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| RESEARCH ARTICLE

Sustainable Apparel Supply Chains: A Review of AI-Driven Optimization, Waste Reduction, and Circular Economy Practices

Nadira Kulsum Papri
Department of Graduate Information Technology/Graduate, University of the Cumberlands, Williamsburg, KY-40769, USA. ORCID: 0009-0006-4665-161X
Corresponding Author: Nadira Kulsum Papri, **E-mail:** npapri18280@ucumberlands.edu

| ABSTRACT
The apparel industry faces persistent sustainability challenges arising from overproduction, inefficient resource utilization, textile waste, and increasingly complex global supply chains. Artificial intelligence (AI) has emerged as a promising technology for improving operational decision-making; however, evidence of its contribution to sustainability remains fragmented across research on forecasting, production, waste management, and the circular economy. This narrative review synthesizes current knowledge on AI-enabled optimization, waste reduction, and circular economy practices within apparel supply chains. Drawing on recent literature, the review examines AI applications in demand forecasting, production planning, supplier selection, logistics, risk management, and explainable decision support, and evaluates their role in reducing textile waste and supporting circular strategies such as product life extension, traceability, reverse logistics, and material recovery. The review finds that AI contributes to sustainability primarily by improving the quality of operational decisions rather than through automation alone. Although AI can enhance resource efficiency, reduce waste, and strengthen circular supply chains, these benefits depend on effective governance, high-quality data, organizational capability, and integration with circular economy practices. Based on this synthesis, an integrated conceptual framework is proposed that positions AI as a decision-support capability linking operational decisions with sustainability outcomes through continuous feedback and governance mechanisms. The review also identifies key research gaps, including the need for industrial validation, apparel-specific datasets, and responsible AI implementation. The findings provide researchers and practitioners with an integrated perspective on how AI can support the transition towards more sustainable and circular apparel supply chains.

| KEYWORDS
Artificial intelligence; Apparel supply chain; Sustainable supply chain management; Circular economy; Textile waste; Decision support.

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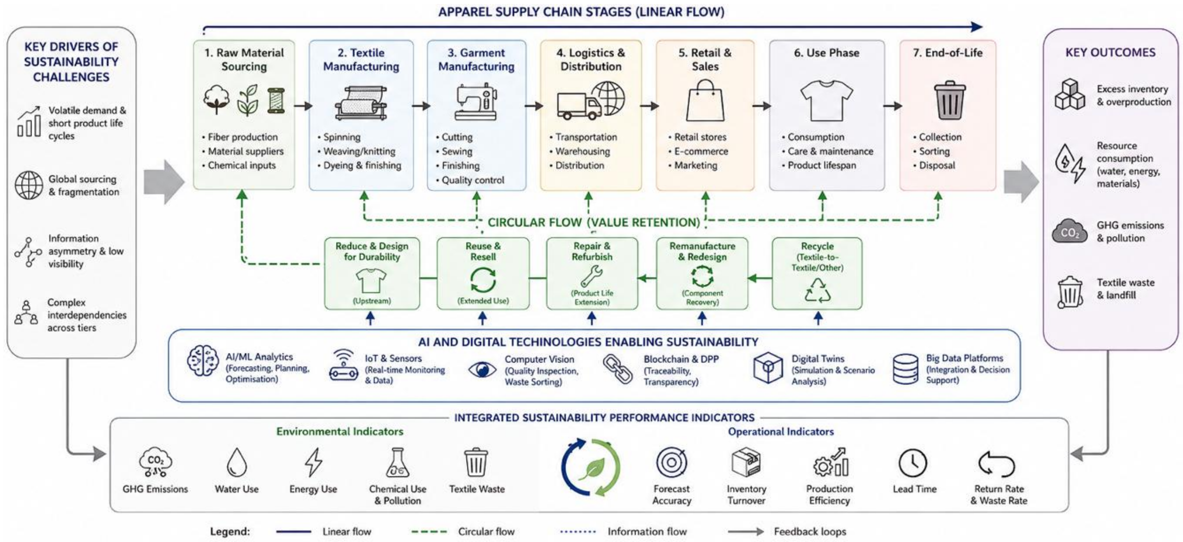
Graphical Abstract



1. Introduction

The apparel industry is one of the world's most resource-intensive manufacturing sectors, consuming substantial quantities of raw materials, water, energy, and chemicals while generating significant greenhouse gas emissions and textile waste. Despite increasing investments in cleaner production technologies, sustainability certifications, and environmental management initiatives, the industry's environmental footprint continues to expand alongside rising production volumes, accelerated product turnover, and growing consumer demand (Niinimäki et al., 2020; Younus et al., 2024). These trends suggest that improvements in manufacturing efficiency alone are insufficient to achieve sustainable development. Instead, environmental performance is increasingly determined by decisions made throughout the entire apparel supply chain, from product design and material sourcing to manufacturing, distribution, retailing, consumer use, and end-of-life management (Singh, 2024). Consequently, improving sustainability requires an integrated supply chain perspective that addresses resource utilization and environmental impacts across the product lifecycle rather than focusing solely on production processes.

The complexity of apparel supply chains further intensifies these sustainability challenges. Unlike many manufacturing industries, apparel production is characterized by short product life cycles, rapidly changing fashion trends, volatile consumer demand, and geographically dispersed production networks involving numerous suppliers, manufacturers, logistics providers, retailers, and consumers (Bin Makhashen et al., 2020; Bruce et al., 2004; Shehun, 2022). While global sourcing has improved manufacturing flexibility and reduced production costs, it has simultaneously reduced supply chain visibility and increased coordination challenges across organizational boundaries (Suhaimi et al., 2026). These conditions complicate procurement, production planning, inventory management, logistics, and demand forecasting, making it difficult for firms to balance economic performance with environmental sustainability (Sauer & Seuring, 2018; Toorajipour et al., 2021; Turker & Altuntas, 2014). As a result, sustainability in apparel supply chains depends not only on environmentally friendly production practices but also on effective decision-making across interconnected supply chain activities.

