Artificial Intelligence Technologies Usage Decides the Success or Failure of Garment Industry Ecosystem

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Abstract] Today, clothing enterprises face heightened global competition and ever-changing consumer demands, necessitating continual enhancements to production processes and services for swift and cost-effective delivery of finished products. This study conducts a review of research in related fields and analyzes the applications of artificial intelligence technology (AITA) in the garment industry. It provides a comprehensive analysis of recent studies on AI utilization in the garment sector and explores the utilization of AI tools (AIT) across various industrial applications in response to the demand for innovative strategies. Additionally, the study delves into the challenges associated with adopting AI technologies in the apparel sector.

[Keywords] artificial intelligence, garment industry, production, supply chain, quality, customer

Introduction

Customers currently have increased expectations on things when purchasing due to improved living conditions. Organizations are trying to improve the quality of the product while minimizing the cost for maintaining a competitive position in the market. To meet the demand, some organizations increase production efficiency, which negatively influences the quality of the product. On the contrary, some organizations, particularly those in labor- intensive industries, believe that to guarantee product quality, they must compromise on production efficiency. Such a trade-off problem afflicts numerous businesses, particularly the garment industry, which is an experienced –rich industry with limited technological capabilities. Most decisions in garment sectors are based on human experience, there are no guidelines which elements to be employed to optimize efficiency and product quality. There is no standard of monitoring process of production while maintaining the product quality in the absence of knowledge supporting system. There are many investigators have been recommended to use data mining and artificial intelligence to acquire knowledge to enable decision taking in garment manufacturing,

Because of rising populations, changing consumer attitudes toward rapid fashion, and rising average wealth per capita in many nations, the demand for clothes has multiplied globally. The developing nations, which are increasingly serving as the production base for major global fashion firms, provide this rising demand for apparel. Despite various commercially accessible automation options, clothing manufacture is still a labor-intensive operation in these developing nations. The lack of technological adoption in the garment sectors is due to the availability of cheap labor and significant initial expenditure. However, the increased demand for premium clothing worldwide and fierce competition are forcing many

manufacturers to use automated technology. The labor-intensive characteristics of the garment business are characterized by inadequate immovable capital investment, a diverse array of product schemes and corresponding raw materials, variable production bulks, ferocious competition level, and often stringent requirements for product quality. To address these requirements, it is imperative to implement automation through the utilization of computer systems, information technology frameworks, digital technologies, and artificial intelligence, thereby streamlining labor-intensive processes.

Data management is essential for businesses to manage their decision-making. Artificial intelligence technologies are especially effective in such circumstances. Artificial intelligence has a wide range of potential applications in the fashion industry, including design support systems, fashion recommendation systems, sensory evaluation, intelligent tracking systems, quality control, fashion forecasting, digital marketing, supply chain management, and fashion e-marketing. The study of artificial intelligence (AI) focuses on the creation and evaluation of intelligent computational agents. This paper also discusses many AI techniques utilized in the production of clothing, including expert systems, neural networks, fuzzy logic, genetic algorithms, and others. This paper also discusses the problem faced in adopting artificial technology in the garment industry.

Literature Review

When it comes to trade, investment, income, and employment generation, the global apparel industry is among the most significant economic sectors. It produces an extensive variety of apparel items that remain often altered to reflect seasonal and style shifts and is highly segmented. The process of making a garment involves numerous processing steps, which start from order receiving and end with the distribution of completed clothing. According to the current apparel business, garment processing steps are classified as pre-production, production, and post-production procedures. Pre-production activities involve sampling, raw material sourcing, cost analysis, and approval of the planned product. Cutting and stitching are two of the manufacturing operations. Thread cutting, inspection, packaging, and consignment scrutiny are examples of postproduction procedures. Every procedure has its own problems and necessities and needs to be considered and handled successfully before moving to the next level. All these processes are making garment manufacturing more intricate and become more complicated in understanding and controlling.

Konina, (2023) identified the key areas of AI utilization by large fashion corporations and AI application factors: significant breakthroughs in data collecting, additional high-tech research, increasing competitiveness, and profound shifts in consumer behavior. The main trend, according to the survey, is that more and more fashion businesses are combining different AI technology. The author's analysis of how fashion companies employ AI apps reveals that a growing number of these apps, which are now essential tools for their businesses, are having an impact on hitherto untapped markets.

