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# Industry 4.0 and Digital Revolution: Does 4th Industrial Revolution Influence Manufacturing Capability in Textile Industry of Pakistan?

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## Abstract

This article explores the relationship between big data, Internet of Things (IoT), and interoperability on the manufacturing capability of the textile industry. The textile industry is a complex and dynamic industry that faces numerous challenges, such as production inefficiencies, supply chain management, quality control, and energy usage. To address these challenges, textile companies are leveraging big data, IoT, and interoperability to improve their manufacturing capability. Big data enables textile companies to collect and analyze vast amounts of data to make data-driven decisions, while IoT allows for the integration of physical devices and sensors to provide real-time insights and optimize production processes. Interoperability ensures that different systems and devices can communicate and exchange data with each other, improving supply chain management, quality control, predictive maintenance, and energy usage. However, the implementation of these technologies also presents challenges, such as the complexity of the production process, the cost of investment, and data security and privacy concerns. Despite these challenges, textile companies must embrace and invest in these technologies to stay competitive in today's marketplace and meet the demands of their customers. In conclusion, big data, IoT, and interoperability are essential tools for textile companies to improve their manufacturing capability and succeed in today's rapidly changing marketplace.

**Keywords:** Big Data, Internet of Things (IoT), Interoperability, Manufacturing Capability.

## 1. Introduction

The Fourth Industrial Revolution or Industry 4.0 is a term used to describe the current technological advancements that are revolutionizing the way businesses operate (Hassoun et al., 2022; Moktadir, Ali, Kusi-Sarpong, & Shaikh, 2018; Raj, Dwivedi, Sharma, de Sousa Jabbour, & Rajak, 2020; Scavarda, Daú, Scavarda, & Goyannes Gusmão Caiado, 2019). It involves the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and automation into various industries, including the textile industry. The textile industry is one of the oldest and most important industries in the world and in Pakistan. The manufacturing of textiles has undergone significant changes over the years, from the invention of the spinning jenny to the use of electric looms. However, with the advent of Industry 4.0, the textile industry is undergoing a transformation that is changing the way textiles are produced, distributed, and consumed. The integration of Industry 4.0 technologies (Raj et al., 2020; Sahal, Breslin, & Ali, 2020) into textile manufacturing has led to the creation of "smart textiles." These textiles are embedded with sensors that can detect and transmit data about the wearer's vital signs, body temperature, and location. Pakistani textile industry also has the ability to change color or texture in response to changes in the wearer's environment. Revolution in technology is presented in Figure 1.

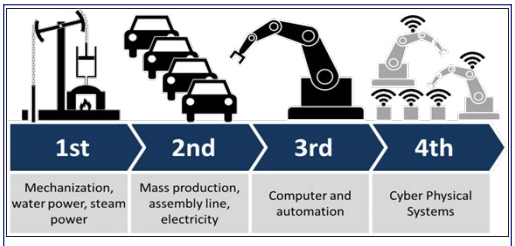


**Figure 1. Industry 4.0**

The impact of Industry 4.0 on the manufacturing (Raj et al., 2020; Sahal et al., 2020; Scheuermann, Verclas, & Bruegge, 2015) of textiles is a rapidly evolving area of research that is still relatively unexplored. There are several gaps in the existing literature that require further investigation. Firstly, there is a lack of research on the specific technologies that are being

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used in the textile industry as part of the industry 4.0 revolution. While some studies have looked at the use of automation, artificial intelligence, and the Internet of Things (IoT) in manufacturing, there is little research that focuses specifically on their application in the textile industry. Secondly, there is a need for more research that examines the impact of Industry 4.0 on different aspects of the textile manufacturing process. For example, how does it affect the design process, production planning, supply chain management, and quality control? Furthermore, little is known about the impact of Industry 4.0 on worker training and skill requirements in the textile industry. Thirdly, the social and environmental impact of Industry 4.0 in the textile industry has not been adequately studied. While automation and other technologies may lead to greater efficiency and productivity, there may also be negative consequences such as job displacement and increased energy consumption. Additionally, the environmental impact of Industry 4.0 on textile manufacturing processes, such as the use of more complex chemicals and materials, has yet to be fully understood. In summary, there is a significant literature gap in the specific application of Industry 4.0 in the textile industry and the impact of this revolution on different aspects of the textile manufacturing process, worker training, and social and environmental impact.