Operational inefficiencies within these fragmented supply chains contribute directly to persistent environmental problems, including overproduction, excess inventory, textile waste, greenhouse gas emissions, and inefficient resource utilization (Leal Filho et al., 2024). To minimize the risk of stock shortages and respond quickly to uncertain market demand, fashion retailers frequently produce or procure quantities exceeding actual consumer requirements. Although this strategy improves product availability, it often results in unsold inventory, aggressive markdowns, premature disposal of garments, and increased waste throughout the product lifecycle (Jia et al., 2020; Shirvanimoghaddam et al., 2020). Furthermore, the continued dominance of linear production systems—where products are manufactured, consumed, and discarded with limited material recovery—places considerable pressure on natural resources while restricting opportunities for reuse, remanufacturing, and recycling (Kirchherr et al., 2017; Sandin & Peters, 2018). These environmental challenges are highly interconnected: overproduction increases inventory levels, transportation requirements, and carbon emissions, while limited supply chain visibility constrains organizations' ability to optimize production schedules, recover materials, and improve circular resource flows (Erhun et al., 2021; Niinimäki et al., 2020). Therefore, achieving sustainability requires coordinated, data-driven decisions across the entire apparel value chain.

Recent advances in AI, machine learning (ML), big data analytics, and related digital technologies have created new opportunities to improve decision-making throughout apparel supply chains (Chowdhury et al., 2024; Giri et al., 2019). Unlike conventional analytical approaches that rely primarily on predefined statistical relationships, AI systems can process large volumes of structured and unstructured data to identify complex patterns, generate predictions, optimize operations, and automate decision-making (Baryannis et al., 2019; Toorajipour et al., 2021). Consequently, AI applications have expanded rapidly across demand forecasting, inventory optimization, supplier evaluation, production scheduling, logistics planning, quality inspection, and textile waste classification. More recently, AI has been integrated with complementary technologies, including computer vision, the Internet of Things (IoT), blockchain, digital product passports, and advanced sensing systems, to improve traceability, information sharing, and lifecycle management across apparel supply chains (Dissanayake et al., 2025; Rejeb et al., 2019).

Nevertheless, the increasing adoption of AI should not be interpreted as evidence that technological innovation alone can resolve the sustainability challenges confronting the apparel industry. Existing studies frequently evaluate AI according to predictive accuracy, computational performance, or operational efficiency, whereas comparatively less attention has been devoted to understanding whether these technological improvements translate into measurable reductions in resource consumption, waste generation, and environmental impacts. For example, more accurate demand forecasting does not necessarily reduce overproduction if organizations continue to prioritize product availability, maintain conservative inventory policies, or operate under fast-fashion business models that encourage rapid product turnover (Hossain et al., 2025; Waltersmann et al., 2021; Xue et al., 2025). Similarly, advances in automated textile sorting alone cannot substantially improve circularity without effective collection systems, recycling infrastructure, and secondary material markets. Consequently, the sustainability value of AI depends not only on technological capability but also on how AI-supported decisions are embedded within broader organizational strategies, governance structures, and circular economy initiatives.

Although research on AI, sustainable fashion, and the circular economy has expanded considerably during the past decade, these research streams have largely evolved independently. Existing reviews primarily examine AI applications for forecasting, optimization, resilience, and operational performance (Toorajipour et al., 2021), while reviews of circular economy practices focus on material recovery, product life extension, recycling technologies, and circular business models within the textile and apparel sector (Dissanayake & Weerasinghe, 2022; Jia et al., 2020). More recent studies have explored digital innovations for sustainable fashion supply chains (Suhaimi et al., 2026), AI-enabled textile waste sorting (Faghih et al., 2025), and digital product passports for circular supply chain management (Zhang & Seuring, 2024). However, these reviews generally examine individual technologies or isolated sustainability practices rather than explaining how AI-driven decision-making interacts with waste-reduction strategies and circular-economy principles across different stages of the apparel supply chain. Consequently, current knowledge remains fragmented, limiting a comprehensive understanding of how AI contributes to sustainability beyond isolated technological applications.

To address this gap, this review synthesizes the current evidence on AI-enabled optimization, waste reduction, and circular economy practices within apparel supply chains through an integrated lifecycle perspective. Rather than examining these topics independently, the review investigates how AI-supported decision-making influences environmental performance across product design, sourcing, manufacturing, logistics, retailing, consumption, and end-of-life management. Specifically, the review (i) examines AI applications across key supply chain functions, (ii) evaluates their contributions to waste reduction, resource efficiency, and circular economy implementation, (iii) identifies the organizational and technological conditions that influence successful adoption, and (iv) highlights future research priorities for developing more sustainable, resilient, and intelligent apparel supply chains. Figure 1 presents the conceptual framework underpinning this review, illustrating how AI-enabled decision-making, governance mechanisms, and continuous operational feedback collectively support sustainable outcomes throughout the apparel lifecycle.

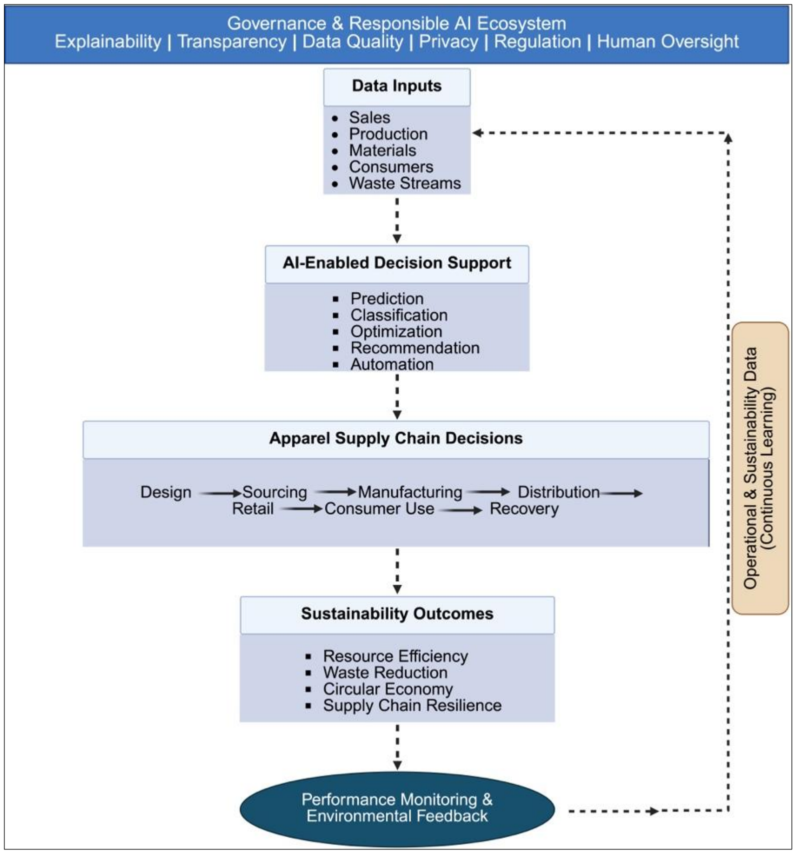


Figure 1: Conceptual framework of AI-enabled decision support for sustainable apparel supply chains.