Production Perspective

Production planning, control, and scheduling are crucial components of the garment industry, as they play a pivotal role in facilitating the synchronization of material and information flow between consumers, suppliers, and the business itself. These processes are vital in establishing the value stream of the products. The management of material flow, employee utilization, and meeting customer expectations are key aspects that it oversees. Nevertheless, this procedure is susceptible to many disruptions that hinder the achievement of the desired efficacy in the implemented measures. Hence, the utilization of artificial intelligence methodologies throughout many domains of production planning and control holds the potential to effectively govern the knowledge inside the field, thereby facilitating enhancements in meeting client expectations.

Artificial intelligence-based technologies such as robots and machines are utilized to boost accuracy, minimize labor hours, and even forecast when a machine is likely to malfunction, hence reducing production machine downtime. AI can also be applied in the fashion and garment industries to improve product design and streamline the manufacturing process (Rathore, 2023).

Supply Chain Perspective

Supply chains are critical to excellent client experiences, cost control, and a company's adaptability in the face of market opportunities and uncertainties. Companies desire speed, dependability, and traceability while keeping in mind budgetary constraints, deadlines, and inventory optimization. According to the findings of (Mentzer *et al*.,2001), a supply chain may be defined as an intricate network of unified firms engaged in many systems and events aimed at generating wealth through the manufacturing and distribution of products and services to the end user. According to (Borges *et al*.,2021) such links, processes, and activities require monitoring, forecasting, prediction, and optimization to function well in the complex contexts in which supply networks operate and to produce more flexible and resilient supply chains. Across recent years, artificial intelligence (AI)-based applications have evolved across a variety of industries, including supply chains. AI enables computers to make intelligent decisions and carry out activities without the need for human interaction.

The product life cycle in fashion business is short, product variation is varied, unpredictable demand, and supply chain is long and non-flexible. Due to complexity and interdependence in fashion supply chain, necessitate a shift away from the "take, make, waste" to a more sustainable strategy.

According to (Hales *et al*., 2012), technologies that are ready to use and highly adaptable can help businesses maintain flexible, efficient, and cost-effective product supply lines. For instance, data from many sources can be gathered and analyzed using analytics and cloud-based technologies. The wants of certain clients can therefore be met by more individualized supply solutions that are made using this knowledge. Additionally, businesses may benefit from technologies like 3D printing, robots, and artificial intelligence by automating and optimizing their manufacturing processes, minimizing waste, and guaranteeing accuracy and quality. Feedback from customers can also help businesses for understanding of consumer buying behaviour. By using this information, organizations can build and modify their supply networks as necessary. Such technology could help businesses create a supply chain that is more adaptable and responsive, which will be crucial for the development of commerce.

Businesses employ artificial intelligence (AI) and machine learning to gain understanding of a range of industries, including supply chain management, logistics, and storage. According to the perspective from which it is defined, AI has different definitions. Any machine or device that leverages computing prowess to imitate human intelligence falls under the wide term of artificial intelligence (AI).

Quality Control Perspective

The visual examination of semi-finished and finished garments is still a critical component of the garment inspection stage of quality control. Due of the wide range of clothes designs, sizes, and fabrics, this step alone takes a long time. Another issue is the quality standardization, which necessitates repeated inspections to satisfy a certain standard (Fung *et al.*, 2011). However, because employees are susceptible to weariness or boredom, manual inspection has limits in maintaining accuracy, steadiness, and productivity. As a result, inspection findings are frequently erroneous, imprecise, and prejudiced. Setting up an advanced garment inspection system that may reduce or even completely remove the need for manual inspection and improve product quality is important to address these issues. In this manner, artificial intelligence methods may be investigated to guarantee precise and trustworthy quality control in the production of commercial clothing.

Customer Perspective

The study conducted by Ngai et al. (2014) indicates that the increasing popularity of AI-based solutions in many industries is influencing client demand. AI can analyze customer data points and insights to create data-driven enterprises that meet customer needs. For example, AI can be used to evaluate user feedback and rapidly customize products and experiences. In addition to examining user preferences, AI has the potential to produce product recommendations.

