CHAPTER 1

INTRODUCTION

1 Introduction

1.1 Evolution of Industry 4.0

With the introduction of steam power during the First Industrial Revolution, manufacturing underwent a profound upheaval. This period, which started in the late 18th century, completely changed how machines were run by switching from manual labor to mechanical power that was mostly powered by steam engines. The invention and application of steam power expanded the possibilities for industrial production and transportation by enabling more productive factory operations and providing power for trains and ships (Hounshell, 1984).

After this, the widespread use of electrical power defined the period known as the Second Industrial Revolution in the late early 20th and late 19th centuries. Steam was supplanted by electricity as the primary industrial power source, allowing industries to run longer hours during the day and achieve higher output capabilities. Significant improvements in steel production and important inventions like the assembly line were also made during this time, increasing industry productivity and efficiency (Landes, 1969).

The Digital Revolution, often known as the Third Industrial Revolution, got its start in the mid- nineteen hundreds. It was marked by the introduction of computers and automation into manufacturing processes. The use of electronics and information technology to automate production brought about significant changes in how factories operated, paving the way for more complex and precise manufacturing techniques (Bell & Truesdell, 1973).

Currently , Industry 4.0, is currently taking place, bringing cutting-edge digital technology like robotics, Internet of Things (IoT) with artificial intelligence (AI) into conventional manufacturing. Fully automated, networked "smart" factories are the hallmark of this revolution. These developments make it conceivable to gather and do real-time data analysis, which improves production procedures and increases efficiency and customisation options. Because of this, firms can react to changes in the market and customer needs more quickly, which greatly increases industrial operations' flexibility and productivity (Schwab, 2017).

Collectively, these industrial revolutions show how manufacturing technologies are always evolving and becoming more sophisticated. Each revolution builds on the advancements made in the preceding age to produce production settings that are more productive, efficient, and flexible.

The German government first pushed the idea of "smart factories," which is the foundation of Industry 4.0, in the early 2010s. This calculated move was a component of a larger plan to establish Germany as a manufacturing technology leader. A major turning point was the official launch of the "Industrie 4.0" program in 2013. With the integration of cyber-physical systems into factory operations, this initiative aims to develop a comprehensive road map for the digitalization of manufacturing processes (Kagermann et al., 2013).

Since its inception, the Industry 4.0 concept has rapidly evolved and gained substantial momentum globally. It is now widely recognized as a pivotal driver of competitiveness and economic progress. The rapid adoption of Industry 4.0 practices can be attributed to their potential to revolutionize manufacturing through increased efficiency, flexibility, and customization. This transformation is supported using cutting-edge technology including robotics, the Internet of Things (IoT), and artificial intelligence, all of which facilitate a more interconnected and intelligent manufacturing environment shown in Fig. 1 (Lasi et al., 2014).

Many academic studies have been conducted on the effects of Industry 4.0, looking at how it affects different industries. Research has indicated that it can improve production speed and quality, save costs, and increase operational efficiencies. According to some researchers(Brettel et al., 2014), Industry 4.0 is credited with promoting a new degree of innovation in the processes involved in product development and production, which has enhanced market responsiveness.

A study (J. Lee, Bagheri, et al., 2015) found that the adoption of Industry 4.0 technologies can lead to significant improvements in manufacturing productivity, quality, and flexibility. Similarly, a study by (Zheng et al., 2018) showed that the implementation of smart manufacturing can reduce production costs and improve supply chain efficiency.

Interestingly, Industry 4.0 has also led to the emergence of new business models and opportunities. A study by (Prause, 2015) highlighted the potential of Industry 4.0, which involves the provision of advanced services such as predictive maintenance and remote monitoring. Another study by (X. Sun & Wang, 2022) discussed the use of Industry 4.0 technologies in enabling circular economy practices such as product remanufacturing and recycling.

Industry 4.0 thus represents a significant transformation in the manufacturing sector that has the potential to create new opportunities and enhance competitiveness. Its impact has been extensively studied in academic literature, highlighting its potential for improving productivity, reducing costs, and enabling new business models. As such, it is crucial for policymakers, industry leaders, and researchers to continue exploring and harnessing the full potential of Industry 4.0.