2.1 Research Design

This review adopts a narrative review approach to synthesise current knowledge on the application of AI in sustainable apparel supply chains, with particular emphasis on supply chain optimisation, waste reduction, and circular economy practices. A narrative review was considered appropriate because the objective of this study is not to evaluate the effectiveness of a single intervention or to aggregate empirical findings statistically, but rather to integrate evidence from multiple research domains, identify emerging themes, examine relationships between concepts, and develop a broader understanding of how AI can contribute to sustainability across different stages of apparel supply chains. Given the multidisciplinary nature of the topic, encompassing supply chain management, textile engineering, artificial intelligence, operations management, sustainability, and the circular economy, a narrative synthesis offers greater flexibility in integrating diverse forms of evidence than more restrictive review methodologies (Madden et al., 2018).

2.2 Literature Search

The literature was identified through comprehensive searches of major academic databases, including Scopus, Web of Science, and ScienceDirect. Additional relevant publications were identified by examining the reference lists of influential review papers and highly cited articles. The search strategy combined keywords related to artificial intelligence ("artificial intelligence", "machine learning", "deep learning", "computer vision", "predictive analytics"), apparel supply chains ("fashion supply chain", "apparel supply chain", "textile industry", "garment manufacturing"), sustainability ("sustainable supply chain", "green supply chain", "resource efficiency"), waste management ("textile waste", "waste reduction", "recycling", "reverse logistics"), and circular economy ("circular economy", "product life extension", "digital product passport", "traceability"). These terms were combined using Boolean operators to improve the retrieval of relevant literature.

2.3 Inclusion and Exclusion Criteria

The review primarily considered peer-reviewed journal articles published in English, while selected reports from internationally recognised organisations, including the Ellen MacArthur Foundation, were incorporated where they provided important conceptual or industry-specific insights. Particular emphasis was placed on studies published between 2018 and 2026 to capture recent advances in AI applications, digital technologies, and circular economy practices within apparel supply chains. Earlier publications were retained when they introduced foundational concepts that continue to influence contemporary research, such as sustainable supply chain management, circular business models, and conceptualisations of the circular economy (Bocken et al., 2016; Kirchherr et al., 2017).

2.4 Thematic Synthesis

Rather than organising the literature chronologically, the retrieved studies were analysed using a thematic synthesis approach (Thomas & Harden, 2008). This method enabled studies from different disciplines to be compared according to their primary contribution to the review rather than their publication date or research methodology. During the synthesis process, the literature was grouped into four broad themes: (i) sustainability challenges in apparel supply chains, (ii) AI-driven optimisation of supply chain activities, (iii) AI applications for textile waste reduction, and (iv) circular economy practices supported by digital technologies. Within each theme, the review critically examined areas of consensus, conflicting findings, methodological limitations, and emerging research opportunities instead of simply summarising individual studies. This approach supports the development of higher-level interpretations regarding the role of AI in improving sustainability throughout the apparel value chain.

2.5 Study Limitation

Although every effort was made to ensure broad coverage of the literature, several limitations should be acknowledged. First, the review focuses primarily on peer-reviewed publications published in English, which may exclude relevant evidence reported in other languages or industry documents. Second, because AI technologies are developing rapidly, newly published studies may emerge after completion of the literature search. Third, the review draws upon evidence from multiple disciplines with different research traditions, making direct comparison of findings challenging in some cases. Finally, although examples from related manufacturing sectors are occasionally discussed to provide broader context, the review primarily focuses on the apparel and textile industry. Therefore, conclusions should be interpreted within this industrial context rather than generalised to all manufacturing supply chains. By combining methodological transparency with thematic synthesis, this review seeks to provide a balanced and critical assessment of the current literature while identifying opportunities for future research. Rather than treating AI, waste reduction, and circular economy as independent research areas, the review integrates these perspectives to explain how data-driven decision-making can support more sustainable and circular apparel supply chains.

3. Sustainable Apparel Supply Chains: Conceptual Background

3.1 Structural Characteristics and Decision Complexity of Apparel Supply Chains

Apparel supply chains are characterised by extensive global production networks involving multiple organisations responsible for raw material sourcing, textile manufacturing, garment assembly, logistics, retailing, and post-consumption activities. Unlike vertically integrated manufacturing systems, apparel production is typically organised through geographically dispersed supplier networks, enabling firms to reduce production costs and respond rapidly to changing market demands (Jia et al., 2020; Turker & Altuntas, 2014). While this distributed structure enhances operational flexibility, it also increases supply chain complexity by creating interdependencies among numerous stakeholders operating under different regulatory, economic, and environmental conditions.

A defining feature of apparel supply chains is the simultaneous movement of materials, products, information, and financial resources across multiple organisational tiers. Decisions related to product design, material sourcing, production planning, inventory management, transportation, and retail operations are closely interconnected, meaning that inefficiencies arising at one stage frequently propagate throughout the supply chain (Altekar, 2023). For example, inaccurate demand forecasts may increase procurement volumes, delay inventory turnover, and generate excess production, ultimately contributing to unsold stock and waste (Mohammed & Mandal, 2023). Consequently, sustainability performance depends not only on the environmental practices of individual firms but also on effective coordination and information sharing across the entire supply network (Köksal et al., 2017; Toorajipour et al., 2021).

This interconnected structure distinguishes apparel supply chains from many traditional manufacturing sectors. Rather than viewing sustainability as an issue confined to production activities, it should be understood as an outcome of decisions made across multiple stages of the supply chain. These structural characteristics also explain why environmental and operational inefficiencies frequently emerge simultaneously, making them difficult to address through isolated interventions.

