International Journal of Computer Applications Technology and Research
Volume 13–Issue 02, 17 - 23, 2024, ISSN:-2319–8656
DOI:10.7753/IJCATR1302.1003

Automation and Robotics in Apparel Industry

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Abstract: In a fiercely competitive and rapidly evolving industry such as apparel, effective supply chain management plays a pivotal role. Given the constant fluctuations in customer preferences, the optimization of supply chain processes requires the integration of cutting-edge technologies to achieve maximum efficiency across various activities. This study draws upon data obtained from secondary sources and a comprehensive review of existing literature to delve into the recent developments in supply chain management and technological advancements within the apparel industry. The paper aims to provide a succinct overview of contemporary literature, highlighting the intersection of supply chain dynamics and technological progress, while also identifying new directions in this emerging field. The review emphasizes technologies utilized in supply chain management across both developed and developing countries, encompassing relevant research on automation in the supply chain. Anticipated outcomes include insights that contribute to the understanding of advancements in supply chain practices, serving as a valuable resource for academic researchers in the field.
Keywords: Supply Chain Management, Literature, Research, Optimization, Automation

1. INTRODUCTION

The fashion sector is undergoing a significant transformation due to the impact of the fourth industrial revolution and manufacturing breakthroughs pioneered in Germany. Automation, characterized by the utilization of control systems like computers, is replacing human operators in the execution of industrial machinery and processes. In contrast to mechanization, which involves machines assisting human operators in their physical tasks, automation goes a step further by substantially reducing the reliance on human sensory and mental capabilities. In the contemporary world, a significant portion of manual labor is being replaced by automated and semi-automatic machines. These advanced equipment have not only improved the quality of products and the efficiency of manufacturing plants but have also contributed to reducing lead times, enabling swift operations in today's fast-paced environment.

The term "supply chain management" lacks a universally agreed-upon definition, as indicated by varying interpretations in the literature (New, 1997; Lummus et al., 2001; Mentzer et al., 2001; Kauffman, 2002). Kathawala and Abdou (2003, p. 141) note that SCM "has been poorly defined, and there is a high degree of variability in people’s minds about what is meant." In an effort to address this ambiguity, Mentzer et al. (2001) proposed a broad definition that transcends specific disciplines and effectively encompasses the wide range of issues typically associated with the term. We have chosen to adopt this comprehensive definition as the guiding framework for our research, emphasizing its inclusivity and relevance to the diverse aspects covered under the umbrella of supply chain management.

Supply chain management is characterized as the systematic and strategic coordination of conventional business functions and strategies both within a particular company and across interconnected businesses within the supply chain. The primary objective is to enhance the long-term performance of individual companies as well as the overall efficiency of the supply chain. This comprehensive approach encompasses various stages, starting from the production of fibers, textiles, and finished garments, adding three crucial links to the chain before involving distributors and retailers. The supply chain initiation involves the conception of innovative designs, which are then manufactured, distributed, and ultimately sold. For the seamless progression of new products through the supply chain and effective control of inventory flow, the presence of an organized and competent logistics leader becomes imperative.

2. REALTED WORK

Garment manufacturing, recognized for its reliance on manual labor, has seen efforts to introduce automation over the past three decades. Despite the availability of robots for various tasks, many countries continue to rely on manual labor for these processes. Over the last 30 years, there has been a consistent push for companies to automate garment manufacturing operations. Substantial financial investments were made in developed countries, including Europe and the United States, during the 1980s to automate garment production processes. Despite these efforts, achieving widespread automation in the clothing industry proved challenging, although some individual processes were successfully automated.

Numerous research studies have been conducted since the 1980s to explore automation in clothing manufacturing. Currently, several companies are actively innovating new technologies to facilitate the automation process, incorporating robotic hands, automated spreading machines, and sewing robots. Robotic handling devices, employing reconfigurable automatic handling technology, are designed for the garment industry to handle cut fabrics. Each cut component is individually picked and delivered using a high-flow rate vacuum, with predetermined positions to minimize folds and wrinkles.

