performance, and support (daviteq, 2020).

Our participant has repeated that the process of implementing SRG can face different challenges. However, these challenges can differ from one client to another. This can depend on several factors like "Organizational Complexity", "Company Culture", and "Company Staff" etc.

5.1. Challenges for Implementation

Firms confront several hurdles while implementing Industry 4.0 technology, encompassing both technological and cultural challenges. Among these difficulties are:

- Innovative business models: a novel approach's concept.
- Updating your organization and procedures to optimize new results.
- Recognizing the company's case.
- Running skilled pilots

Along with to these hurdles, behavioral variables might influence the implementation of Industry 4.0 technologies. There is an absence of digital planning and assets, as well as a lack of norms, expertise, and human and financial resources (Sparkes, 2022; Kalsoom et al., 2021). As mentioned above, each company can face a specific challenge while implementing the provided technology. In the case study, the interviewee has defined 2 challenges:

5.1.1. Technical Challenges

The progress of machine learning and the rise in information processing capacity are projected to unleash a rush of technical advancements that will broaden the scope of robots to non-routine, complicated, and soft skills, and hard skills. Algorithms can now make sophisticated financial market judgments, diagnose ailments, and conduct sophisticated investigations of legislative records, jobs that were formerly handled by highly skilled individuals with postsecondary education (Marengo, 2019).

The interviewee has determined that there is a huge technological concern for most of the clients. The first reason behind this is that the operators are trained and *"used"* to the roller guides as *"a piece of steel"*. As presented before, the new roller guides are smart technologies that radically change the manufacturing process of the rolling mill as the new technologies embedded in the smart guides transform the process into a digital one. This requires the company to prepare itself by facilitating its shopfloor with all required assets to implement the new guides successfully.

In addition, the employees must be trained to operate the digital rolling mill and control the smart process while interacting with intelligent tools. These new tools can be complex and need trained and adequate personnel. To be precise, the employees that were dealing with the conventional guides can damage the smart one in the absence of training initiatives.

5.1.2. Cultural Challenges

Industry 4.0 is being a period of technical innovation that has resulted in considerable alterations to company operations. Yet, some executives and staff members are still a long way from implementing Industry 4.0 technologies in their organizations because of their *"Old mindset"* as defined by our participant. This mentality is distinguished by a lack of understanding of the benefits of Industry 4.0 technologies, reluctance to change, and apprehension about job loss according to Dieste et al. (2022)

Leaders' ought to view Industry 4.0 deployment as a long-term strategic choice to improve not just operational efficiency but also social and environmental outcomes. Workers' embrace of cutting-edge technology ranges from classic opposition or operational doubt to a more lighthearted attitude toward Industry 4.0 adoption. Executives may utilize the recognition of lean management that must be included in a digital transformation program, as well as ideas on how to effectively interact with them, to successfully lead the Industry 4.0 transition path in their firms (Schneider&Sting, 2020; Bellantuono et al., 2021).

5.2. Strategies for Implementation

In our case study, the provider is playing a vital role in supporting its clients to implement Industry 4.0 roller guides giving a complete guidance and providing training programs to help employees and managers through the journey of adoption. It is worth noting that our case is entering the world of servitization by implementing a servitization business model that allows manufacturers to lease the smart roller guides. In this instance, the provider oversees maintenance, operating certain components of the process, and managing others. By doing so, the supplier relieves the producer of the burden of technological complexity.

Nonetheless, the servitization approach is being hampered by clients' concerns about privacy and data ownership, as the provider may have access to various aspects of the manufacturing process.

On the other hand, the interviewee has insisted that it is important for the managers to change their mindset and view the long-term implications of adopting Industry 4.0 technologies by implementing the smart roller guides to be able to remove the cultural burden. Furthermore, it is important that the employees with positive view regarding the implementation try to help their company to evolve it is approach and take initiatives that can help in transforming to digital environment as stated by the participant.