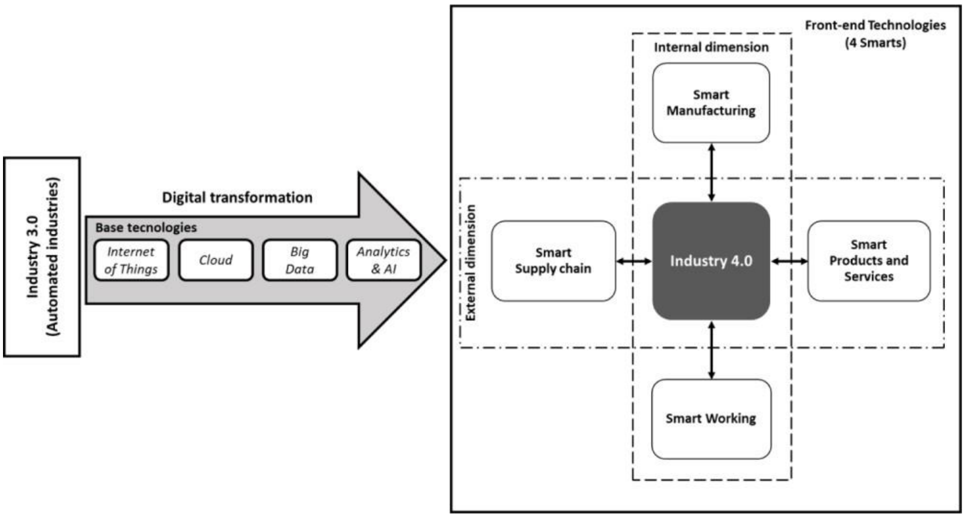

Figure 1: Digital transformation from Industry 3.0 to 4.0

Source:(Frank et al., 2019)

1.2 The technologies of Industry 4.0

1.2.1 Internet of things (IoT)

The Internet of Things (IoT) connects physical devices, sensors, and machines to the internet, allowing them to share data and communicate with each other. IoT has a broad scope, covering various industries such as healthcare, manufacturing, transportation, and smart cities. A significant field of study in IoT is the progress of intelligent systems which could automatically collect and analyze data from various sources, such as sensors and devices, to give decision-making processes automation and in-the-moment insights. As an illustration , researchers (Aboelwafa et al., 2020) developed a real-time data processing system using machine learning algorithms for monitoring and controlling air quality in smart cities through IoT sensors. Similarly, (Kaewkannate & Kim, 2016) developed a remote patient monitoring system using IoT sensors and mobile devices for personalized healthcare services. In the manufacturing industry, (Hameed et al., 2019) developed an IoT-based system using sensors and machine learning algorithms for predictive maintenance, reducing downtime and maintenance costs. The possible uses of IoT in various industries are vast, and ongoing research will continue to uncover new innovative use cases.

1.2.2 The IoT ecosystem

A network of physical objects (referred to as "things") that have been integrated with sensors, software, and other technologies is what makes up an Internet of Things (IoT) system. This network allows the things to communicate with other devices and systems via the internet and exchange data. By enabling objects to gather and transmit data automatically, these systems reduce the need for human involvement while increasing efficiency, accuracy, and economic value.

1.2.3 Components of IoT (internet of things)

Devices and Sensors: Sensors and other gadgets gather data from their surroundings at the most basic level. This may be as basic as a temperature reading or as intricate as an entire video stream.

Connectivity: Data must be sent to a data processing system after it has been gathered. Numerous connectivity alternatives, such as satellite, cellular, Bluetooth, and Wi-Fi, are used to accomplish this.

Data processing: After the information is gathered and uploaded to the cloud, software analyzes it to extract relevant details. Software may determine whether the current temperature reading from the device, for example, is within an acceptable range.

User Interface Components of an IoT System: Lastly, an interface allows the end-user to utilize the information. This might be a phone notice, an automated thermostat adjustment, or a report on patterns in energy use. In an Internet of Things system, data flows seamlessly between various components. Take a smart thermostat system, for instance. The thermostat's sensor records temperature and other environmental information, such as humidity. This information is processed in accordance with user choices established through a mobile app or online interface after being transferred over a Wi-Fi connection to a cloud-based service. The system automatically modifies the thermostat to return the temperature to the intended range if it deviates from the user's chosen range.

In addition, IoT systems frequently integrate other technologies, including machine learning and artificial intelligence, to make increasingly sophisticated judgments, such as forecasting a device's failure date based on past data.