Automated spreading machines, utilizing robotic technology, are programmed to analyze nap, spreading mode, creases, and fabric conservation during the spreading process onto cutting tables. In the realm of sewing automation, there are two primary options. The first involves sewing machines equipped with multiple high-speed vision cameras that transmit input to actuators. The second option introduces a water-soluble stiffener, temporarily endowing the fabric with metal-like properties, allowing robots to cut, flip, sew, and move fabric pieces accurately.

Industry Size- The magnitude of the industry significantly influences the adoption of automated and advanced technologies. While smaller industries possess advantages such as operational agility, flexibility, and adaptability, they often shy away from automation due to their limited production volumes. In contrast, larger industries prioritize research and development efforts to explore and implement newer technologies.

Export Market- The industry's export potential influences its embrace of advanced technologies, providing a competitive edge, enabling cost-effective product pricing, and better navigating the challenges of a global market. In contrast, industries primarily catering to the domestic market may operate efficiently without relying extensively on advanced tools and automation.

Garment Styles- In various cases, the adoption and automation of advanced technologies are influenced by the styles and designs of clothing. For instance, a manufacturer specializing in men's clothing may opt for automatic attachment equipment for cuffs and collars, which is readily available at a competitive price.

Profitability- Increased profit levels directly impact the purchasing power of the industry.

Available Budget- The industry's ability to embrace new technologies is also shaped by the quality of its capital stock. The allocated budget for technology adoption significantly influences the extent of technological integration. Given the often high costs associated with advanced technologies, a constrained budget for adoption poses challenges in achieving technological competitiveness.

Management Policy- The external relationships of the industry and the policies for adopting advanced technologies are overseen by the top management. Top-level management is engaged in strategic decision-making, planning, implementation, research and development policies, as well as innovation and export policies. The extent of commitment from senior management to technology adoption plays a pivotal role in determining the adoption level of advanced technology within the plant. The commitment of top management to technology adoption is characterized by the alignment of their values and perceptions in favor of and openness to technology adoption. Consequently, an industry with a dedicated technology adoption team is indicative of this commitment.

Technical Skills-

The rising global demand for highly skilled operators has prompted an increased focus on the adoption of automated tools and equipment. Contemporary manufacturing industries are striving to equip operators with diverse skills; however, the availability of skilled operators is dwindling. Advanced technology-based manufacturing systems emerge as a viable solution to address the evolving skill requirements in this scenario.

Competitive Advantage- The globalization of clothing production has intensified competition among global partners, creating a highly competitive atmosphere. In such a context, the adoption of newer technologies and automation becomes crucial to secure a competitive advantage. Industries that gain a competitive edge through the implementation of new technologies are more inclined to embrace them.

2.1. Automation in Fabric Inspection

Fabric inspection, once a manual process, has undergone significant changes. Contemporary approaches include the adoption of techniques such as the Statistical Approach, Spectral Approach, and Model-based Approach for automated fabric inspection. In each of these methods, specialized software or modeling tools manipulate the fabric image to extract information regarding the severity of fabric defects. The defects are subsequently analyzed, and if the number surpasses the predetermined limit, the fabric is rejected.

2.2. Automation in Designing (CAD, CAM)

It represents a digital adaptation of the manual drafting process traditionally conducted on a drafting table with a pencil and ruler (Calasibetta and Tortora, 2005). The predominant manufacturing method in the majority of Ludhiana's apparel units (85%) remains the conventional approach, while 15% have adopted a blend of traditional garment production methods and CAD/CAM technology. Manual grading is still practiced in certain units, followed by digitization for computer integration. Notably, Nahar Fabrics and Sobhagia Sales Pvt Ltd utilize Gerber (AccuMark version-7.6) for digitization, grading, and marker layout. Sobhagia Sales Pvt Ltd and Astor Technologies at Bhandhari Hosiery Exports Limited also employ Indian-made M D CAD software. April Cornell, Superfine Knitters Ltd, and Cotton County Retail Ltd all leverage Modaris and Diamino Fashion Lectra software.