This research article aims to explore the effect of Industry 4.0 on the manufacturing of textiles. It examined that how the integration of advanced technologies is changing the textile industry and what benefits and challenges this transformation presents. The article analyzed the impact of Industry 4.0 on textile manufacturers, employees, and consumers. Furthermore, the research article highlighted the opportunities that Industry 4.0 presents to the textile industry, such as increased efficiency, enhanced product quality, and improved sustainability. It also examines the potential risks associated with the integration of Industry 4.0 technologies, such as job displacement and cybersecurity threats. In conclusion, this research article provided a comprehensive overview of the effect of Industry 4.0 on the manufacturing of textiles. It demonstrated how the textile industry is embracing advanced technologies and how this transformation is shaping the future of the industry. The findings of this study can be valuable to textile manufacturers, policymakers, and researchers who are interested in the intersection of Industry 4.0 and the textile industry.

# 2. Literature Review

## 2.1 Manufacturing Capability

The textile industry is one of the oldest and largest industries in the world (Francisco, Cajé, Semaan, & Pacheco, 2017; Pang & Abdullah, 2013; Shah, Warraich, & Kabeer, 2012). It plays a critical role in the global economy by providing essential goods and services to consumers. Textile manufacturing involves a wide range of activities, including the production of fibers, yarns, fabrics, and garments. The manufacturing capability of the textile industry has evolved significantly over the years, with advances in technology, changes in consumer preferences, and global competition driving innovation and growth. The manufacturing capability of the textile industry is a measure of its ability to produce high-quality products efficiently and cost-effectively. The industry has made significant progress in this area over the years, thanks to advances in technology and automation. Textile manufacturers now have access to a wide range of advanced machinery and equipment that enables them to produce textiles that meet or exceed the expectations of consumers.

One of the most critical aspects of textile manufacturing capability is the ability to produce high-quality fibers and yarns. This requires specialized equipment and expertise, as well as access to high-quality raw materials. The quality of the fibers and yarns produced is crucial, as it directly impacts the quality of the final product. Textile manufacturers invest heavily in research and development to create new and innovative fibers and yarns that meet the changing needs of consumers. The production of fabrics is another critical area of textile manufacturing capability (Roosmini, Andarani, & Nastiti, 2010; Siengthai & Udomphol, 2016). The industry has made significant progress in this area in recent years, with advancements in digital printing, finishing technologies, and other processes. These advancements have enabled manufacturers to produce fabrics in a wide range of colors, textures, and patterns, making it easier to meet the diverse needs and preferences of consumers.

The garment manufacturing process is another critical area of textile manufacturing capability. Garment manufacturers must have the ability to produce high-quality products that meet the exacting standards of consumers. This requires a deep understanding of fabrics, patterns, and design, as well as the ability to produce garments efficiently and cost-effectively. The manufacturing capability of the textile industry is also impacted by global competition (Imran, Hameed, & Haque, 2018; Siengthai & Udomphol, 2016). Textile manufacturers must compete with producers from around the world, each vying for market share in an increasingly competitive industry. To remain competitive, manufacturers must invest in advanced technology and automation to reduce costs and increase efficiency. Another important factor impacting the manufacturing capability of the textile industry is sustainability. Consumers are increasingly concerned about the environmental impact of the products they purchase, and the textile industry is no exception. Textile manufacturers are investing in sustainable practices, such as using eco-friendly materials, reducing waste, and improving energy efficiency.

The manufacturing capability of the textile industry is a critical factor in its success. The industry has made significant progress in recent years, thanks to advances in technology and automation. Manufacturers now have access to a wide range of advanced machinery and equipment that enables them to produce high-quality products efficiently and cost-effectively. The industry's ability to produce high-quality fibers, yarns, fabrics, and garments is crucial to meeting the diverse needs and preferences of consumers. As global competition increases and consumer preferences evolve, the textile industry will continue to invest in research and development to improve its manufacturing capability and maintain its position as a leading industry in the global economy.

## 2.2 Big Data

Big data refers to large sets of structured and unstructured data that can be analyzed to reveal patterns, trends, and associations (Asch et al., 2018; Bag, Wood, Xu, Dhamija, & Kayikci, 2020; Sahal et al., 2020). In recent years, big data has become increasingly important in the textile industry, as manufacturers seek to optimize their operations, improve product quality, and better understand customer preferences. In this article, this study explored the use of big data in the textile industry and its impact on the industry's future. One of the key areas where big data is being used in the textile industry is in supply chain management. Textile manufacturers rely on a complex supply chain that involves multiple vendors and suppliers. Big data analytics can be used to track and analyze data on supplier performance, inventory levels, and transportation costs, among other factors. This can help manufacturers optimize

 

their supply chains, reduce costs, and improve delivery times. Another area where big data is being used in the textile industry is in product design and development. By analyzing data on consumer preferences, trends, and behaviors, manufacturers can gain insights into what products will be most successful in the market. Big data can also be used to identify gaps in the market and to develop new products that meet the evolving needs and preferences of consumers.