1.3 Big Data

The term "big data" refers to data sets that are large and complex and cannot be analyzed using traditional data processing methods. Big data has a wide range of applications in various industries such as healthcare, finance, transportation, and social media.

One area of research in big data involves developing algorithms for machine learning that can conduct extensive data analysis to find trends and forecast future events. As an illustration, (H. Cui et al., 2020)developed a deep learning model that used electronic health record data to predict the risk of heart disease. The model achieved high accuracy, demonstrating the potential of big data in improving healthcare outcomes.

Another area of research in big data involves developing predictive analytics tools to detect fraudulent activities in finance. (Bhatnagar et al., 2021)developed a predictive analytics tool that used machine learning techniques to examine a lot of large amounts of transaction information and detect paradigms associated with fraudulent activities.

Big data has also been applied in transportation to improve traffic management and reduce congestion. (Choudhary & Dwivedi, 2021) developed a big data platform that collected and analyzed traffic data from various sources, such as GPS devices and sensors, to develop real-time traffic management strategies.

Overall, big data is a fast-emerging domain having vast potential applications in various industries. Continued research in this field is likely to result in many more innovative applications and use cases in the coming years. To avoid plagiarism, it is important to accurately paraphrase the original text while still conveying the same message and information.

1.4 Artificial intelligence (AI)

Industry 4.0 is a novel industrial revolution that focuses on integrating advanced technologies, including the Internet of Things (IoT), big data, and artificial intelligence (AI), into various industries, particularly manufacturing. AI is considered a crucial enabler of Industry 4.0 because of its ability to enhance production efficiency, quality, flexibility, and other advantages.

Predictive maintenance is a key application of AI in Industry 4.0. It involves using data and analytics to forecast when a machine or equipment might fail, allowing maintenance to be scheduled before a breakdown occurs. This approach reduces downtime, maintenance costs, and extends the lifespan of machinery. (Cavalieri & Salafia, 2021) developed an AI-based predictive maintenance system for a semiconductor plant's production line, using machine learning algorithms to examine sensor data and anticipate when maintenance was required.

Another area of AI application in Industry 4.0 is quality control. AI can monitor and analyze production processes in real-time, detecting defects or anomalies that might impact product quality. (Samatas et al., 2021),developed an AI-based quality control system for a manufacturing process that used computer vision and deep learning algorithms to analyze product images and accurately detect defects.

AI can also optimize manufacturing processes in Industry 4.0. (X. Sun & Wang, 2022), developed an AI-based optimization system for a food processing plant that combined machine learning and optimization algorithms to minimize waste and maximize efficiency.

Overall, AI has the potential to revolutionize Industry 4.0 by making manufacturing processes more efficient, flexible, and sustainable. Further research in this field is likely to produce more innovative applications and use cases in the years ahead.

1.5 Cloud computing

Cloud computing has become a game-changer in Industry 4.0, offering businesses unparalleled levels of scalability and flexibility. In an era where industrial applications generate and process increasing amounts of data, cloud computing provides a cost-effective solution for storing and processing large volumes of data. One significant impact of cloud computing in Industry 4.0 is its ability to facilitate real-time data analysis for industrial applications. (Hattinger et al., 2021), revealed that cloud computing technology can instantly process and evaluate sensor data, which is crucial for monitoring and controlling manufacturing processes, leading to increased production efficiency, reduced downtime, and better quality of production processes. Another significant impact of cloud computing on Industry 4.0 is its ability to provide greater flexibility and mobility. (Asim et al., 2020) showed that cloud computing technology can enable access to industrial applications and data from mobile devices, making it easier for employees to work remotely or from different locations, which can increase productivity, collaboration among teams, and reduce travel costs for businesses. Additionally, (Y. Zhang et al., 2020) demonstrated that cloud computing technology provides a more cost-effective solution for storing and processing data, reduces hardware costs for businesses, and provides a secure and reliable storage solution for industrial data. Therefore, cloud computing is a powerful technology that has transformed the operations of businesses in Industry 4.0. Its ability to provide real-time data analysis, flexibility, mobility, and cost-effective data storage and processing has made it an indispensable tool for modern industrial applications. As more research is conducted in this field, we can anticipate the emergence of innovative applications and use cases for cloud computing in Industry 4.0.

1.6 Additive Manufacturing

Additive manufacturing, also known as 3D printing, has emerged as a prominent technology in Industry 4.0. This technology involves the construction of objects layer by layer, based on a digital design, using a variety of materials, including plastics, metals, and ceramics. The manufacturing industry has been revolutionized by this technology as it enables the production of complex and customized parts with high precision and efficiency.