Challenges	Reference	Strategies to Overcome
Technical Concerns	Complexity	Provider Support
Cultural Challenges	Managers and Executives	Breaking the "Old mindset"

Table 8. Challenges for Industry 4.0 Roller Guides Implementation Overview

(Author's illustration)

6. Results of Implementation and Future Developments

As per Morengo (2019), a portion of Industry 4.0 reimbursement effects will be significantly parallel to those seen in earlier industrial revolutions: the creation of new jobs in technology industries, physical activities that enhance such servers, and in all areas, while undergoing a reduction in labor value per unit of goods, will gain from a significant increase in demand due to lower prices and greater productivity facilitated by mechanization as whole. Furthermore, one of the primary outcomes of this industrialization will be improved working conditions.

In our case, the presented reasons for implementing the SRG in the manufacturer's facilities were the desire for improved security by shielding employees from the harsh conditions of the manufacturing process, gaining a competitive advantage while decreasing operational costs and boosting the innovative environment internally, and being able to maintain superior quality of the product.

6.1. Implementation Outcomes

The intelligent guides are the result of numerous years of mindful customer support in the sector of roller guide applications, which, thanks to the ability of company engineers to integrate mechanical and digital technologies, resulted in the resolution of all major problems and constraints associated with conventional roller guides: Misalignment issues were resolved; guide failures were resolved; guide configuration adjustments were reduced; and safety conditions were adjusted.

Although each client has a specific goal for the implementation, each customer has received satisfactory results from adopting the SRG. For the case studied, the firm's aims are the same as the clients, and the company has met both major objectives: enhanced security and improved efficiency. Employees in the new process are no longer near the rolling mill, but rather in the machine's room, which protects them from any potentially hazardous physical touch with the rollers because maintenance can be done digitally, and roller position can be adjust in the same manner.

Moreover, the increased productivity is tangible for the manufacturers after the implementation of SRG. One example is a German customer who, following the installation, reached a milestone in his rolling campaign. When compared to the previous campaign, the efficiency achieved is four times greater. This is because downtime has been reduced and the process is now more independent and runs for longer periods of time.

6.2. Future Developments

In a highly competitive industry like steel manufacturing, an innovative and creative workplace is necessary. In the fight to acquire market share, this industry has seen continuous improvements and innovativeness. The interviewee has stated that due to this competition it is not easy to share future plans or innovations: *"Competitors are waiting to steal our technologies!"* he stated.

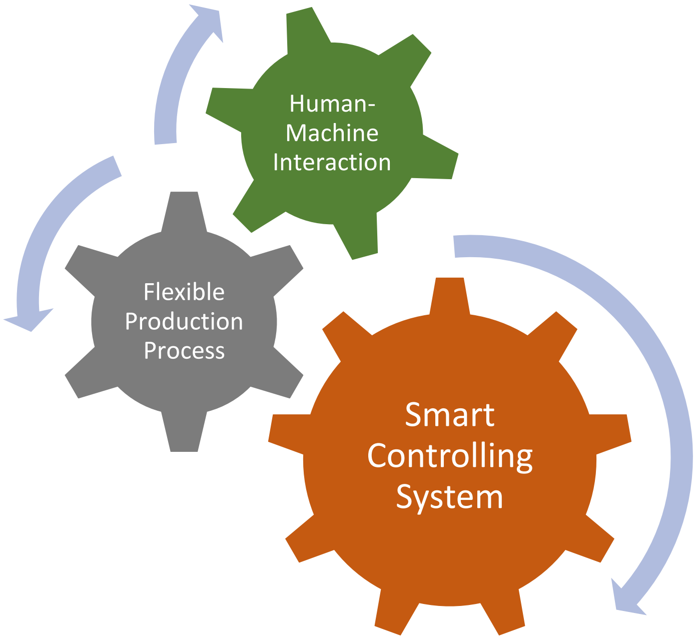

Figure 19. Smart Control System Implications

(Author's illustration)

The sales manager highlighted the company's ambitions for many developments and opted to speak briefly about the introduction of new Industry 4,0 technologies. One new technology is a lot more dependable technique for controlling and checking the forces, which will assist clients in even more flexible production process. If, for example, the incoming section in the roller guide changes due to wear in the rolling stands prior, the force pushing the rollers apart increases. The system, which is linked to a computer system, measures this rise. The computer system records all data. Significant changes in power can be observed if the rollers of the SRG are broken or if the bearings are not properly seated. The computer provides notifications indicating that the errors must be fixed (See Figure 19).