Big data is also being used in the textile industry to improve product quality (Sahal et al., 2020). By analyzing data on product defects, manufacturers can identify patterns and trends that can help them address quality issues more effectively. Big data analytics can also be used to monitor production processes and identify potential issues before they become significant problems. The use of big data in the textile industry is not without its challenges, however. One of the biggest challenges is the sheer volume of data that must be analyzed. Textile manufacturers generate large amounts of data every day, and it can be difficult to manage and analyze all of this data effectively. To address this challenge, many manufacturers are turning to big data platforms that can handle large volumes of data and provide advanced analytics tools to help them make sense of the data. Another challenge is the need for skilled data analysts who can interpret the data and provide insights that can be used to improve operations and products. Textile manufacturers must invest in training and development programs to ensure that they have the skilled personnel they need to make the most of big data analytics.

Despite these challenges, the use of big data (Ahn et al., 2019; El-Kassar & Singh, 2019)in the textile industry is expected to continue to grow in the coming years. As manufacturers seek to remain competitive in an increasingly crowded marketplace, the insights provided by big data analytics will become more critical to their success. By leveraging big data, textile manufacturers can optimize their operations, improve product quality, and better understand customer preferences, ultimately driving growth and profitability. Therefore, the use of big data in the textile industry is a growing trend that is expected to continue in the coming years. By leveraging the insights provided by big data analytics, textile manufacturers can optimize their operations, improve product quality, and better understand customer preferences. While there are challenges associated with the use of big data, such as the volume of data that must be analyzed and the need for skilled personnel, the benefits of big data analytics are significant and can help manufacturers remain competitive in an increasingly crowded marketplace. As the textile industry continues to evolve, the role of big data will become even more critical in driving growth and profitability. The benefits of big data for textile industry are given in Figure 2.


**Figure 2. Benefits of Big Data in Textile Industry**

### 2.2.1 The relationship between Big Data and Manufacturing Capability

The textile industry is one of the oldest and most important industries in the world (de Oliveira Brasil, de Abreu, da Silva Filho, & Leocádio, 2016; Farhan, Hussain, Khan, Tahir, & Bhatti, 2020; Lee, 2015). For centuries, people have been using textiles for clothing, shelter, and other essential items. Over the years, the textile industry has evolved to become more sophisticated, with the introduction of new materials, production methods, and technologies. Today, the industry is facing a new challenge in the form of Big Data. The relationship between Big Data and the manufacturing capability of the textile industry is complex and multifaceted, and understanding this relationship is crucial for companies to stay competitive in today's marketplace. Big Data refers to the vast amounts of information generated by individuals, businesses, and machines every day. This information includes everything from social media posts and online transactions to manufacturing data and sensor readings. In recent years, advances in technology have made it possible to collect, store, and analyze this data in ways that were previously impossible. This has led to a revolution in the way businesses operate, with companies in every industry using Big Data to improve their operations and gain a competitive advantage.

The textile industry is no exception (Newspaper, 2017; Yang & Wang, 2020). In fact, the industry is particularly well-suited to take advantage of Big Data because of the large amount of data generated during the manufacturing process. Every step of the production process, from sourcing raw materials to delivering finished products, generates a wealth of data that can be used to improve efficiency, reduce waste, and increase profitability. One area where Big Data is particularly useful in the textile industry is in supply chain management. The textile supply chain is complex and global, with raw materials and finished products moving between multiple countries and suppliers. Big Data can be used to track these movements and provide real-time insights into inventory levels, production schedules, and delivery times. This information can be used to optimize the supply chain, reduce lead times, and improve customer satisfaction. Another area where Big Data is useful is in quality control. The textile industry is highly regulated, with strict standards for product quality and safety. Big Data can be used to track every step of the production process, from the sourcing of raw materials to the final inspection of finished products. This data can be used to identify patterns and trends in quality issues, allowing companies to address these issues quickly and efficiently. This can lead to significant cost savings and improved customer satisfaction.