One of the most significant advantages of additive manufacturing is the reduction in costs and lead times. (Bi et al., 2021),demonstrated in their study that additive manufacturing can significantly lower the cost of production for certain parts, particularly for low-volume production runs. Moreover, the technology facilitates faster prototyping and product development cycles, enabling manufacturers to bring new products to the market more quickly.

Additive manufacturing has also made it possible to produce highly intricate and complex parts that were previously difficult or impossible to manufacture with traditional methods. (Martinez-Marquez et al., 2022) demonstrated the use of additive manufacturing to produce a complex turbine blade with a hollow internal structure, which was impossible to produce using traditional manufacturing methods.

In addition to the above, additive manufacturing has the potential to significantly reduce waste and improve sustainability in manufacturing. (Zare Bidoky et al., 2020) showed that additive manufacturing can reduce waste by up to 90% compared to traditional manufacturing methods. Furthermore, this technology enables the use of more sustainable materials, such as bioplastics, which can help reduce the environmental impact of manufacturing.

Additive manufacturing is a crucial technology in Industry 4.0 with extensive potential applications in various industries. As research in this field continues, it is expected that more innovative applications and use cases will emerge in the future.

1.7 Virtual Reality Augmentation

The technique known as augmented reality (AR) superimposes digital content on the physical environment, building a mixed reality environment which users could interact with. In the context of Industry 4.0, AR has emerged as a crucial technology with the potential to transform various aspects of the manufacturing process.

One of the primary applications of AR in Industry 4.0 is in maintenance and repair, where it can offer visual guidance to technicians, enabling them to perform their tasks more efficiently and accurately. This, in turn, can result in reduced downtime and cost savings for manufacturing facilities (Mompeu et al., 2024). Another promising application of AR in Industry 4.0 is in training, where it can provide immersive and interactive environments to train employees in new skills, leading to increased productivity and reduced training costs (Bonavolonta et al., 2020).

In addition, AR can also be used for quality control and inspection, offering inspectors real-time information and visual guidance to detect defects and ensure product quality more efficiently (Arpaia et al., 2020). AR can improve supply chain efficiency by allowing logistics operators to track shipments in real-time, visualizing the location and status of goods, resulting in better inventory management, reduced lead times, and increased customer satisfaction (Fani et al., 2023). Finally, AR can also enhance the customer experience by enabling customers to visualize products in their own environment, leading to more informed purchasing decisions, increased sales, and customer loyalty (Yussof et al., 2019).

Therefore, AR is a critical technology that has the potential to revolutionize various aspects of the manufacturing process in Industry 4.0. The ability of AR to offer visual guidance, immersive training environments, real-time information, and enhanced customer experiences can significantly improve productivity, quality, and efficiency in manufacturing facilities.

1.8 Robotics and Automation

The advancements in robotics and automation have significantly impacted various industries by improving productivity, efficiency, and safety. The manufacturing industry has implemented these technologies for assembly, material handling, and quality control. Research conducted (Correa, 2020) showed that robots can enhance productivity and reduce labour costs in material handling tasks. Similarly, the use of machine vision systems for automated quality control can improve accuracy and reduce inspection time (J. Zhang et al., 2021),.

The healthcare industry has also adopted robotics and automation in surgical procedures, patient care, and drug delivery. Robotic assistance during surgery can improve precision and reduce complications (Chikhaoui et al., 2019),while automated drug delivery systems can enhance medication management and reduce errors (McKendrick et al., 2021),

In the logistics industry, robotics and automation are used for material handling, order picking, and delivery. Automated guided vehicles have been shown to enhance efficiency and reduce labor costs for material handling tasks (Elzomor & Pradhananga, 2021), while automated order picking systems can improve accuracy and reduce picking time (Sgarbossa et al., 2020),.

The agriculture industry has also adopted robotics and automation for crop harvesting, planting, and monitoring. Autonomous vehicles can improve crop yield and reduce labor costs in crop monitoring tasks (Strisciuglio et al., 2018),. Similarly, automated crop harvesting systems can enhance efficiency and reduce the need for manual labor (Shafique et al., 2020),.

Overall, the use of robotics and automation has been widespread across various industries, leading to improvements in productivity, efficiency, and safety. With continued technological advancements, these technologies are expected to further transform industries in the future.