This study's research employed a multi-phase research methodology to show how important marketing analytics capabilities are to an organization's ability to identify, capture, and reshape the market in order to gain a sustainable competitive edge. The use of artificial intelligence (AI) on a marketing analytics platform improves the efficiency of detecting, seizing, and reorganizing internal business processes (Hossain et al., 2022).

Seasonality and quickly changing trends and styles cause fashion products, which can include anything from clothes to accessories to shoes, to constantly change (Shelly & Rosenblatt, 2012). The increasing number of customers who are shopping online adds to the complexity of this issue and makes it more difficult for businesses to properly meet customer demand and maintain correct and current inventory levels. Artificial Intelligence has the potential to lessen complexity by offering insight into customer preferences and demand projections. Because of this, businesses will be able to estimate client needs with accuracy and allocate inventory appropriately. To improve the shopping experience, AI may also automate processes like product assortment management, product categorization, and personalized product recommendations.

Unintended Consequences and Negative Impacts of AI

Researcher's major focus is on the advantages of AI usage, a number of recent incidents show that unintended consequences could occur in the absence of effective AI governance tools. One of the most obvious instances is when companies fail to classify and correct bias in data, which leads to unfavorable consequences for particular racial or demographic segments. For instance, multiple stories highlight biased AI results relating to racial bias (Zuiderveen Borgesius, 2020) and gender bias (Dastin, 2018; Vigdor, 2019). According to Arrieta et al. (2020), one example of the unintended consequences of AI algorithms is the increasing need from businesses for explainability on how they arrive at specific outputs. Moreover, this method has led to a broad desire for increased openness at every stage of the process, from gathering data to developing outcomes (Loyola-Gonzalez, 2019). According to Samek and Müller (2019), insufficient openness and a deficiency of explainability practices erode people's trust in AI systems. Additionally, employment of AI for citizen and customer engagement (such as chatbots) in circumstances where human-centric principles were neglected led to user complaints and frustration, which negatively impacted the reputation of the firm (Marcondes et al., 2019).

Challenges Faced in AI Adoption

One of the primary challenges in this study is the dearth of accessible data and the constrained size of the samples. Indeed, contemporary artificial intelligence methodologies necessitate a substantial amount of annotated data to attain satisfactory levels of precision in their predictive capabilities. However, garment firms have a shortage of adequately labeled training data due to the high cost and time-consuming nature of labeling, resulting in insufficient solutions. Hence, it is imperative for AI methodologies to progress towards the use of Unsupervised Learning models, which eliminate the necessity for labeled data in the training process of AI models. Bhalerao et al., (2022) found that manpower competencies, inadequate finance, small size of the organization, attitude of the promoter of the business and poor data quality are the major challenges faced by SMEs.

1. The current financial burden associated with integrating artificial intelligence into routine operations remains substantial, with the potential for future technological breakthroughs to mitigate these costs. Nevertheless, the allocation of funds and resources necessary for the development of intelligent computers capable of executing intricate human jobs may not be seen justifiable in light of the potential enhancements in productivity or reductions in costs.

2. Most of the prior research has mostly concentrated on proposing a methodology based on Artificial Intelligence (AI) to address a specific problem. However, only a limited number of scholarly articles have undertaken a comparative analysis of various AI tools.

3. The significant calculated period necessary for processing the dataset of considerable magnitude. Undoubtedly, problems that are straightforward or readily identifiable can be resolved within a polynomial time complexity. Nevertheless, when dealing with intractable problems, the required time to solve those increases exponentially as a function of the problem size.

4. Configuration of various elements in artificial intelligence technology significantly impacts its performance. The lack of a robust theoretical framework for AI techniques often necessitates the

reliance on experiential knowledge or trial-and-error approaches for parameter tuning in prior research.

5. A significant portion of our workforce may lose their jobs because of AI meddling in human roles. Therefore, detractors can advocate against the use of expanded AI.

6. Even though adoption of an AI-based system could result in major advantages, lack of confidence in its fairness will restrict support for its usage and probably prevent it.