In addition, a software that runs on the iCloud will be implemented. This program is an update to the previous version, and it incorporates iCloud. It aids the roller mill in determining the design of the roller pass. This will assist operators in understanding how to deal with metal to improve quality and productivity by receiving more filtered and precise data. Implementing the upgraded software will help clients to calculate how many passes and which shape they need. This software can be connected also to the intelligent system because it gives operators the feedback provided by the guides, due to this the operator can modify the parameter using the software in order to realize the best production plan. Also, it helps setting the best production design that the manufacturer needs for one product to increase the quality (See Figure 20).

Chapter 4

Suggestions for Future Development

Industry 4.0 technologies are transforming the industrial process and revolutionizing the world of industries. More advanced production processes, new organizational divisions, and new staff talents are being seen. It has sparked intense discussion among academics, engineers, industry professionals, and managers. No one can deny that Industry 4.0 technologies may assist industrial processes and management to improve efficiency, productivity, and competitiveness. However, some individuals are apprehensive about the socio-technical repercussions of using these technologies on employees. As described in Chapter 2, the group with positive view of Industry 4.0 implications anticipates better working circumstances and good consequences on the same employees.

Nonetheless, the adoption of Industry 4.0 across industries in both developed and developing countries are rising. There are convincing indicators of the economy's digitization march. Microsoft, Apple, Facebook, Uber, and other organizations are leveraging digitalization to help them run their operations. Digital technologies are becoming more and more important every day to small and medium-sized organizations. In Hamburg, for example, around 92,000 enterprises are registered; 90% of these organizations utilize digital devices to enhance their work processes (Spöttl&Windelband, 2021). This rate of deployment is particularly noticeable for IoT and CPS technologies, as demonstrated in our case study. As mentioned in Chapter 1, North America is one of the leading areas in embracing IoT technologies, while Europe is a key participant in deploying CPS and Cloud computing technologies. Italy is becoming a hub of Industry 4.0 implementation through efforts such as highly specialized center network allocation and fostering investments in innovation in highly competitive manufacturing clusters through its "Industria 4.0" program. Chapter 2, helped in understanding better the integration of Industry 4.0 through explaining the RAMI4.0 architecture.

In accordance with Chapter 2 of the Future of Jobs (2016) study, IoT, smart sensors, and cloud computing technologies will have little employment impact on manufacturing and production job categories. However, the impact on installation and maintenance tasks would be unfavorable, with -3.89% for smart sensors and cloud computing, and 8% for IoT. Furthermore, these technologies had a beneficial impact on Math and Computer occupations, with 3,71% and 5,54%, respectively. In our example, the SRG provider has noticed a significant improvement in the shopfloor conditions. Employees are now safe from potentially dangerous situations and injuries. Furthermore, less physical effort is now required. White collar employees, on the other hand, are in an improved position and getting further information through know-how. Maintenance may now be performed digitally. Because of the sensors, the operator can now get default notes before any harm occurs. However, the manufacturing process has gotten more complex, demanding the development of new skills to assist people in adapting to and engaging with new technology.

In our case, IoT and CPS as represented by smart sensors are viewed as a supporter and addition to employees' tasks rather than a substitute, particularly on the shopfloor. Our participant told us that no SRG consumers contemplated work substitution by applying intelligent guides. In contrast, the primary goal of integrating technology was to improve employees' positions in most situations and achieve a competitive edge in others. The influence on employee profiles is obvious in the instance provided, and this is supported by the respondent, who stated that all employees must be educated to utilize the SRG properly, and various employees now require a new set of abilities.

The participant stated that the first and most effective strategy to address the difficulty of skills and abilities is to ensure that the finest training methods are used, and that staff are prepared by altering their *"old mindset"* of being dubious of new improvements. Managers have a variety of additional hurdles in order to successfully adopt Industry 4.0. Most businesses are still in the early stages of implementing Industry 4.0, therefore managers must be aware of how to manage this adoption and prepare their employees for this change.