2.3. Automation in Fabric Spreading & Cutting

In mass garment manufacturing, multiple fabric plies are concurrently cut, and the skill of the spreader significantly influences the quality of the cut components, fabric consumption, and waste during the cutting operation. Traditionally, spreading is a manual process that involves several assistants and spreaders working together to handle tasks such as drawing the fabric, laying it out, and controlling the fabric edge on one side. Manual spreading is known for being time-consuming. To address this, automated spreading machines have been introduced for the spreading process, leading to more efficient fabric utilization. Automated spreading machines reduce the dependency on manual labor, resulting in improved efficiency and a reduction in fabric waste.

Automated spreading equipment is operated by one individual, while another person is positioned on the opposite side of the spreading table. The second person's responsibilities include inspecting the fabric edge, eliminating any excessive creases from the fabric layer, and gathering end parts. The implementation of automatic cutting machines has resulted in a notable reduction in both the workforce required and the time expended compared to manual or operator-controlled devices.

Fig. 1. A fully automatic fabric-spreading machine

2.4. Automation in Sewing: Sewbots

The sewing process is the most prevalent method for joining textiles, constituting 85 percent of all joining techniques. Despite being highly dependent on skilled manual labor, sewing contributes to 35 to 40% of overall costs. In a bid to reduce manufacturing expenses, many sewn goods producers have shifted their production facilities to low-wage developing countries in recent decades. Steve Dickerson, a professor at the Georgia Institute of Technology and the founder of Softwear Automation in Atlanta, delved into robotics technology for sewing. This exploration led to the creation of SEWBOT, an autonomous sewing system comprising an automatic sewing machine (ASM), a robotic arm for handling and moving textiles, and budgers facilitating multidirectional cloth movement to facilitate the sewing process.

Fig. 2 (a): Automatic sewing machine (ASM)

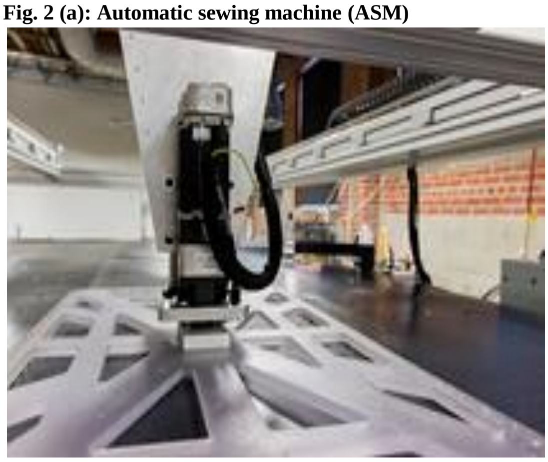

Fig. 2 (b): Robotic arm

Fig. 2 (c): Budgers

Zornow's creation, the "Sewbo" robot, possesses the capability to autonomously handle fabric pieces during the stitching process. Designed in 2015, the "Sewbo" robot is adept at sewing an entire T-shirt from beginning to end. Another notable creation in this realm is the LOWRY SewBot, developed by the Atlanta-based company "Softwear Automation." Specifically designed for the textile industry, these SewBots incorporate cutting-edge technologies from the industrial 4.0 revolution, including computer vision and advanced robotics. These technologies enable them to analyze and manipulate fabric like human capabilities.

Table 1: Advantages and Disadvantages of implementing robotics in Garment Manufacturing.

Merits	**Demerits**
Increase in Productivity	High initial cost of installation
Increased Inventory Turnover	High cost of research and development
Improvement in quality	Security threats
Reduction in repetitive and monotonous work.	High cost of maintenance
Reduction of direct human labor cost	Unexpected product delays
Reduction of variability among the products and product batches.	Limited scope
Performing jobs beyond	Lack of

human capabilities	flexibility

3. Robotics and Automation in Apparel Supply Chain Management

The garment business, being vast, diverse, and global, has undergone significant revolutions in terms of shifting dynamics, evolving from the fundamental concept of "fashion" to the widely acknowledged notion of "fast fashion." The influence of globalization has extended competition in the garment industry beyond domestic borders, compelling it to maintain a youthful and agile character. This sector encompasses a diverse range of subsectors, including clothing, dyes, synthetic fibers, and performance fibers, catering to specific industries such as performance garments and healthcare garments, reflecting its multifaceted nature (Bruce et al., 2004).