3.2 Environmental and operational inefficiencies in Apparel Supply Chains

Despite growing sustainability initiatives, environmental and operational inefficiencies persist in apparel supply chains. While these challenges are commonly associated with excessive water consumption, greenhouse gas emissions, chemical pollution, and textile waste (Arora et al., 2022; Shirvanimoghaddam et al., 2020), such impacts are better understood as consequences of fragmented supply chain decisions rather than isolated environmental problems. Inaccurate demand forecasting, poor inventory management, inefficient production planning, and weak coordination among supply chain partners often lead to unnecessary resource consumption and waste.

Overproduction illustrates this relationship. Although frequently attributed to fast fashion and volatile consumer demand, excess production also reflects managerial decisions aimed at avoiding stock shortages and maintaining high product availability. Consequently, unsold inventories, markdowns, product destruction, and textile waste become recurring outcomes of prevailing business models rather than unexpected operational failures (Roberts et al., 2023; Turker & Altuntas, 2014). This suggests that downstream recycling initiatives alone cannot substantially reduce waste unless the upstream causes of overproduction are addressed.

Similarly, environmental indicators such as water use, energy consumption, and carbon emissions are closely linked to operational performance. Inefficient production scheduling, low material utilisation, excessive transportation, and high product return rates increase resource consumption throughout the supply chain (Awaad et al., 2024; Jonsson et al., 2024). However, operational efficiency should not be equated with sustainability. Although efficiency improvements reduce environmental impacts per unit of production, they may fail to reduce the industry's overall footprint if increasing production and consumption offset these gains (Roemer et al., 2023). Therefore, improving sustainability requires coordinated decision-making across sourcing, manufacturing, logistics, retail, and end-of-life management rather than isolated process optimisation.

3.3 Transitioning from Linear to Circular Apparel Supply Chains

Traditional apparel supply chains operate predominantly within a linear production model in which raw materials are extracted, manufactured into garments, consumed, and ultimately discarded (Jia et al., 2020; Kirchherr et al., 2017). Although this model has supported rapid production and market responsiveness, it has also intensified resource depletion, textile waste, and environmental degradation (Akter et al., 2022). In response, the circular economy has emerged as an alternative approach that seeks to retain the value of products and materials through strategies such as durability, repair, reuse, remanufacturing, and recycling (Bocken et al., 2016; Geissdoerfer et al., 2026).

However, transitioning to circular apparel systems involves considerably more than increasing recycling rates. Existing studies often emphasise recycling as the primary circular strategy, yet its effectiveness depends on upstream decisions concerning product design, material selection, traceability, and reverse logistics (Almelhem et al., 2025; Jia et al., 2020; Mishra et al., 2023). Furthermore, blended fibres, material contamination, and limited textile recycling infrastructure continue to constrain large-scale textile-to-textile recycling (Sandin & Peters, 2018). Consequently, recycling should be viewed as one component of a broader circular system rather than a standalone solution.

Equally important, circularity is not solely a technological challenge but also an operational one. Effective reverse logistics, product take-back schemes, repair services, and resale models require collaboration among supply chain partners, reliable information sharing, and active consumer participation (Dissanayake & Weerasinghe, 2022; Pal et al., 2019). Without these complementary capabilities, circular initiatives may deliver limited environmental benefits despite technological advances. This perspective highlights that AI should not replace circular economy strategies but rather strengthen them by improving traceability, resource allocation, and decision-making across the product life cycle.

3.4 An Integrated Framework for Assessing Sustainability Performance

Assessing sustainability in apparel supply chains requires a broader perspective than measuring environmental impacts alone. Traditional indicators, such as greenhouse gas emissions, water consumption, energy use, and textile waste, remain essential for quantifying the industry's environmental footprint (Leal Filho et al., 2024). However, these measures provide only a partial assessment of supply chain sustainability if they are considered independently of operational performance.

Recent studies increasingly recognise that operational indicators, including forecast accuracy, inventory turnover, production efficiency, lead time, return rates, and material utilisation, also influence environmental outcomes by shaping how resources are consumed throughout the supply chain (Naik & Rashmi, 2024; Russell & Taylor, 2019). Improvements in these indicators may reduce unnecessary production, transportation, and inventory accumulation, thereby contributing indirectly to lower emissions and waste generation. Nevertheless, better operational performance should not automatically be interpreted as improved sustainability. Efficiency gains may reduce environmental impacts per unit of output, while total resource consumption continues to increase because of expanding production and consumption volumes (Huo & Peng, 2023).

Accordingly, evaluating sustainable apparel supply chains requires an integrated set of performance indicators that capture both operational effectiveness and environmental outcomes. Such an approach is particularly important when assessing AI-enabled supply chains, where improvements in forecasting, production planning, or logistics should ultimately be evaluated according to their contribution to resource efficiency, waste reduction, and circular material flows rather than algorithmic performance alone. This perspective provides the conceptual basis for the following sections, which critically examine how AI applications influence sustainability across different supply chain functions (Figure 2).