The author will study the facts offered in our case and analyze findings in order to propose suggestions and work toward contributing to managers in utilizing Industry 4.0 technology. The work will be ended in the last part by outlining the major points relating the thesis's objectives, questions, and contributions, as well as reviewing the study's limits and presenting suggestions for future research. Following the research's goal and concluding the third chapter, three suggestions will be provided in this part aimed at helping managers in effectively implementing Industry 4.0 in their facilities. The first suggestion ‘Training and locating the appropriate use cases’ considering the technical position of the employees and helps the managers to implement the right technology in the right place and prepare the employees to successfully interact with it. The second suggestion is critical in assisting the company to confront the digital transformation and to be linked vertically and horizontally, which is a critical part of effective Industry 4.0 implementation. The last proposal, "Leverage Internal Capabilities," outlined how a firm might successfully implement Industry 4.0 by developing an innovative culture, investing in ongoing learning and growth, and building cross-functional cooperation. These suggestions emulate the socio-technical situation of the employees and the economic position of the managers' company and aims to contribute to exploring and presenting a guidance for companies' managers in how to successfully embrace Industry 4.0 and smart factories while maintaining the harmoniously human-machine interaction the smart factory.

1. Training and Locating the Appropriate Use Cases

Many companies lack the competency of training and preparing their employees for Industry 4.0 technologies. Especially when we speak about SMEs. In our case, the Industry 4.0 technology provider is offering and immediate on field training for the employees of the implementor. However, it is essential that each company should align the employees with an internal educational program. On the other hand, Executives must find the appropriate Industry 4.0 applications that correspond with their company's objectives and targets. To be competent to implement new technology, employees must have qualities such as desire of learning and transiting to a new way of processes.

Identifying the appropriate field and area in which to integrate technology, as well as the appropriate technology to apply in accordance with the company's strategy and goals, will assist in adequately training staff. Aligning the firm's goals with the implementing components of Industry 4.0 is essential for the organization to accomplish its objectives and ambitions. All personnel of an organization must be familiar with IT security problems. It is critical to enhance knowledge among all production personnel, from expert machine operators to security software programmers and industrial planning engineers. The method employee personas proposed by Deloitte is an effective method to assign the right skills and training program to the right employees.

2. Validate Vertical, Horizontal, and End-to-End Integration

The necessity of vertical and horizontal integration is described in Chapter 2's architecture design RAMI4.0. The vertical axis is the axis of the six levels that organize organizational operations, business communication, and transition management to address the digitalization transition phase. The hierarchical levels linked with the shopfloor are known as horizontal integration, and the whole organization is a connected world with the shopfloor.

Abilities for using technology to interact between employees, equipment, and goods; and the need for workers in Industry 4.0 to do more cerebral labour and less physical labour are a must in Industry 4.0.

Vertical, horizontal, and end-to-end integration are required for successful Industry 4.0 adoption. Integration mechanisms in Industry 4.0 has been proposed, taking into account the socio-technical systems influence on people, infrastructure, technology, processes, culture, and objectives. Utilizing fully integrated and networked facilities improves capacities and efficiency. It also improves staff ability to innovate more. Remote control and horizontal integration are possible with the Functional Layer. This preserves the reliability of data and process circumstances, in addition to the technical level's incorporation. This will assist managers in developing a clear vision of what they want to accomplish with Industry 4.0 and how it fits into their entire company strategy.

3. Leverage Internal Capabilities

The benefits associated with Industry 4.0 technologies, particularly IoT and CPS technologies, include that they improve employees' positions if they are properly enabled. Because of a more flexible and directed production process, the technologies deployed in the scenario given helped achieve greater performance and improved efficiency.

Managers must examine both socio-technical challenges and economic benefits while developing a plan to adopt Industry 4.0. On the one hand, staff must accept the transformation and embrace new technology. On the other hand, management should strike a balance between employee requirements and achieving a competitive edge by lowering manufacturing costs and increasing internal innovation. Lean manufacturing is a customer-focused practice that aims to give customer perceived value with minimal resource utilization and waste removal.