1.8.1 IoT, the fulcrum of industry 4.0 technologies

Within the context of Industry 4.0, the Internet of Things (IoT) is a key technology that serves as a vital connecting factor between various digital technologies. Artificial intelligence (AI), robotics, big data analytics, and other Industry 4.0 technologies may all be easily incorporated into the production process thanks to the Internet of Things. According to (L. Da Xu et al., 2014), this integration is necessary to build fully automated smart factories that perfectly represent Industry 4.0. The Internet of Things (IoT) is essentially networks of sensors and actuators that are wired and wirelessly connected and embedded in real-world items. These networks gather information from their surroundings, transmit it, and take appropriate action. Internet-connected gadgets (IoT) connect to other devices and systems as well as to each other. Manufacturers can identify inefficiencies and issues earlier and react more swiftly because to this connectivity, which makes real-time information processing and analysis previously unachievable possible (Atzori et al., 2010).

IoT plays a more significant role in Industry 4.0 than just providing connectivity; it makes it possible for information technology (IT) and operational technology (OT) to come together. The ability to make data-driven decisions and operational modifications that improve manufacturing processes' flexibility and efficiency makes this convergence essential (B. Zhou & Zheng, 2023).

Additionally, IoT's capabilities support energy management, improved supply chain management, and predictive maintenance—all of which are essential for maximizing output and minimizing downtime in factories. IoT systems provide proactive intervention by predicting when a machine may fail or when a process is departing from its optimal condition by continuous monitoring and data analysis (J. Lee et al., 2013).

1.8.2 The Impact of IoT on manufacturing

The Internet of Things (IoT) has been a significant technological innovation for the manufacturing industry. IoT adoption is growing worldwide, and its impact is transforming the industry.

The adoption of the Internet of Things (IoT) across sectors rapidly increasing in recent years. According to a report by MarketsandMarkets, the global IoT in manufacturing market size is expected to grow from USD 12.67 billion in 2019 to USD 45.30 billion by 2024, at a Compound Annual Growth Rate (CAGR) of 29.4% during the forecast period. This significant growth can be attributed to the increasing demand for industrial automation and real-time monitoring in manufacturing. At its core, IoT consists of connecting and allowing devices to communicate with one another. This connectivity is essential to Industry 4.0; it is not merely a convenience. Large volumes of data are gathered by IoT devices from the manufacturing floor, and these data are crucial for powering other technologies.

1.8.3 Coordination and Communication

Interoperability and technology integration are essential to Industry 4.0 and a major problem. IoT makes this integration easier by giving systems and devices a common foundation and set of standards for communication. An IoT platform, for instance, can combine data from linked devices, apply AI to process it, and utilize the insights gathered to manage robots or other machines in real-time.

In the automotive industry, IoT is being used for predictive maintenance and improving supply chain management. According to a report by Deloitte, the adoption of IoT in the automotive industry is expected to reach USD 82.79 billion by 2022. This is due to the growing demand for connected cars and the increasing focus on reducing operational costs.

The healthcare industry is also adopting IoT for improving patient care and increasing operational efficiency. According to a report by Allied Market Research, the global IoT in healthcare market is expected to reach USD 136.8 billion by 2021, growing at a CAGR of 12.5% during the forecast period.

In the services industry, IoT is being used to optimize business processes and enhance customer experience. According to a report by Accenture, the adoption of IoT in the retail industry is expected to reach USD 35 billion by 2020. This is due to the growing demand for personalized shopping experiences and the increasing use of digital channels.

Overall, the adoption of IoT is expected to continue growing across various industries, as businesses recognize the benefits of real-time data monitoring, predictive maintenance, and improved efficiency. However, challenges such as security concerns and the need for interoperability between different IoT devices and systems must be addressed to ensure successful implementation.

According to a report by Allied Market Research, the global IoT in the manufacturing market size is expected to reach $994.22 billion by 2027, growing at a CAGR of 24.7% from 2020 to 2027 (https://www.alliedmarketresearch.com, n.d.). This significant growth in the market is a result of the increasing demand for industrial automation and the need for efficient supply chain management.

In a survey conducted by Zebra Technologies, a multinational technology company, 82% of manufacturers globally have plans to implement IoT solutions by 2022 (Zebra Technologies, n.d.). The survey also revealed that IoT adoption in manufacturing is driven by the need to improve operational efficiency, reduce downtime, and enhance production quality.