The textile and garment industries play a pivotal role in a country's economic well-being, contributing significantly to employment through manufacturing, distribution, and retail activities. This holds true for both developed and developing nations, with a substantial portion of the workforce engaged in these sectors. The migration of garment manufacturing from wealthier nations to developing ones has been propelled by the allure of cheaper labor and reduced production costs in the latter.

Stengg (2001) observes the impact of globalization, particularly the localization of production in third-world countries, altering the competitive landscape for corporations and nations. This shift has led to a growing trend where certain nations find it challenging to compete with the cost advantages offered by countries engaged in lower-cost manufacturing (Nayak et al., 2015). As per en (2008), the clothing industries can be categorized into three groups based on their life cycle: "basic," "seasonal," and "fashion" items. Basic items typically have the longest life cycle compared to the other two, often remaining relevant throughout the entire year. Seasonal items, on the other hand, have a product life cycle of approximately 20 weeks, while fashion products exhibit the shortest life cycle of just 10 weeks. Abernathy et al. (1995) have modified this classification, asserting that "basic" and "seasonal" items primarily focus on men's and children's clothing, while women's wear falls into the "fashion" category, characterized by a greater emphasis on styles, variety, and possibilities.

As noted by Bhardwaj and Fairhurst (2010), "fashion" is a dynamic expression that evolves over time and is distinct for each individual. The emergence of international trade, intensified competition, concentrated production in developing nations, and the continually changing preferences of consumers gave rise to the concept of fast fashion (Djelic and Ainamo, 1999). Sparks and Fernie (2004) characterize fashion by attributes such as limited predictability, extensive diversity, fluctuating demand, a shorter life cycle, and impulsive buying tendencies. Several multinational corporations, including Zara, H&M, and Benetton, engage in competition to offer appealing items that capture a broader audience, expanding the market for their products (Christopher et al., 2004). Porter (1998) asserts that in a contemporary environment, it is not nations but supply networks that engage in competition, leading to significant transformations in supply chain dynamics. Mangan et al. (2008) describe the shift from a fragmented to a fully integrated supply chain. They highlight that in the 1960s, supply chain services, including transportation, storage, purchasing, and production, operated independently. Up until the late 1980s, fashion retailers traditionally relied on predicting trends and understanding customer preferences to place orders, operating on the concept of ready-to-wear clothing (Guercini, 2001). Doyle (Barnes et al., 2006a,b,c) illustrated the comprehensive integration of the modern fashion industry by shifting from the structural format of ready-to-wear clothing to bespoke items. This transformation compelled businesses to enhance flexibility, responsiveness, and offer a broader range of products to the market. Achieving this was made possible by integrating supply chain operations and sharing information across all stakeholders in the supply chain. Marketing and capital expenditure, along with factors like variety, speed, and flexibility, are crucial drivers of a company's competitiveness (Sinha et al., 2001).

As per Taplin (1997), contemporary retailers are increasingly adopting the concept of "rapid fashion," emphasizing speed to market and product customization to reduce the lead time between design inception and consumer consumption. Barnes et al. (2006a,b,c) observed that in the late 1980s, the fashion industry strategically embraced this approach and established an infrastructure that facilitated a rapid response by minimizing lead times, thus delivering clothing at the lowest feasible cost. Nowadays, the principles of low cost and short lead times are integral to the competition within the clothing industry. Consequently, the trend of relocating manufacturing processes to low-cost foreign locations, through outsourcing or offshoring, has become prominent in the garment business. According to Bruce et al. (2004), retailers prefer sourcing clothing from low-cost nations to save costs, as regularly adjusting infrastructure to accommodate evolving client demands would be impractical in industrialized countries. This strategy enables merchants and businesses not only to concentrate on their core competencies but also to allocate their resources and capital elsewhere for a higher return on investment.