Davies et al. (2017) discussed a Lean/Six sigma initiatives of lean manufacturing. Six Sigma is a problem-solving technique that is organized and based on the DMAIC [Define, Assess, Improve, Control] gradual implementation strategy. The advantages of starting a lean/six sigma improvement project extend beyond providing customer value and enabling cost reduction. Among these advantages is the creation of a culture of continuous improvement in which both the management structure and the general workforce will not only tolerate but actively push change. Furthermore, there is bound to be a built-in problem-solving framework in place where individuals use solid scientific approaches to execute long-term solutions to difficulties. Subsequently in a lean/six sigma setting, manufacturing and service systems are likely to be solid, productive, and efficient, with minimum production delays, errors, and rejects. Thus, adopting Industry 4.0 and exploiting a step change in operational performance inside a corporation is made easier by a lean environment.

Conclusion

This research aimed to examine the challenges and possibilities given by implementing Industry 4.0 technologies, as well as the socioeconomic and socio-technical impact of Industry 4.0 on employees. The main purpose of this thesis is to contribute to the exploration and presentation of suggestions for business managers on how to successfully adopt Industry 4.0. To achieve this, the abovementioned points the study answered the following questions:

1. What are the challenges for implementing Industry 4.0 in manufacturing processes?
2. How will Industry 4.0 technologies impact Employees?
3. How can managers successfully implement Industry 4.0 technologies at the shopfloor?

The first question was addressed in the first chapter through explaining the main challenges for Industry 4.0 on different levels from them the technical concerns and the organizational challenges. In addition, to explain the mechanism and pushing forces that help understanding Industry 4.0 and define the possible challenges. Furthermore, the presented case study took that followed a semi-structured interview in the third chapter in which the author discussed the challenges in implementing the IoT and CPS to their conventional roller guides, as well as the challenges facing the implementation of the Industry 4.0 roller guides in the client facilities.

Doing a thorough literature analysis, in addition to the study performed for two major studies in the second chapter on the employment impacts of Industry 4.0 has helped to address the second question. Furthermore, our interviewee responded to this question, stating that the impact of Industry 4.0 technology on employees in our case was evident in the trajectory of increased safety, reduced physical work, and improved performance among staff members.

Understanding the challenges and integration of Industry 4.0 and analyzing the findings of the case study in the steel manufacturing business aided the author in exploring and offering a guide for company executives on how to successfully adopt business 4.0 by suggesting the suggestions for future development.

The author chosen the title "Challenges and Opportunities of Industry 4.0: a Case Study" to assist in better understanding the trajectories of Industry 4.0 technologies and discovering the possibilities that may be faced when Industry 4.0 technologies are more applied. Furthermore, to contribute to an ongoing debate concerning the

In a literature study, the majority of research discovered focused on exploring the idea of Industry 4.0 and its applications. The most significant limitations were a lack of comprehensive documents. Every article has addressed a distinct issue or has concentrated on a single significant topic. Although the quantitative studies we examined in Chapter 2 were adequate in some ways, they did not cover all Industry 4.0 technologies and their potential implications and limitations.

ANNEXES

Annex 1: Interview guide

1. Why does your enterprise adopt Industry 4.0?

2. What are the Industry 4.0 technologies implemented by your company? Where are they mostly deployed? (e.g., production, maintenance, R&D, planning, budgeting, logistics, inventory management)

3. Do you consider your/client phase of adoption for each technology as advanced, medium, or low level?

4. How each technology changed employees' jobs? (E.g., more/less complex, more/less varied, more/less skills, more/less autonomy, …)

5. Do you think these changes are more evident for blue collars vs. white collars? Why?

6. What are the benefits your company witnessed at employees' level as a result of the implementation of each technology?

7. How managers make sure that their employees are prepared for Industry 4.0? How did they change their leadership approach or their job because of Industry 4.0?

8. How could you describe any challenges your/client company encountered when adopting Industry 4.0 technology and how it overcame them? (e.g., technological concerns, environmental concerns, lack of trust from employees and other social concerns)

9. Has your/client company achieved the goals it set when it started investing in Industry 4.0?

10. Can you share any upcoming Industry 4.0-related developments your company is working on?

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