IoT adoption in the manufacturing industry has also increased the use of predictive maintenance, which has been identified as one of the significant benefits of IoT. A study by Capgemini Research Institute revealed that 87% of manufacturers who have implemented IoT in their operations have seen a significant improvement in their maintenance practices (Https://www.capgemini.com/insights/research-institute/, n.d.).

Internet of Things (IoT) technology has been rapidly adopted across various sectors in India in recent years. This technology enables devices to be connected and communicate with each other through the internet, resulting in improved efficiency, productivity, and cost savings. In this paper, we aim to provide a comparative analysis of IoT adoption in various sectors in India up until 2021.

In the manufacturing sector, IoT adoption has been on the rise with the use of connected sensors and devices in factories and warehouses to optimize processes. According to a study by Research and Markets, the IoT market in manufacturing in India predicted to grow of 28.2% from 2021 to 2026 compounded annually. The study also found that the adoption of IoT in manufacturing is driven by the need for real- time monitoring, predictive maintenance, and improved supply chain management.

In the healthcare sector, IoT adoption has led to the development of innovative solutions such as remote patient monitoring and telemedicine. A study by the Indian Journal of Public Health Research & Development found that the use of IoT in healthcare can improve patient outcomes, reduce costs, and increase access to healthcare services (Garcia N.M. Pires I.M., 2020).

In the agriculture sector, IoT adoption has been increasing with the use of connected sensors and devices for precision farming, crop monitoring, and livestock tracking. A study by the Journal of Agroecology and Natural Resource Management found that IoT adoption in agriculture can result in increased yields, reduced costs, and improved sustainability (Sishodia et al., 2020).

In the transportation sector, IoT adoption has led to the development of smart transportation systems and connected vehicles. A study by the International Journal of Engineering and Advanced Technology found that IoT adoption in transportation can result in improved safety, reduced congestion, and lower emissions.

Overall, the adoption of IoT technology in various sectors in India has been on the rise, resulting in significant benefits such as improved efficiency, productivity, and cost savings. As the technology continues to evolve, it is expected to play an increasingly important role in driving innovation and growth across sectors.

1.9 Global textile manufacturing industry

The textile manufacturing industry has a long history and is currently a major player in the global economy, employing over 300 million people worldwide and generating around $1.2 trillion in revenue. While countries like China, India, and Bangladesh dominate the industry, other countries like the United States, Turkey, and Vietnam are also significant players. However, the industry faces challenges such as competition from low-cost producers and changing consumer preferences. Despite this, the industry is expected to continue growing due to technological advancements, including automation and digital printing, as well as an increasing focus on sustainability. According to various reports, the world textile consumption is predicted to continue to go upwards annually compounded at a rate of around 4%, with the Asia Pacific region remaining the largest market. Additionally, the demand for technical textiles and sustainable materials is driving growth in the textile chemicals market. Overall, the outlook for the textile manufacturing industry is positive, as it continues to adapt and evolve in response to changing market conditions.

1.9.1 The Indian textile Industry

The Indian textile industry is a significant contributor to the country's economy, with a rich history dating back thousands of years. The industry is known for its diverse range of textiles and skilled workforce, and it has played a key role in India's economic development.

1.9.2 Historical Background:

India has a long history of textile manufacturing, dating back to ancient times. Indian textiles were famous worldwide for their quality, and the country was a major exporter of textiles during the British colonial era. However, the industry suffered a decline during the 20th century due to competition from imported textiles and lack of modernization.

1.9.3 Current Status:

Today, the Indian textile industry is the second-largest employer after agriculture, providing jobs to around 45 million people, both in the organized and unorganized sectors. The industry also contributes significantly to the country's GDP, accounting for 7% of India's total industrial output. The organized sector comprises around 30% of the industry, with the remaining 70% comprising small-scale and unorganized players.

The Indian textile industry is known for its diversity in fabrics and products, including cotton, silk, wool, and synthetic fabrics. India is also one of the world's largest producers of cotton, with the country producing around 6 million tons of cotton every year.

1.9.4 Challenges:

Despite its significant contribution to the economy, the Indian textile industry faces several challenges. One of the main challenges is the competition from low-cost producers in countries like China, Bangladesh, and Vietnam. The unorganized sector also faces challenges such as poor working conditions and lack of access to finance, which affects their ability to modernize and compete with larger players.