Big Data is also useful in product design and development (Sahal et al., 2020). By analyzing data on consumer preferences, market trends, and competitor offerings, textile companies can develop products that meet the needs of their target customers. This can lead to higher sales and increased profitability. Finally, Big Data can be used to optimize production processes. By analyzing data on machine performance, energy usage, and production schedules, textile companies can identify areas for improvement and implement changes to increase efficiency and reduce waste. This can lead to significant cost savings and increased profitability. Despite the many benefits of Big Data in the textile industry, there are also some challenges that must be overcome. One of the biggest challenges is the sheer volume of data that is generated. Textile companies must have the infrastructure and tools in place to collect, store, and analyze this data. They must also have skilled personnel who are able to make sense of the data and use it to make informed decisions. Another challenge is the cost of implementing Big Data solutions. Textile companies must invest in technology and personnel to collect, store, and analyze data. This can be expensive, especially for smaller companies that may not have the resources to make these investments. Finally, there is the challenge of data security and privacy. Textile companies must ensure that sensitive data, such as customer information and intellectual property, is kept secure and confidential. This requires robust data security protocols and strict access controls. Hence, big Data has the potential to revolutionize the textile industry by improving supply chain management, quality control, product design and development, and production processes

## 2.3 Internet of things (IoT)

The Internet of Things (IoT) is a network of connected devices that are embedded with sensors, software, and other technologies that allow them to collect and exchange data (Y.-Y. Chen, Huang, & Sung, 2021; Ghanbari, Laya, Alonso-Zarate, & Markendahl, 2017; Lin, Chen, Zhang, Guan, & Shen, 2016). In recent years, IoT has emerged as a powerful tool for improving operations and efficiency in the textile industry. In this article, we will explore the use of IoT in the textile industry and its impact on the industry's future. One of the key areas where IoT is being used in the textile industry is in production and operations. By integrating sensors into machines and equipment, textile manufacturers can track and monitor production processes in real-time. This allows manufacturers to identify potential issues and inefficiencies and make adjustments to optimize operations. IoT-enabled equipment can also automatically alert technicians when maintenance is required, reducing downtime and improving productivity. Another area where IoT is being used in the textile industry is in quality control. By integrating sensors into fabrics and garments, manufacturers can monitor the quality of products as they move through the production process. This allows manufacturers to identify defects early in the process and take corrective action before products reach customers. IoT-enabled quality control systems can also automatically reject defective products, reducing waste and improving overall product quality.

IoT is also being used in the textile industry to improve supply chain management (Ali & Haseeb, 2019; Lee, 2015). By tracking the movement of goods using sensors and other technologies, manufacturers can gain real-time visibility into the location and status of products. This allows manufacturers to optimize transportation routes, reduce inventory levels, and improve delivery times. IoT can also be used to monitor environmental conditions, such as temperature and humidity, during transportation, ensuring that products arrive in optimal condition. The use of IoT in the textile industry is not without its challenges, however. One of the biggest challenges is the need to ensure data security and privacy. With so many devices and systems connected to the internet, there is a risk that sensitive data could be compromised. Manufacturers must implement robust security measures to protect data and ensure that only authorized personnel have access to it. Another challenge is the need for skilled personnel who can manage and analyze the data generated by IoT devices. Textile manufacturers must invest in training and development programs to ensure that they have the skilled personnel they need to make the most of IoT technology.

Despite these challenges, the use of IoT (Hatzivasilis et al., 2019) in the textile industry is expected to continue to grow in the coming years. As manufacturers seek to remain competitive in an increasingly crowded marketplace, the insights provided by IoT technology will become more critical to their success. By leveraging IoT, textile manufacturers can optimize their operations, improve product quality, and better understand customer preferences, ultimately driving growth and profitability. In addition to improving operations and efficiency, IoT is also opening up new opportunities for innovation in the textile industry. For example, IoT-enabled wearable technology is becoming increasingly popular among consumers (Del Giudice, 2016). Smart fabrics and garments embedded with sensors can track vital signs, monitor activity levels, and provide other valuable data to users. This technology has the potential to revolutionize the way we think about clothing, making it not just a fashion statement but also a tool for improving health and wellness. IoT is also driving innovation in the development of sustainable textiles. By integrating sensors into fabrics, manufacturers can track the environmental impact of production processes and identify opportunities to reduce waste and improve sustainability. IoT can also be used to monitor the use and disposal of textiles, ensuring that they are recycled or disposed of in an environmentally responsible way. In conclusion, the use of IoT in the textile industry is a growing trend that is expected to continue in the coming years. By leveraging the insights provided by IoT technology, textile manufacturers can optimize their operations, improve product quality, and better understand customer preferences. While there are challenges associated with the use of IoT, such as data security

 

and the need for skilled personnel, the benefits of IoT technology are significant and can help manufacturers remain competitive in an increasingly crowded marketplace. IoT is presented in Figure 3.