Effectively managing supply chain operations and maintaining flexibility poses a substantial challenge in the realm of global outsourcing. Businesses may encounter difficulties restocking fast-selling items in the midst of the season if they run out or experience a surge in demand. Therefore, efficient logistics and supply chain management between suppliers and retailers, along with the exchange of real-time information and collaborative decision-making among all participants in a global supply chain, become crucial. Importantly, while this trend has generated a significant number of jobs in developed nations, it has also created additional opportunities in developing ones.

3.1 Activities in the garment supply chain

Since the late 1980s, the term "supply chain" has gained increasing popularity and usage. The heightened significance of the supply chain can be attributed to various factors, with global sourcing being a key driver. The forces of globalization have compelled businesses to establish online connections and explore innovative methods for enhanced productivity and efficient coordination of product and information flows. Tyndall et al. (1998) illustrated that the implementation of supply chain management varies in perspective, viewed by some as a management philosophy and by others as a management method, differing from operational viewpoints that focus on product and information flow. According to Jones (1995), the supply chain encompasses the movement of products and services from the provider to the end customer. Stevens (1989) defines supply chain management as the synchronization of operations to align with customer expectations, emphasizing high levels of customer service, inventory control, and logistics processes.

The initiation of the garment supply chain begins with the creation of a design. The first concrete phase involves the creation of fibers, which are then processed into yarn. Following various procedures, the yarn is woven or knitted into fabric, ultimately being transformed into a garment. While garment manufacturing processes are commonly perceived as labor-intensive, it's important to note that upstream processes like yarn and fabric manufacturing are capital-intensive.

3.2 Contemporary Trends in Apparel Supply Chain

In the 1990s, a significant transformation occurred for manufacturers and retailers, driven by the imperative of minimizing costs in the market. Despite significant market players achieving cost management through scale economies in production processes, bulk purchasing, ocean cargo transportation, and centralized distribution, they still struggled to match the cost efficiency of garments produced in the Far East and low-wage nations. Consequently, companies with extended process durations needed to enhance and make their supply chains more flexible and shorter (Fernie and Azuma, 2004). This led to the emergence of contemporary supply chain practices such as Just-In-Time (JIT), total quality management, and comprehensive functional support, helping manage complexities associated with substantial geographical distances (Bruce and Daly, 2006).

Supply chains are now more integrated than ever, primarily due to the utilization of Electronic Data Interchange (EDI). However, certain major players in the fashion industry, such as Zara and Benetton, prefer vertical integration, especially for capital and knowledge-intensive processes (Birtwistle et al., 2003; Bruce et al., 2004). The subsequent section discusses some prevailing trends widely accepted and utilized in the garment industry.

3.3 Electronic commerce and radio-frequency identification

The transformation spurred by advancements in information technologies and the Internet has impacted nearly every industry, and the clothing business is no exception. Online product sales have become the predominant market, superseding physical stores and experiencing rapid growth due to various cost-saving advantages. By showcasing products online, retailers can maintain a minimal level of inventory to serve customers from a centralized location, which can often be in a low-cost country.

RFID (Radio-Frequency Identification) stands out as the most promising upcoming technology employed for automatic product identification using radio waves (Dutta et al., 2007; Whitaker et al., 2007). RFID technology has superseded the barcode scanning system, as barcodes have a lower capacity to store data compared to RFID. Moreover, RFID provides the additional advantage of swiftly scanning items even without direct line of sight (Nath et al., 2006; Miles et al., 2008). While RFID can store up to 1000 bytes of data, the amount of information stored on a barcode is considerably less.