Methodology Adopted

The research paper adopts an exploratory case-based approach and has selected a diverse range of garment industry cases representing different segments of the value chain, including AI in design and manufacturing. A detailed literature study was conducted and fact statements from peer reviewed journals of the highest category were drawn on various scenarios about study. Cases were selected based on their significance, innovation, and relevance to AI technology adoption. A sequence of historical events and economic slowdown scenarios from various developing nations were studied. Careful observation of literature has led the researchers to propose robust suggestions for the research paper. Data for the case was collected through secondary sources which includes industry reports, academic publications, and news articles. The collected data was analyzed using qualitative research methods, including thematic analysis and pattern recognition. Themes related to AI technology adoption, implementation challenges, success factors, and industry implications were identified and analyzed across different case studies. Also, the best practices adopted, emerging trends, and critical success factors for AI adoption in the garment industry ecosystem was identified in the case.

Case 1: The Utilization of Artificial Intelligence (AI) in the Realm of Garment Design with the Objective of Reducing Water Consumption

In the process of developing novel garments using a newly introduced fabric, clothing companies are required to subject the fabric to over 1,000 washing cycles to ascertain the point at which the ink on the fabric's instructional label begins to fade. The longevity of the ink is intended to endure for the whole lifespan of the garment. Due to the continuous emergence of novel fabric types, a substantial quantity of water is being used in the process of assessing the durability of ink. The resolution of this problem is among the objectives that Avery Dennison, a US-based company specializing in luggage and fabric tag manufacturing with a market value of $8.4 billion, aims to address through the utilization of artificial intelligence (AI) at its newly established research and development (R&D) center in India. Sanjay Agrawal, Vice President of Information Technology at Avery Dennison RBIS (Retail Branding and Information Solutions), expresses the intention to contribute towards the accurate anticipation of ink fading occurrences while minimizing water use. The proposed methodology involves doing a comprehensive examination of the materials employed, analyzing the chemical composition of the ink utilized, evaluating the ink's performance in prior instances, and afterwards employing artificial intelligence techniques to forecast the efficacy of the ink on instructional labels. Avery Dennison has established a comprehensive ten-year digitalization strategy with the objective of enhancing its sustainability practices.

The firm is also actively engaged in promoting sustainability initiatives from the perspective of end users. Efforts are underway to include the printing of barcodes on garments, enabling consumers to scan them in order to establish a connection with the local recycling facility. The company intends to generate barcodes that consumers may utilize for the purpose of tracking the provenance of their purchased garments. Agrawal's study showcased the functionality of his mobile device, whereby scanning a barcode attached to a clothing item led him to the official website of the company. This website provided comprehensive information on the specific collection to which the clothes belonged, details regarding its manufacturing batch, and its corresponding pricing. Several beta testings are now underway. The objective is to reduce the occurrence of counterfeit activities. The objective of our initiative is to provide consumers with a

comprehensive perspective of the product. According to Agrawal, the development of this project would take place in the digital acceleration center located in Bengaluru. The proposed strategy aims to provide marketers increased freedom in determining the specific information they wish to convey to customers via barcodes. Various brands have distinct preferences about the information they like to have presented. According to Agrawal, it is imperative to devise strategies for effectively addressing and implementing such demands on a significant scale, as well as successfully introducing them to the market. The primary focus of the company's research endeavors pertains to the monitoring of food and the mitigation of food waste. The utilization of RFID technology is being considered as a means to provide end users with precise information on the date of food item preparation, its origin, and to establish a connection between hotels and organizations involved in the collection of food waste.

The current workforce at the R&D center in Bengaluru consists of 50 individuals. However, Agrawal has expressed the intention to expand this number to encompass 1,000 researchers by the year 2030. The organization is now in the process of hiring individuals with expertise in data science, data engineering, and machine learning. Researchers from various regions of Avery Dennison are anticipated to visit the Bengaluru center in order to engage in collaborative endeavors.

Case 2: Real-Life Use Cases of Generative AI in Fashion and Textiles

The utilization of generative AI algorithms has been implemented in the domain of fabric and pattern design, enabling the creation of sophisticated fabric patterns and textures. One example of the application of generative AI in the fashion industry is observed in the utilization by Zara, a renowned fashion brand, to create distinctive fabric designs that emulate the visual characteristics associated with conventional artisanal techniques. This software facilitates the production of aesthetically impressive textiles that were previously challenging to make through human means.