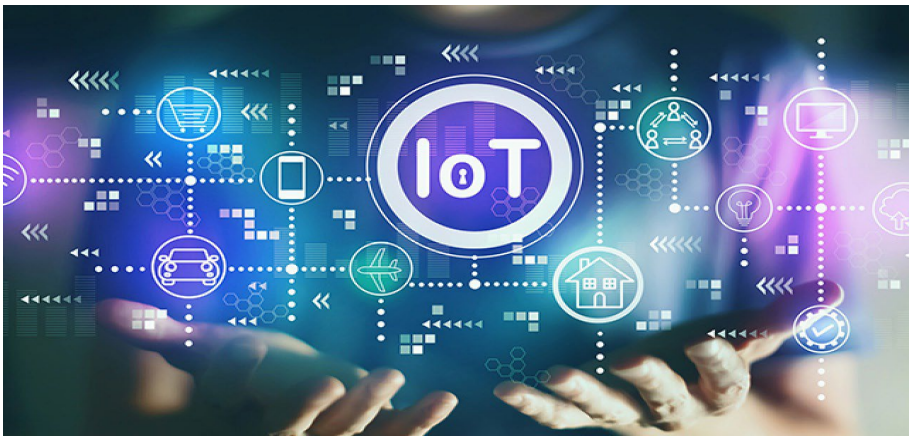


**Figure 3. Internet of things (IoT)**

### 2.3.1 The relationship between Internet of things (IoT) and Manufacturing Capability

The Internet of Things (IoT) is rapidly changing the way businesses operate across industries (Y.-Y. Chen et al., 2021; Del Giudice, 2016), and the textile industry is no exception. IoT refers to the interconnected network of devices, sensors, and systems that can collect and share data in real-time, allowing businesses to make more informed decisions and optimize their operations. The relationship between IoT and the manufacturing capability of the textile industry is complex and multifaceted, and understanding this relationship is crucial for companies to stay competitive in today's marketplace. One of the most significant impacts of IoT on the textile industry is in supply chain management. The textile supply chain is complex and involves multiple steps, from sourcing raw materials to delivering finished products. IoT sensors can be used to track the movement of materials and products throughout the supply chain, providing real-time data on inventory levels, production schedules, and delivery times. This information can be used to optimize the supply chain, reduce lead times, and improve customer satisfaction.

IoT sensors can also be used to monitor the quality of textile products at every stage of the production process (Dachyar & Risky, 2014). For example, sensors can be placed on weaving machines to monitor the speed and tension of the loom, ensuring that the fabric is being produced at the desired quality level. Similarly, sensors can be placed on finishing machines to monitor the temperature, humidity, and other environmental factors that can impact the quality of finished products. This real-time data can be used to identify issues and make adjustments to the production process, improving the quality of the final product. Another area where IoT can have a significant impact on the textile industry is in predictive maintenance. Textile manufacturing equipment is expensive and requires regular maintenance to ensure that it is functioning at peak performance. IoT sensors can be used to monitor the performance of machines and identify potential issues before they become major problems. This allows textile companies to schedule maintenance at the most opportune time, reducing downtime and improving overall equipment effectiveness.

IoT can also be used to optimize energy usage in textile manufacturing facilities. Textile manufacturing is an energy-intensive process, and energy costs can be a significant expense for textile companies. IoT sensors can be used to monitor energy usage throughout the production process, identifying areas where energy is being wasted and making recommendations for improvements. For example, sensors can be placed on lighting fixtures to automatically turn off lights when a room is empty, or on HVAC systems to adjust temperature settings based on occupancy levels. In addition to improving operational efficiency, IoT can also be used to improve the customer experience in the textile industry. For example, IoT sensors can be used to track shipments and provide real-time updates on delivery times, improving customer satisfaction. Similarly, IoT can be used to monitor customer preferences (Dash, Farooq, Panda, & Sandhyavani, 2019) and provide personalized product recommendations based on past purchases or browsing history. Despite the many benefits of IoT in the textile industry, there are also some challenges that must be addressed. One of the biggest challenges is the sheer volume of data that is generated. IoT sensors can generate vast amounts of data, and textile companies must have the infrastructure and tools in place to collect, store, and analyze this data. They must also have skilled personnel who are able to make sense of the data and use it to make informed decisions. Another challenge is the cost of implementing IoT solutions. Textile companies must invest in technology and personnel to install and maintain IoT sensors and systems. This can be expensive, especially for smaller companies that may not have the resources to make these investments. Finally, there is the challenge of data security and privacy. IoT sensors collect sensitive data, such as customer information and production data, and this data must be kept secure and confidential. This requires robust data security protocols and strict access controls. Thus, IoT has the potential to revolutionize the textile industry by improving supply chain management, quality control, predictive maintenance, energy usage, and the customer experience. However, textile companies must