RFID technology is also employed in the clothing industry at various stages of the supply chain, marking one of the most significant technological advancements in modern times. In retail, distribution, and integrated operations, RFID is utilized to track and pair items, for theft control, inventory control and management, and more (Gimpel et al., 2004; Liu et al., 2010). Spinning, a capital-intensive process involving the creation of various sizes (counts) of yarn that are easily mixed, is critical. Even a single bobbin of incorrectly mixed yarn can have downstream effects when the fabric or garment is dyed due to different color pickup by different yarn counts. RFID can be used to prevent yarn mixing at the yarn stage. In fabric manufacturing and processing stages, RFID can be employed to segregate batches effectively.

A significant advantage arises at the garment stage, as retail stores and distribution centers can manage large numbers of stock-keeping units with garments easily tracked and traced in real-time. This stands in contrast to the barcode scanning system, which requires line of sight and is a time-consuming process. Retail chains house numerous products and brands under one roof, making it easy and feasible to monitor all items at an individual level using RFID (Loebbecke and Huyskens, 2008). Several retailers, including Walmart, Tesco, and Prada, have realized benefits from employing RFID, especially American clothing companies. This technology has saved many labor hours and reduced instances of unavailable products (Nayak et al., 2015a).

Sankei, a Japanese manufacturer, has implemented RFID at the clothing manufacturing stage for efficient inventory control and item tracking (Wu et al., 2009). Walmart emerged as an early adopter of this technology, urging its suppliers to incorporate RFID if they intended to continue doing business with Walmart. According to a report from the American Production and Inventory Control Society, Walmart persuaded its suppliers to adopt RFID by providing them regular access to point-of-sale (POS) data, ensuring they remained informed about their inventory levels to minimize overproduction costs (Weil, 2005). The successful implementation of this technology by Walmart aligned with its corporate strategy of being cost competitive and having a Quick Response (QR) (Vowels, 2006).

Fast fashion companies like Zara, H&M, and Benetton have captured a significant market share due to their agility, low cost, and high inventory turnover ratio. The realization of these advantages is made possible with the support of technology, and RFID emerges as a suitable choice (Nayak et al., 2015a). According to Loebbecke and Huyskens (2008), the renowned German brand Kaufhof utilized RFID technology to provide clothing and trend recommendations to men in the fitting room automatically, suggesting suitable suits or accessories through a "smart mirror." A RFID reader attached to the smart mirror scanned the items by reading the tag attached to the garment brought into the fitting room. Suggestions were made regarding matching accessories to facilitate upselling at a strategic point of interaction. Additionally, products attached to RFID tags helped prevent theft by sending signals and information to relevant departmental authorities if the item was removed from the store without authorization or without being scanned.

3.4 IoT

As the Internet of Things (IoT) continues to evolve daily, its further advancement is anticipated through related technologies that will propel it into powerful concepts such as Cloud computing, Big Data, robotics, Semantic technologies, and services. These technologies will contribute significantly to fostering the development of IoT and are, in a sense, interdependent. The primary goal of IoT is to enable various electronic devices to be connected anytime and anywhere in the world without constraints of a specific access point or service

The Internet of Things (IoT) is recognized as the new revolution in the realm of the Internet. Objects and devices are becoming more intelligent, manifesting their presence, and gaining knowledge by making various decisions based on their programmed interactions. This is primarily facilitated by their ability to communicate with each other using a common learning protocol. These products and devices can access information collected by physical objects, devices, and sensors, or they can be integral components of a complex network of services. This transformation is empowered by the advent of cloud computing capabilities and the progression of the Internet toward the IPv6 protocol, which offers nearly limitless addressing capacity, addressing a limitation in IPv4.

The Internet of Things provides solutions based on the integration of various information technologies, encompassing both hardware and software utilized for storing, retrieving, and processing information, and communications technology that includes electronic systems used for communication between individuals or groups of devices. The rapid development and convergence of information and communications technology are occurring at three layers of technological advancement: the cloud, data and communication pipelines/networks, and devices. Factors driving this convergence and contributing to the integration and transformation of the cloud.