I. STRUCTURAL CHARACTERISTICS OF SUPPLY CHAIN

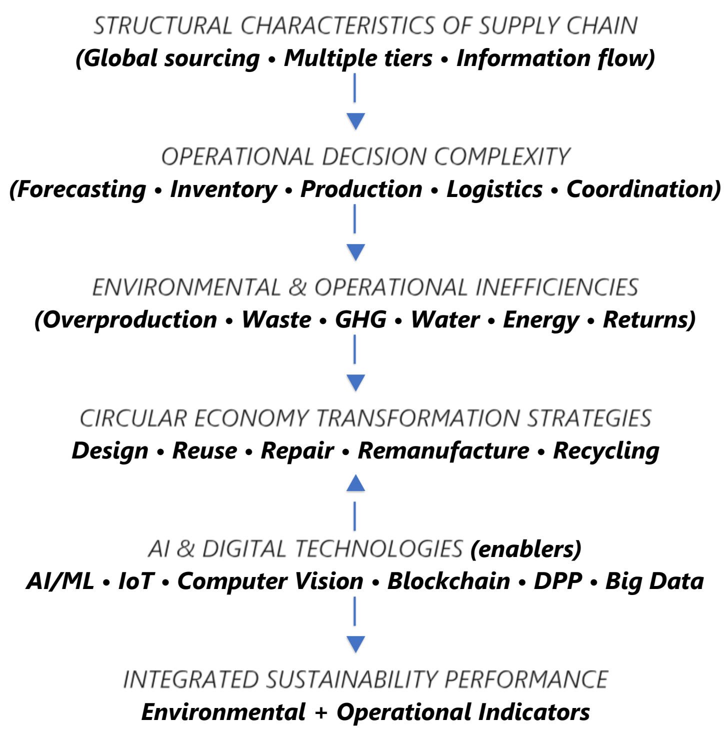


Figure 2: Shows the Conceptual Stages of the Apparel Supply Chain

4. AI-Driven Optimization in Apparel Supply Chains

Artificial intelligence is increasingly being applied across apparel supply chains to support decisions related to demand forecasting, production planning, supplier evaluation, logistics, risk management, and managerial decision-making. These applications seek to improve operational efficiency while reducing resource consumption and supporting more sustainable supply chain practices. However, the extent to which AI delivers measurable sustainability outcomes varies considerably across functions and depends on organisational priorities, data quality, governance, and implementation capability. Table 1 summarises the principal AI applications, their potential sustainability contributions, and the key limitations identified in the literature. The following sections critically evaluate the evidence supporting these applications and the conditions under which they contribute to more sustainable and circular apparel supply chains.

4.1 AI-Enabled Demand Forecasting and Inventory Decisions

Demand forecasting remains one of the most challenging functions in apparel supply chain management because consumer demand is highly volatile and influenced by seasonality, fashion trends, promotional activities, weather conditions, and increasingly, digital consumer behaviour. Forecasting errors propagate throughout the supply chain, affecting procurement, production planning, inventory allocation, and distribution decisions. Consequently, inaccurate forecasts contribute to excess inventory, stock shortages, unnecessary markdowns, and textile waste, making forecasting both an operational and sustainability challenge (Toorajipour et al., 2021). Recent advances in AI have improved forecasting by integrating diverse data sources beyond historical sales records, including social media, online search trends, weather information, point-of-sale transactions, and consumer purchasing patterns. Compared with conventional statistical approaches, machine learning models provide more adaptive demand predictions that better reflect rapidly changing market conditions (Sharma & Mehta, 2024; Toorajipour et al., 2021). These improvements support more responsive inventory allocation and production planning, potentially reducing unnecessary production and material consumption (Belhadi et al., 2024).

However, the relationship between forecasting accuracy and sustainability should not be overstated. Most studies assess AI using predictive performance measures while providing limited evidence that improved forecasts consistently reduce textile waste or environmental impacts in industrial settings. Production decisions continue to be shaped by commercial objectives, contractual obligations, inventory policies, and marketing strategies. Many fashion retailers deliberately maintain high inventory availability to maximise sales opportunities, meaning that more accurate forecasts do not necessarily translate into lower production volumes or reduced waste. Likewise, the short product life cycles characteristic of the apparel industry may quickly diminish the value of even highly accurate predictions. These findings indicate that forecasting creates sustainability value only when improved demand predictions are translated into procurement, production, and inventory decisions that explicitly incorporate environmental objectives. Future research should therefore move beyond prediction accuracy and examine how AI-supported forecasting influences overproduction, resource efficiency, and textile waste across the supply chain.

4.2 Intelligent Production Planning and Capacity Optimization

Production planning in apparel supply chains is inherently complex because manufacturers must balance fluctuating demand, short product life cycles, limited production capacity, and globally dispersed sourcing networks. Conventional planning approaches often rely on historical demand and fixed production schedules, making them less responsive to rapidly changing market conditions. Consequently, mismatches between production and demand can result in excess inventory, underutilised capacity, expedited manufacturing, delayed deliveries, and unnecessary resource consumption (Toorajipour et al., 2021). AI has strengthened production planning by integrating demand forecasts, production capacity, inventory availability, and supplier information to support dynamic scheduling and capacity allocation. These capabilities improve coordination across geographically dispersed manufacturing networks and enable firms to respond more effectively to changing demand while reducing operational inefficiencies (Belhadi et al., 2024). In principle, better planning can also reduce unnecessary production and improve resource utilisation.

Despite these operational benefits, evidence linking AI-enabled production planning to environmental sustainability remains limited. Most studies evaluate improvements using indicators such as production efficiency, machine utilisation, and scheduling performance rather than resource consumption or emissions. Moreover, efficient production planning does not necessarily reduce environmental impacts if firms continue to prioritise rapid product turnover or maintain high production volumes to satisfy commercial objectives. Adoption also remains uneven, particularly among small and medium-sized enterprises (SMEs), where fragmented data, limited digital infrastructure, and implementation costs constrain AI deployment. Consequently, the sustainability benefits of AI depend not only on optimisation algorithms but also on organisational readiness and the integration of environmental objectives into production planning decisions.

4.3 AI-Assisted Supplier Selection and Sustainable Procurement

Supplier selection is a strategic function in apparel supply chains because a substantial share of environmental and social impacts originates upstream during raw material extraction, textile processing, dyeing, and garment manufacturing. Traditionally, supplier evaluation has prioritised cost, quality, and delivery performance, while sustainability criteria, including environmental compliance, labour practices, and resource efficiency, have received less attention due to limited supply chain visibility (Köksal et al., 2017). As global sourcing networks become increasingly complex, balancing operational and sustainability objectives has become a significant managerial challenge. AI is improving supplier selection by integrating information from supplier performance records, environmental audits, certifications, logistics data, and market intelligence. Rather than relying on periodic assessments, AI-enabled systems continuously evaluate supplier performance, identify emerging risks, and support more informed sourcing decisions (Belhadi et al., 2024; Toorajipour et al., 2021). These capabilities can strengthen procurement transparency and help firms identify suppliers with stronger environmental performance while responding more rapidly to supply disruptions.

However, the effectiveness of AI-assisted supplier evaluation depends on the quality and availability of supplier data. Many suppliers, particularly small and medium-sized enterprises in developing economies, lack robust digital reporting systems, resulting in incomplete or inconsistent sustainability information (Martins et al., 2022; van Gerven et al., 2025). Moreover, AI can identify sustainability risks but cannot address structural governance challenges such as weak environmental regulation, inadequate labour standards, or limited supplier accountability. Sustainable sourcing therefore depends not only on analytical capability but also on transparent data sharing, supplier collaboration, and effective governance. AI should be regarded as a tool that strengthens procurement decision-making rather than a substitute for responsible sourcing practices.