The concept of virtual fitting and customization is undergoing a revolutionary transformation through the application of generative artificial intelligence (AI). Adidas and Nike are prominent examples of companies that have successfully implemented generative artificial intelligence (AI) platforms, enabling their customers to engage in the creation and customization of footwear products. Customers can choose from a variety of patterns, colors, and materials, enabling them to obtain a product that is truly distinctive and customized to their preferences.

The application of Generative AI in trend prediction and forecasting involves the analysis of extensive datasets, including social media posts, fashion blogs, and historical sales data, to anticipate fashion trends. This capability empowers fashion firms to proactively anticipate consumer preferences and develop designs that match with current trends, thereby mitigating the risk of excess inventory and optimizing business strategy.

The utilization of generative AI algorithms is prevalent in the development of fashion styling and recommender systems. Through the analysis of client data, these systems have the capability to provide personalized outfit recommendations by taking into account individual tastes, body morphology, and the specific occasion. Fashion e-commerce platforms, such as Stitch Fix, have incorporated this technology into their operations, resulting in improved online shopping experiences for customers and heightened levels of customer engagement.

Case 3: AI @ H&M

Artificial intelligence (AI) is being used strategically by the H&M Group to create a value chain that is climate-positive by 2040. Linda Leopold, the head of AI at H&M, claims that the clothing retailer uses demand forecasting methods powered by AI to improve the effectiveness of its supply chain. Over 200 data scientists work for H&M and are committed to understanding trends and patterns in consumer behavior across all the company's many retail locations. The company uses big data analytics to evaluate the unique needs of clients at a local level. In order to study client requests, the research team has created algorithms for examining store receipts, in-store returns, and loyalty benefit cards. Additionally, the programs used in

postings and search engine results as additional sources of knowledge about fashion trends. The business uses a regional approach. For instance, the personnel at a Stockholm-based H&M store used artificial intelligence to examine the fashion preferences of the female customers. The results of the investigation showed that consumers preferred fashion-oriented clothing, such as floral skirts, and showed a larger propensity to buy items with higher price tags. The store incorporated the addition of a coffee shop and changed its inventory as a result of the study's findings. H&M has consequently recorded a considerable increase in sales at this specific store.

To improve the effectiveness of its supply chain operations and reduce waste, H&M uses artificial intelligence (AI) technology. The company uses machine learning algorithms to estimate product demand and evaluate sales data. In order to reduce waste and improve operational performance, H&M adapts its production levels and distribution networks in response to these estimates.

The ability to meet the requirements of the current generation without endangering the environment's ecology is referred to as sustainability. As evidenced by their pledge to only use 100% recycled or sustainable materials by the year 2030, H&M is actively pursuing sustainable practices within the fast fashion sector. The company is also using artificial intelligence (AI) to evaluate the environmental impacts related to its raw materials. Our strategy entails integrating artificial intelligence (AI) throughout the whole value chain to improve our business solutions. In this research, we will look at notable instances that show how it is important to take into account the volume and intricacy of a company, such H&M, which has 5000 stores. We will concentrate on the business' substantial turnover of more than 200 million kroners in the previous year, in particular. H&M's lead data scientist, Errol Kollmeister, claimed that the use of AI in our clothing shopping decisions has a big impact.

This influence covers a range of topics, such as choosing the precise products to buy, when to buy them, how many outfits to get, where to put them in stores best, and ultimately making sure we remain relevant to customers throughout this process. The person claims that the framework has proven to be beneficial by significantly reducing the time needed for use case creation, from a period of 12 months to a more accelerated timeframe of six months, by 50%. H&M has created a framework for artificial intelligence (AI) that is based on a list of nine principles. These values cover the following topics: honoring human agency, being focused, beneficial, fair, transparent, governed, cooperative, and reliable.

Conclusion

AI can be applied to several aspects of textile and clothing product quality control and inspection. The quality of clothing, fabric, and yarn has already improved thanks to the use of AI-enabled systems in developed nations. Significant advancements are being made in Al at a rapid pace, and in the near future it is anticipated that the AI will play a significant role in the quality inspection and control processes used by the apparel industry. To integrate elements like production, quality, cost, etc., to deal with lean manufacturing, just-in-time production, and computer integrated production, an AI system is one of the finest options in the textile and clothing business. Therefore, it goes without saying that applying artificial intelligence to the textile business has enormous potential, just like applying it to other fields.