## 2.4 Interoperability

Interoperability is the ability of different systems and technologies to work together seamlessly (Dini et al., 2008; Gürdür, El-Khoury, Seceleanu, & Lednicki, 2016). In the textile industry, interoperability plays a critical role in ensuring that different stages of the textile

manufacturing process can communicate with each other effectively. This helps to improve efficiency, reduce costs, and ensure the quality and consistency of textile products. The textile manufacturing process involves several stages, including fiber production, spinning, weaving, dyeing, printing, and finishing. Each stage of the process requires specialized equipment and technology, and there is often a need for different systems and technologies to work together seamlessly. Interoperability is critical in ensuring that data can be shared between different systems and that information can be exchanged in real-time. One of the key areas where interoperability is important in the textile industry is in the area of supply chain management. The textile supply chain is complex, involving multiple suppliers, manufacturers, and retailers. Ensuring that all stakeholders can communicate effectively is critical in ensuring (D. Chen, Doumeingts, & Vernadat, 2008) that the supply chain runs smoothly. For example, a textile manufacturer may need to communicate with a cotton supplier to ensure that the cotton being used in the manufacturing process meets certain quality standards. The manufacturer may also need to communicate with a logistics provider to ensure that materials and finished products are transported to and from the factory in a timely and cost-effective manner. Interoperability is critical in ensuring that all stakeholders in the supply chain can communicate effectively and that information is shared in real-time. There are number of benefits of Interoperability in the Textile Industry which are as follows;

1. Improved Efficiency: Interoperability can help to improve the efficiency of the textile manufacturing process by reducing the need for manual data entry and streamlining communication between different systems. This can help to reduce errors, improve productivity, and reduce costs.
2. Improved Quality Control: Interoperability can also help to improve the quality control process by allowing data to be shared between different stages of the manufacturing process. This can help to identify potential issues early on, allowing for corrective action to be taken before the product reaches the market.
3. Improved Supply Chain Management: Interoperability is critical in ensuring that all stakeholders in the textile supply chain can communicate effectively. This can help to reduce lead times, improve inventory management, and reduce costs.
4. Improved Collaboration: Interoperability can also help to improve collaboration between different stakeholders in the textile industry. By allowing data to be shared in real-time, manufacturers, suppliers, and retailers can work together more effectively, leading to improved outcomes for all stakeholders.

Despite the many benefits of interoperability in the textile industry, there are also several challenges that need to be addressed. These include:

1. Fragmented Systems: One of the biggest challenges to interoperability in the textile industry is the fragmentation of systems and technologies. Many manufacturers use different software systems and technologies, making it difficult to ensure that all systems can work together seamlessly.
2. Lack of Standards: Another challenge to interoperability is the lack of standardization across different systems and technologies. This can make it difficult for different systems to communicate with each other effectively.
3. Data Security: Interoperability also raises concerns around data security. Sharing data between different systems and technologies can increase the risk of data breaches and cyberattacks.
4. Resistance to Change: Finally, there may be resistance to change among stakeholders in the textile industry. Some manufacturers may be hesitant to adopt new technologies or systems, which can make it difficult to achieve interoperability across the industry.

Addressing these challenges will require collaboration between different stakeholders in the textile industry, including manufacturers, suppliers, and technology providers. Efforts to standardize systems and technologies, improve data security, and promote the benefits of interoperability will be critical in ensuring that the textile industry can continue to evolve and innovate new things. The interoperability in textile sector is given in Figure 4.