4.4 AI for Logistics, Distribution, and Circular Reverse Logistics

Logistics decisions play a central role in both the economic and environmental performance of apparel supply chains. The global distribution of apparel production requires extensive transportation of raw materials, intermediate products, and finished garments, contributing to fuel consumption, greenhouse gas emissions, and increasing logistical complexity (Jia et al., 2020). Conventional logistics planning, which often relies on static routing and historical demand, is limited in its ability to respond to rapidly changing operating conditions. AI enhances logistics management by integrating transportation, inventory, and demand data to support dynamic routing, warehouse operations, delivery scheduling, and inventory allocation (Toorajipour et al., 2021). These capabilities can improve vehicle utilisation, reduce transportation distances, and lower energy consumption and associated emissions. However, most reported benefits relate to improvements in operational efficiency rather than direct environmental performance, with relatively few studies quantifying reductions in carbon emissions or resource use.

AI is also increasingly relevant to reverse logistics, which is fundamental to circular apparel supply chains. Product returns, take-back programmes, repair services, resale, and textile recycling require efficient collection, sorting, and redistribution systems. AI can support these activities by predicting return volumes, optimising collection networks, and improving product classification for reuse or recycling. Despite this potential, research within the apparel sector remains heavily concentrated on forward logistics, while AI applications supporting end-of-life material recovery are comparatively underdeveloped (Huang et al., 2025). This imbalance suggests that AI has primarily been used to improve the efficiency of linear supply chains rather than enabling circular material flows. Greater sustainability gains are therefore likely to depend on extending AI-enabled optimisation beyond product delivery to include product recovery, remanufacturing, reuse, and recycling within integrated forward and reverse logistics networks.

4.5 AI-Driven Risk Intelligence and Supply Chain Resilience

Beyond supporting individual supply chain functions, AI increasingly contributes to supply chain resilience by improving the prediction and management of operational risks. Apparel supply chains are particularly vulnerable to disruptions because they depend on globally dispersed production networks, single-source suppliers, volatile consumer demand, geopolitical uncertainty, and climate-related events. Conventional risk management approaches are often reactive, relying on historical assessments that provide limited support for responding to rapidly evolving disruptions (Ivanov et al., 2025; Modgil et al., 2022). AI strengthens risk management by continuously analysing data from supplier networks, logistics systems, market conditions, weather forecasts, and other external sources to identify emerging disruptions and recommend alternative sourcing, production, or distribution strategies (Baryannis et al., 2019; Belhadi et al., 2024). These capabilities enable organisations to respond more rapidly to disruptions and improve operational continuity across the supply chain.

However, resilience should not be equated with sustainability. Strategies that improve supply continuity, such as sourcing from alternative suppliers, increasing safety stocks, or relying on expedited transportation, may also increase resource consumption and greenhouse gas emissions. Despite growing interest in AI-enabled resilience, relatively few studies examine how resilience strategies balance operational continuity with environmental performance. Consequently, future AI-enabled decision-support systems should evaluate economic, operational, and environmental objectives simultaneously rather than optimising resilience in isolation.

4.6 Explainable AI for Sustainable Decision Support

As AI becomes increasingly embedded in forecasting, production planning, sourcing, logistics, and risk management, attention is shifting from predictive accuracy to the transparency and interpretability of AI-supported decisions. Many advanced AI models operate as "black boxes", producing recommendations without clearly explaining how decisions are generated. Limited explainability can reduce managerial trust, hinder accountability, and constrain the adoption of AI in strategic supply chain decisions (Baryannis et al., 2019; Toorajipour et al., 2021). XAI seeks to address these concerns by providing interpretable recommendations that help managers understand the factors influencing AI-generated decisions. Greater transparency is particularly important in apparel supply chains, where decisions often involve trade-offs between economic performance, environmental sustainability, and social responsibility. Rather than replacing managerial judgement, XAI supports informed decision-making by combining analytical capability with human expertise (Coussement et al., 2024).

However, explainability alone does not ensure responsible decision-making. AI recommendations remain dependent on the quality of underlying data, while biased datasets, incomplete sustainability reporting, and weak governance can still produce misleading outcomes regardless of how transparent the model appears. Consequently, the effectiveness of AI-supported decision-making depends not only on explainable algorithms but also on robust data governance, organisational capability, and appropriate human oversight.

Table 1. AI-enabled decision-support applications, sustainability contributions, implementation limitations, and representative literature across apparel supply chain functions.

Supply Chain Function	Principal AI Application	Potential Sustainability Contribution	Key Limitation	Representative References
Demand forecasting & inventory optimization	Predictive analytics integrating historical sales, consumer behaviour, social media, weather, and market data	(i)Improves demand–inventory alignment, (ii) Reduces overproduction risk, (iii) Minimizes excess inventory, and (iv) supports resource-efficient production planning	Improved forecasting does not necessarily reduce overproduction because commercial inventory policies and fast-fashion strategies may still encourage excess production	Toorajipour et al. (2021); Belhadi et al. (2024); Sharma & Mehta (2024); Waltersmann et al. (2021); Hossain et al. (2025)
Production planning & capacity optimization	Dynamic production scheduling, AI-assisted capacity allocation, and resource optimization	(i) Enhances manufacturing efficiency, (ii) Improves resource utilization, (iii) Reduces unnecessary production adjustments, and (iv) supports flexible manufacturing	Most studies evaluate operational efficiency rather than direct environmental outcomes; adoption remains limited among SMEs due to infrastructure and cost constraints	Belhadi et al. (2024); Toorajipour et al. (2021); Waltersmann et al. (2021)