3.5 Future Plant Idea with IoT

As development and industry transformation unfold, production will undergo a significant shift. Living beings and machines will be more interconnected and communicate with each other. In future factories, individuals will need to interact with a complex environment of processes, networks of processes, machines, sensors, robotics, and devices. This system will necessitate diverse operating concepts for improved human-machine interaction. In the future, the benchmarks for success and competitive advantage will revolve around fast, intelligent, and self-adaptive manufacturing processes.

Currently, the majority of manufacturing and production facilities are designing systems that will render devices and machines adaptable, fully integrated, intelligent, and more efficient, operating in a manner akin to living beings. These emerging manufacturing systems and devices will be the new industrial revolution, referred to as the factory of the future. This model heralds a new era of smart manufacturing based on full automation and increased utilization of technology in the manufacturing process. In the future, the factory model, integrating mechanical equipment and systems with the digital era, will be robust. Data accumulation will occur at a rapid pace, and a robust analytical system will be crucial for processing this data.

The concept of the future production line is primarily oriented towards ensuring and facilitating the availability of all relevant information for real-time processing. This will be achievable through the connectivity present among all components in the value chain. The interaction between people, objects, and various other system elements makes it possible for the value chain to evolve into a continuous process. Consequently, this can help achieve various business objectives, such as reducing costs, optimizing resource utilization, and ensuring high availability.

Manufacturers, factory workers, and customers need to comprehend and embrace the future supply chain as an increasingly complex system, involving various processes, equipment, and components that will operate in an integrated manner. This necessitates different operational concepts to enhance and foster collaboration between humans and machines, aiming to increase efficiency and reduce time-to-market. This approach ensures manufacturers can compete in a way that minimizes operational costs and maximizes resource utilization.

The global smart factory market is projected to reach nearly USD 87 billion by 2023, growing at a compounded annual growth rate of 6% from 2014 to 2020. Communication, automation, robotics, and programmatic intelligence will transform the product landscape as we know it today. Companies like SAP aim to accelerate growth in their IoT solution portfolio, enhance sales and marketing efforts, scale service, support and co-development, and expand their ecosystem of partners and startups in the estimated €350 billion IoT market by 2023.

3.6 Industry 4.0

In the context of Industry 4.0, the term represents the next industrial revolution, signifying a new level of control and coordination across various supply chain industries and their product life cycles, with a focus on individualized customer needs. The processes encompass the entire journey from idea generation, demand creation, development, and manufacturing of the product to its final delivery to the end consumer. Furthermore, it ensures recycling and all post-delivery services. The objective of the fourth industrial revolution is to ensure the availability of current information in real-time by integrating and connecting all parties involved in the value chain. In Industry 4.0, determining the optimal value-added flow is essential throughout the process. The interaction between people, things, and various systems creates a dynamic, interconnected, optimized, and value-adding flow across all organizations in the supply chain in real-time.

4. CONCLUSION

RFID and other technologies have been integral to supply chains since their inception, finding widespread adoption across various industries, especially in the fast fashion sector. The fashion industry has particularly embraced RFID technology for its potential to innovate numerous processes, including manufacturing, incoming and outbound logistics, transportation, distribution, inventory management, and after-sales services. While RFID benefits may vary across industries, its positive implications for the fashion sector are noteworthy.

This paper introduces and details a framework designed for the automation of multiple transactions within an ERP-enabled supply chain. Although RFID is predominantly utilized for item-level tagging and inventory management, the proposed framework goes beyond traditional applications. It leverages RFID data gathered at different points in the value chain to initiate various transactions and streamline processes within an ERP system, significantly enhancing operational efficiency. This becomes crucial in light of the ongoing industry transformation, requiring fashion companies to rapidly adapt their IT infrastructure to keep pace with global market changes.

The widespread adoption of RFID in supply chain manufacturing is now imperative, with a crucial need for the cost of RFID tags to decrease for item-level tagging to become more economically viable for fashion retailers. Companies must strategically restructure their IT landscapes to integrate the technologies discussed in this study. This transformation is necessary to compete with industry leaders, offer superior services to customers, enhance the overall shopping experience in the digital era, and sustain their business in the context of Industry 4.0.

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