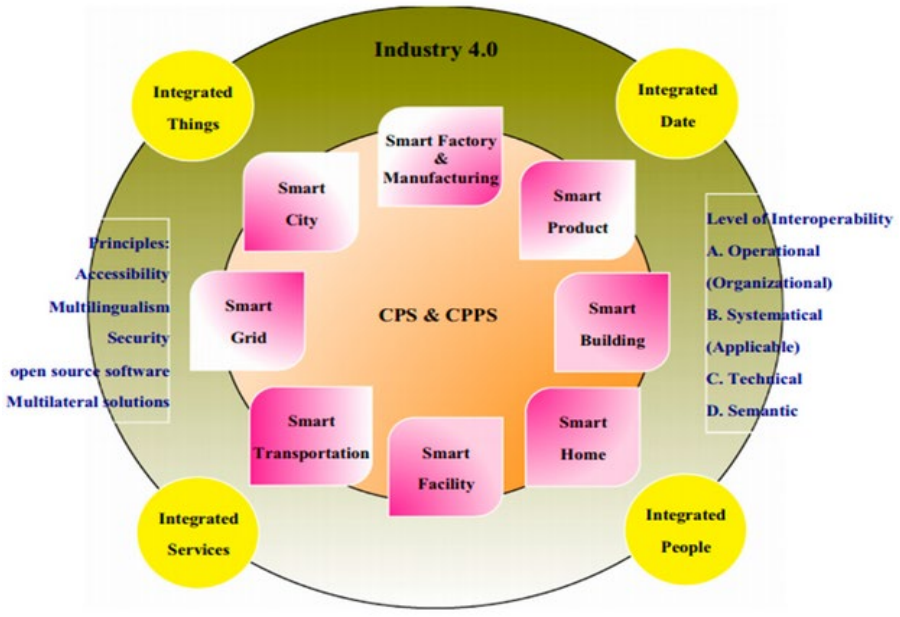


**Figure 4. Interoperability in Textile Sector**
**Source: Imran et al. (2018)**

 

### 2.4.1 The relationship between Interoperability and Manufacturing Capability

Interoperability refers to the ability of different systems (Berre et al., 2007; D. Chen et al., 2008) and devices to communicate and exchange data with each other. In the context of the textile industry, interoperability is crucial for improving manufacturing capability and ensuring that different components of the production process work seamlessly together. This relationship is complex and multifaceted, and understanding it is essential for textile companies to stay competitive in today's marketplace. One of the most significant benefits of interoperability in the textile industry is in supply chain management. The textile supply chain involves multiple steps, from sourcing raw materials to delivering finished products, and it is crucial for different systems and devices to communicate with each other to ensure that the process runs smoothly. For example, a manufacturer may use a warehouse management system (WMS) to track inventory levels and a transportation management system (TMS) to schedule deliveries. These systems must be interoperable (Dini et al., 2008) to ensure that inventory levels are accurately reflected in the TMS and that delivery schedules are optimized based on real-time data. Interoperability is also essential for quality control in textile manufacturing. Different components of the production process, such as weaving machines, finishing machines, and cutting machines, must work seamlessly together to produce high-quality products. If these components are not interoperable, it can lead to issues such as inconsistent sizing, incorrect colors, and poor stitching. By ensuring that different systems and devices can communicate and exchange data with each other, textile companies can improve the accuracy and consistency of their production processes.

Another area where interoperability can have a significant impact on the textile industry (Imran et al., 2018) is in predictive maintenance. Textile manufacturing equipment requires regular maintenance to ensure that it is functioning at peak performance, and interoperability can help identify potential issues before they become major problems. For example, if a weaving machine is not communicating with a maintenance management system (MMS), it may be difficult to identify when the machine requires maintenance. By ensuring that different systems are interoperable, textile companies can improve the accuracy and efficiency of their maintenance processes, reducing downtime and improving overall equipment effectiveness. Interoperability can also help textile companies optimize energy usage in their manufacturing facilities. Different systems, such as HVAC systems and lighting systems, can work together to ensure that energy is being used efficiently throughout the production process. For example, if a lighting system is not communicating with an occupancy sensor system, lights may be left on in empty rooms, leading to unnecessary energy usage. By ensuring that different systems are interoperable, textile companies can reduce their energy costs and improve their environmental sustainability.

Despite the many benefits of interoperability in the textile industry (Imran et al., 2018), there are also some challenges that must be addressed. One of the biggest challenges is the complexity of the production process. Textile manufacturing involves multiple steps, and different components of the process may use different systems and devices. Ensuring that these systems and devices can communicate with each other can be a complex and time-consuming process. Another challenge is the cost of implementing interoperability solutions. Textile companies must invest in technology and personnel to ensure that different systems and devices are interoperable. This can be expensive, especially for smaller companies that may not have the resources to make these investments. Finally, there is the challenge of data security and privacy. Interoperability requires different systems and devices to exchange data with each other, and this data may be sensitive or confidential. Textile companies must have robust data security protocols and strict access controls to ensure that this data is kept secure and confidential. In conclusion, interoperability is essential for improving manufacturing capability in the textile industry. By ensuring that different systems and devices can communicate and exchange data with each other, textile companies can improve supply chain management, quality control, predictive maintenance, and energy usage. Based on the above discussion, the current proposed a framework as shown in Figure 5.