Supplier selection & sustainable procurement	AI-assisted supplier evaluation, ESG assessment, sustainability scoring, and supplier risk prediction	(i) Improves supplier transparency, strengthens environmental and social performance monitoring, and (ii) Supports responsible sourcing decisions	Effectiveness depends on reliable supplier data, digital reporting systems, governance quality, and supplier collaboration	Köksal et al. (2017); Belhadi et al. (2024); Martins et al. (2022); van Gerven et al. (2025)
Logistics & reverse logistics	Route optimization, warehouse optimization, transportation planning, return-flow optimization, and AI-supported product recovery	(i) Reduces transportation distance, fuel consumption, and logistics costs while improving product recovery, reuse, remanufacturing, and recycling	Existing applications remain concentrated on forward logistics, with relatively limited adoption in reverse logistics and circular recovery systems	Toorajipour et al. (2021); Jia et al. (2020); Huang et al. (2025); Mishra et al. (2023)
Risk management & supply chain resilience	Predictive risk analytics, disruption forecasting, scenario modelling, and digital supply chain monitoring	(i)Enables earlier disruption detection, proactive decision-making, improved resilience, and (ii) Better supply chain continuity	Resilience strategies (e.g., safety stock or expedited transport) may increase emissions, energy consumption, or resource use if sustainability objectives are not considered simultaneously	Baryannis et al. (2019); Belhadi et al. (2024); Ivanov et al. (2025); Modgil et al. (2022)
Explainable AI & decision support	XAI, interpretable machine learning, transparent recommendation systems, and human-in-the-loop decision support	(i)Enhances managerial trust, accountability, transparency, governance, and informed decision-making	Explainability cannot compensate for poor data quality, biased datasets, or inadequate governance; effective human oversight remains essential	Baryannis et al. (2019); Toorajipour et al. (2021); Coussement et al. (2024)

Taken together, the evidence reviewed in this section indicates that AI creates sustainability value primarily by improving the quality of operational decision-making rather than through automation alone (Figure 3). As summarized in Table 1, the principal barriers to achieving environmental and circular economy outcomes are less technological than organizational, including data quality, governance, implementation capability, and the integration of sustainability objectives into supply chain decisions. These themes provide the foundation for the subsequent discussion of AI-enabled waste reduction and circular economy practices.

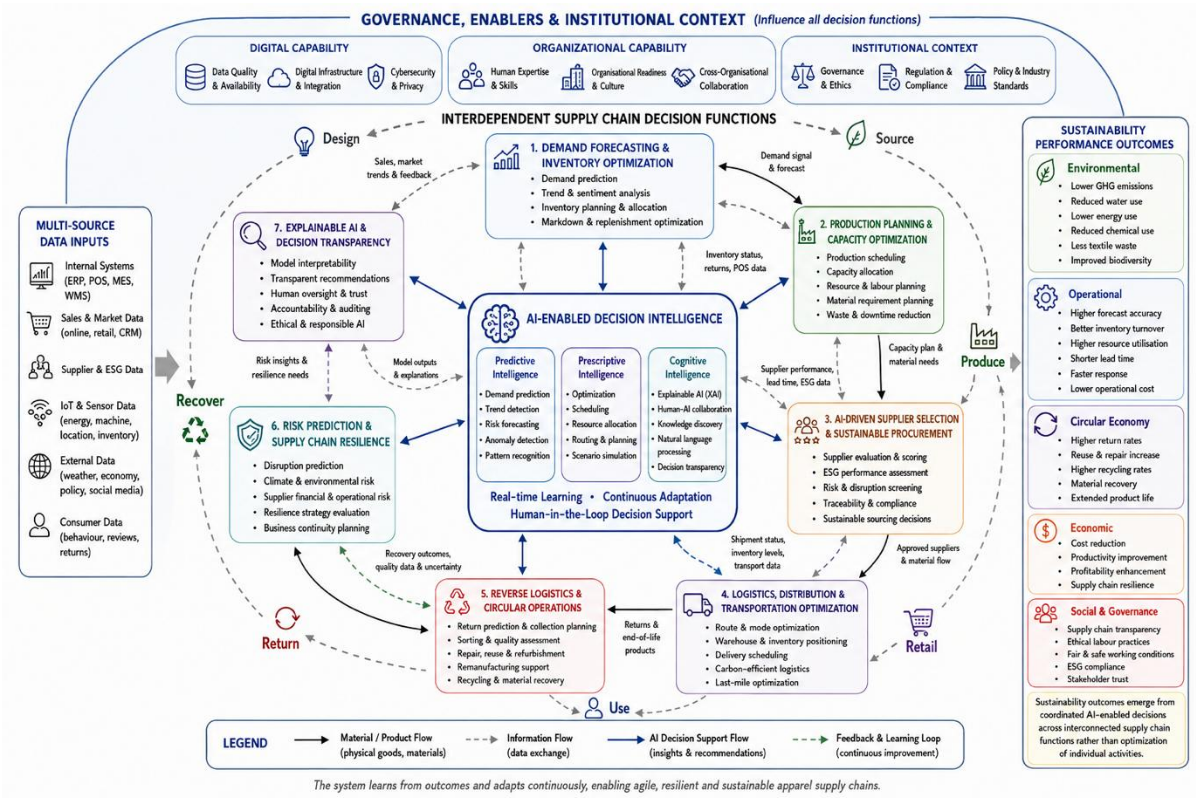


Figure 3: Integrated AI-Enabled Decision Intelligence Framework for Sustainable Apparel Supply Chains

5. AI for Waste Reduction in Apparel and Textile Systems

Waste is generated at every stage of the apparel lifecycle, from demand planning and fabric cutting to product returns and final disposal. Its causes are equally diverse, arising from inaccurate forecasts, inefficient material utilisation, manufacturing defects, unsold inventory, and inadequate recovery systems. This distribution of waste highlights that effective intervention cannot rely solely on downstream recycling. Increasing attention has therefore shifted towards preventing waste before it is created, an approach that aligns more closely with sustainable supply chain management (Mostaghimi & Behnamian, 2023; Shirvanimoghaddam et al., 2020). Within this context, AI has emerged as a practical means of improving resource efficiency across multiple stages of the apparel value chain. The principal applications are summarised in Figure 4.

The greatest opportunity lies upstream, where forecasting influences procurement, inventory, and production simultaneously. By combining historical sales with weather patterns, online behaviour, and social media signals, machine learning models capture demand dynamics more effectively than conventional forecasting approaches (Toorajipour et al., 2021). Better predictions can also mitigate excess inventory and unnecessary production, yet they do not eliminate overproduction on their own. Commercial priorities, short product lifecycles, and inventory strategies continue to shape production decisions, often limiting the environmental gains achievable through improvements in forecasting alone.