Another challenge is the environmental impact of the industry, with concerns about pollution and waste generated from textile production. The industry is also facing a shortage of skilled workers, as younger generations are increasingly opting for careers in other industries.

1.9.5 Future Outlook:

The Indian textile industry is expected to continue growing in the coming years, with a focus on increasing exports and promoting domestic production. The state has introduced various initiatives to support the industry, including the Technology Upgradation Fund, which offers financial support for modernization and technology adoption.

There is also a growing focus on sustainability in the industry, with a push towards eco-friendly production methods and use of sustainable materials. This is expected to be a key area of growth in the coming years, as customers become increasingly conscious of the natural repercussions of their purchases.

The adoption of technology in the Indian textile industry has been slower compared to the global textile industry, and this write-up outlines the challenges faced by the Indian industry in the adoption of technology in comparison to the global textile industry. The cost of technology implementation and a lack of awareness of the potential benefits of technology adoption are the main challenges faced by the Indian industry. In addition, there is a shortage of skilled workers, making it difficult to implement and maintain technological advancements. Developed countries like the United States, Japan, and Germany have invested heavily in research and development, leading to the creation of innovative products and processes. The global textile industry is dominated by large, organized players, while the Indian industry has many small-scale and unorganized players, making it difficult for the industry to invest in technology upgrades and implement new processes. The future success of the Indian industry will depend on its ability to address these challenges and leverage technology to stay competitive in the global market.

1.10 Studying IoT adoption

The Internet of Things (IoT) has emerged as a significant technological innovation that is being widely adopted in different industries, including healthcare, manufacturing, transportation, and agriculture. The adoption of IoT technologies by end-users and organizations has gained momentum over the years, with several adoption models developed to study the phenomenon.

1.10.1 End-User Adoption Models

End-users refer to individuals who use IoT technologies for personal or household purposes. Several models have been developed to study end-user adoption of IoT. One of the earliest models is the Technology Acceptance Model (TAM), which proposes that end-users' intentions to adopt IoT are determined by their attitudes towards the technology and their perceived usefulness and ease of use (Davis, 1989). The TAM has been used in several studies to examine the adoption of IoT devices, such as smart home appliances.

Another widely used model is the Unified Theory of Acceptance and Use of Technology (UTAUT), which considers several factors that influence end-users' intentions to adopt IoT, such as performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003).

1.10.2 Organizational Adoption Models

Organizational adoption models focus on the factors that influence the adoption of IoT technologies by organizations. One of the most widely used models is the Technology-Organization-Environment (T-O-E) framework, which proposes that the adoption of IoT is influenced by technological, organizational, and environmental factors (Tornatzky et al., 1990). The TOE framework has been used in several studies to examine the adoption of IoT in different industries, such as healthcare (Alqahtani, 2022) and internet banking (Yousafzai et al., 2010),.

Another model used extensively in recent years is the Innovation Diffusion Theory (IDT), which proposes that the adoption of IoT technologies is influenced by the characteristics of the technology, the adopters, and the social system (Rogers et al., 1983). The IDT has been used in several studies to examine the adoption of IoT technologies, such as radio-frequency identification (RFID) technology.

The adoption of IoT technologies has gained momentum in recent years, with several adoption models developed to study the phenomenon. End-user adoption models, such as TAM and UTAUT, focus on the factors that influence end-users' intentions to adopt IoT. On the other hand, organizational adoption models, such as TOE and IDT, focus on the factors that influence the adoption of IoT technologies by organizations. These models provide valuable insights into the factors that influence the adoption of IoT technologies and can guide policymakers and practitioners in promoting the adoption of IoT in different industries.

1.11 Purpose of this research thesis

With this substantial global impact of IoT on manufacturing, it lends perspective to compare the position of India in the adoption of IoT in various manufacturing sectors and try and understand sectors where there is scope for India to adopt IoT and what models could be used to study the adoption of IoT in the lagging manufacturing sector. The challenges faced by the Indian industry have been highlighted earlier in the chapter and will be discussed in detail during the research.

This forms the basis of this research thesis.

The thesis is structured as follows.

1. Introduction
2. Literature review
3. Rationale of study

4. Construct, measurement scale and questionnaire development.
5. Research methodology.
6. Data collection and analysis
7. Findings, implications and discussion
8. Conclusions