The case study on the utilization of artificial intelligence (AI) in the realm of garment design with the objective of reducing water consumption summarizes that Avery Dennison employs AI to forecast ink durability, reducing water usage in garment design. The company promotes sustainability through barcode printing for consumer tracking and recycling. It's also exploring RFID for food waste monitoring. With plans to expand its workforce in data science and machine learning, Avery Dennison aims to enhance sustainability practices in the garment industry.

The case on Real-Life Use Cases of Generative AI in Fashion and Textiles highlights the real-life use cases of generative AI in fashion and textiles demonstrate its transformative impact on various aspects of the industry, including design, customization, trend forecasting, and customer experience. By harnessing the power of generative AI, fashion brands can innovate, personalize, and optimize their operations to meet the evolving needs and preferences of consumers in an increasingly competitive market.

The case study on AI @ H&M highlights how H&M leverages AI across its operations to enhance sustainability, optimize supply chains, and meet customer demands. Led by Linda Leopold, H&M's AI team

analyzes consumer behavior to drive localized decisions. Using AI-powered forecasting and machine learning, H&M adapts production and reduces waste. The company aims to use 100% recycled materials by 2030 and employs AI to assess environmental impacts. Errol Kollmeister emphasizes AI's role in improving decision-making and reducing time-to-market. H&M's AI framework prioritizes ethical and responsible use. Overall, H&M's strategic AI integration reflects its commitment to sustainability and innovation in the fast fashion industry.

Discussion

It is obvious that practical AI applications in the textile industry are still in their infancy, and it is possible that the textile and apparel industries are more likely to adopt cutting-edge AI manufacturing applications for quick and error-free quality inspection of textile and apparel products. Most scholars have noted that it is evident that AI-enabled quality inspection would eventually replace manual quality control. It is already well-established that quality inspection systems with AI capabilities can regulate product quality effectively in a shorter time frame and with fewer human interventions. Investment in AI-enabled automated inspections systems is highly capable of achieving adequate ROI because it is free from human error and weariness.

Case 1

Avery Dennison's strategic utilization of artificial intelligence (AI) in garment design aims to address environmental concerns such as water consumption while enhancing sustainability practices. By employing AI techniques to forecast ink efficacy on garment labels, the company seeks to minimize water usage during fabric testing processes. Additionally, Avery Dennison is actively promoting sustainability initiatives by incorporating barcodes on garments for consumer tracking and recycling purposes. The company's comprehensive digitalization strategy underscores its commitment to sustainability and innovation. With plans to expand its research and development (R&D) center in Bengaluru and hire experts in data science and machine learning, Avery Dennison is poised to further advance its AI-driven sustainability efforts in the garment industry.

Case 2

The real-life applications of generative AI in fashion and textiles present transformative opportunities across various aspects of the industry. From fabric and pattern design to virtual fitting and customization, trend prediction, and fashion styling, generative AI enables companies like Zara, Adidas, Nike, and Stitch Fix to enhance creativity, personalize products, and optimize business strategies. By leveraging extensive datasets and AI algorithms, these companies can anticipate consumer preferences, minimize inventory risks, and improve the online shopping experience for customers. Overall, generative AI is revolutionizing the fashion industry by driving innovation, efficiency, and customer satisfaction.

Case 3

H&M's integration of AI technologies demonstrates a strategic commitment to sustainability, data-driven decision-making, and customer engagement. By leveraging AI for demand forecasting, regional customer analysis, and supply chain optimization, H&M aims to reduce waste, improve operational efficiency, and meet sustainability goals. The company's pledge to use 100% recycled or sustainable materials by 2030 underscores its dedication to environmental responsibility. Additionally, the adoption of AI frameworks has led to increased efficiency and innovation in decision-making processes. Overall, H&M's approach highlights the transformative potential of AI in driving sustainability and competitiveness in the retail industry.

Practical Implications

This study provides substantial foundation to various stakeholders of garment industry and AI based technology companies. AI has a lot of potential for the engineering of clothing because it can significantly speed up product creation and save money. It turns into a fantastic tool for policy makers to plan efficiently

and carry out challenging industrial operations, spot and address urgent quality issues, and produce goods that meet specific client needs.

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