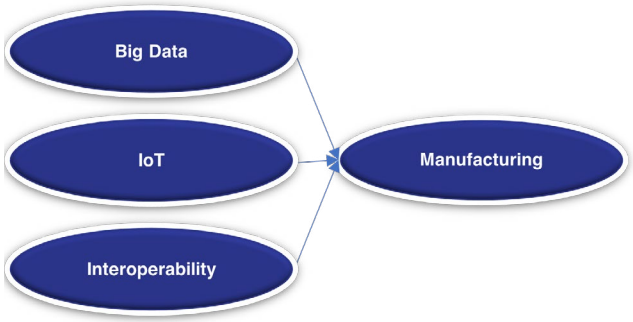


**Figure 5. Conceptual Framework of the Study**

## 3. Conclusion

In conclusion, big data, Internet of Things (IoT), and interoperability are all critical factors in improving the manufacturing capability of the textile industry. Big data enables textile companies to collect and analyze vast amounts of data to make data-driven decisions, while IoT allows for the integration of physical devices and sensors to provide real-time insights and optimize production processes. Interoperability ensures that different systems and devices can communicate and exchange data with each other, improving supply chain management, quality control, predictive maintenance, and energy usage. The relationship between these three factors is complex and multifaceted, and understanding it is essential for textile companies to stay competitive in today's marketplace. By leveraging big data, IoT, and interoperability, textile companies can improve their manufacturing capability, reduce costs, increase efficiency, and meet the demands of their customers. However, textile companies must also address the challenges associated with these technologies, such as the complexity of the production process, the cost of investment, and data security and privacy concerns. In conclusion, the textile industry must continue to embrace and invest in these technologies to stay ahead of the competition and meet the challenges of the future. Ultimately, big data, IoT, and interoperability are essential tools for textile companies to improve their manufacturing capability and succeed in today's rapidly changing marketplace.

## 4. Implications of the Study

The implications of the relationship between big data, Internet of Things (IoT), and interoperability on the manufacturing capability of the textile industry are vast. By leveraging these technologies, textile companies can improve their efficiency, reduce costs, and meet the

demands of their customers. Big data enables textile companies to analyze vast amounts of data to make data-driven decisions, improve quality control, and optimize production processes. By leveraging IoT, textile companies can integrate physical devices and sensors to collect real-time data and insights, allowing for predictive maintenance and energy usage optimization. Interoperability ensures that different systems and devices can communicate and exchange data with each other, improving supply chain management, quality control, and energy usage. The implementation of these technologies also has broader implications for the textile industry, such as improving sustainability and reducing the environmental impact of textile production. By reducing waste, optimizing energy usage, and improving supply chain management, textile companies can reduce their environmental footprint and improve their social responsibility. However, the implementation of these technologies also presents challenges, such as the complexity of the production process, the cost of investment, and data security and privacy concerns. Textile companies must address these challenges and ensure that their implementation of these technologies aligns with their business goals and values. Thus, the implications of big data, IoT, and interoperability on the manufacturing capability of the textile industry are vast. By embracing and investing in these technologies, textile companies can improve their efficiency, reduce costs, and meet the demands of their customers, while also improving their sustainability and social responsibility.

## 5. Limitations and Future Directions

While the relationship between big data, Internet of Things (IoT), and interoperability on the manufacturing capability of the textile industry is promising, there are still limitations and challenges to be addressed. One major limitation is the cost associated with implementing these technologies, which may be a barrier for small and medium-sized textile companies. Additionally, there may be a lack of skilled workers or expertise in these technologies, which may further limit their adoption. Another limitation is data privacy and security concerns, as textile companies must ensure that their data is secure and not compromised in any way. Furthermore, the sheer volume of data generated by these technologies may be overwhelming and challenging to manage, requiring new and innovative approaches to data analysis and storage. Despite these limitations, the future of these technologies in the textile industry looks bright. As the cost of these technologies continues to decrease, smaller textile companies may also be able to implement them. Furthermore, advancements in artificial intelligence and machine learning may further optimize the use of these technologies in the textile industry, allowing for even greater efficiencies and cost savings. In conclusion, while there are limitations and challenges associated with the implementation of big data, IoT, and interoperability in the textile industry, the future looks promising. By addressing these limitations and continuing to innovate, textile companies can unlock the full potential of these technologies and stay competitive in today's rapidly changing marketplace.

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