During manufacturing, the emphasis shifts from demand uncertainty to material efficiency. Computer vision systems identify defects in real time, while optimisation algorithms improve marker planning and fabric utilisation, reducing losses associated with cutting, rework, and rejected garments (Amjad & Joshi, 2025). Although these technologies consistently improve production efficiency, most evidence remains confined to pilot implementations or controlled manufacturing environments. Whether comparable benefits can be sustained across large, globally distributed production networks remains insufficiently explored. Downstream applications focus on recovering value from discarded textiles rather than preventing waste generation. Advances in fibre recognition, automated sorting, and textile classification have improved the identification of reusable and recyclable materials, increasing the efficiency of post-consumer recovery systems (Faghih et al., 2025). Their effectiveness, however, is constrained by practical challenges, including blended fibre compositions, inconsistent product labelling, contamination, and limited recycling infrastructure. These constraints suggest that technological capability alone cannot establish a circular textile system without parallel improvements in traceability and collection networks.

The literature also reveals a persistent implementation gap. Across many apparel-producing regions, adoption is constrained less by algorithmic capability than by fragmented data environments, limited digital infrastructure, high implementation costs, and shortages of technical expertise, particularly among small and medium-sized manufacturers (Thorngren, 2025). As a result, many promising AI applications remain confined to demonstration projects rather than routine industrial practice.

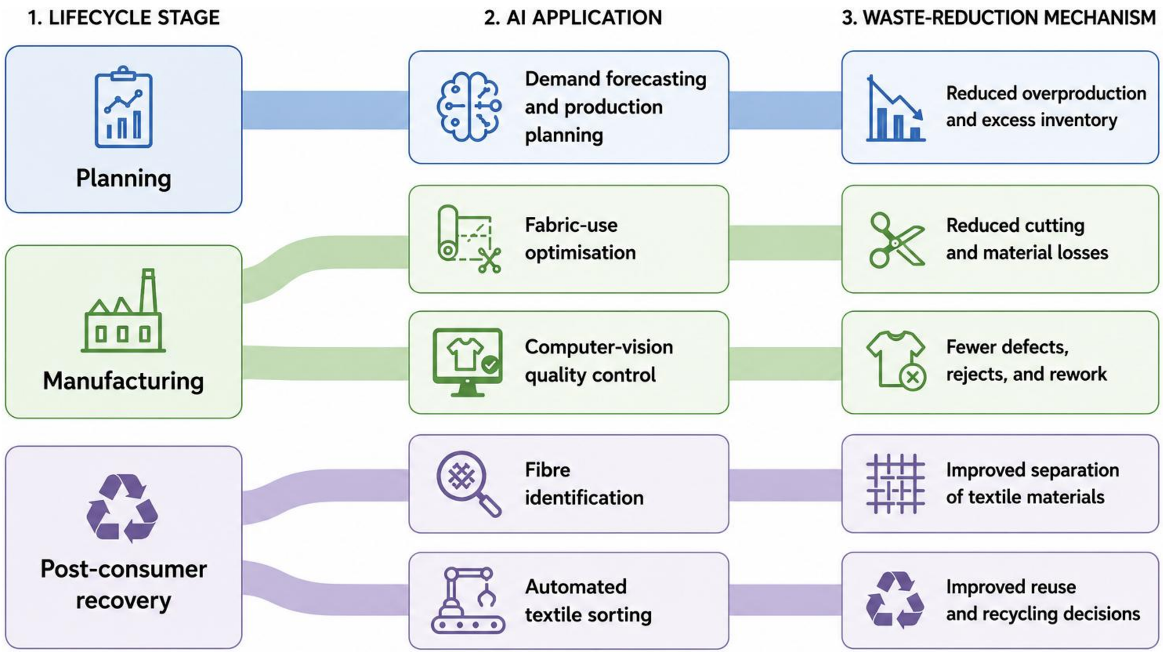


Figure 4. Conceptual pathways linking apparel lifecycle stages, AI applications, and waste-reduction mechanisms

6. Circular Economy Practices in AI-Enabled Apparel Supply Chains

The transition from linear to circular apparel supply chains has become a key strategy for reducing resource consumption and extending product life cycles. Unlike the traditional "take-make-dispose" model, circular systems retain the value of products and materials through repair, reuse, resale, remanufacturing, and recycling (Bocken et al., 2016; Geissdoerfer et al., 2026). AI supports these activities by improving data availability, operational coordination, and decision-making across the product life cycle. However, AI should be viewed as an enabler of circularity rather than its primary driver.

One important application is circular product design. AI-assisted design tools can evaluate material choices, predict product durability, and recommend design alternatives that improve recyclability while reducing material consumption (Ragava Raja & Khanna, 2025). AI also supports product life extension by analysing consumer behaviour and product usage patterns to improve repair services, resale platforms, rental schemes, and refurbishment programmes, thereby reducing reliance on virgin materials (Dissanayake & Weerasinghe, 2022). AI further contributes to circular supply chains by strengthening material traceability. Digital product passports, supported by AI alongside IoT and blockchain technologies, record information on material composition, manufacturing history, repair records, and recovery pathways throughout a product's life cycle (Rejeb et al., 2019; Zhang & Seuring, 2024). Improved traceability facilitates product recovery, supports compliance with emerging sustainability regulations, and enhances reverse logistics by helping firms identify appropriate reuse, remanufacturing, or recycling options.

Despite these advances, evidence for AI-enabled circularity remains limited. Much of the literature proposes conceptual frameworks or emerging business models, while relatively few studies demonstrate implementation at industrial scale (Almelhem et al., 2025; Spieth et al., 2025). Digital product passports, for example, depend on standardised product information and data sharing across multiple supply chain partners, yet interoperability remains a persistent challenge. Similarly, AI-based traceability cannot compensate for weak collection systems, inconsistent product labelling, or insufficient recycling infrastructure.

The assumption that digitalisation automatically leads to circularity also warrants caution. AI, blockchain, and IoT require substantial investments in digital infrastructure, data governance, and organisational capability. Their contribution depends not on the technologies themselves but on whether they improve material circulation and recovery in practice. This challenge is particularly relevant in developing economies, where fragmented supplier networks, limited digital maturity, and resource constraints continue to restrict the adoption of advanced circular solutions. Overall, AI has considerable potential to strengthen circular apparel supply chains by supporting product design, traceability, and material recovery. However, circular economy outcomes depend on effective collaboration among supply chain partners, supportive policy frameworks, robust governance, and technological capability. These interdependent relationships are examined further in the integrated conceptual discussion that follows.

7. Integrated Framework

The preceding review demonstrates that AI contributes to sustainable apparel supply chains by improving decision-making across interconnected supply chain activities rather than through individual technologies. Building on this synthesis, Figure 1 presents an integrated conceptual framework that positions AI as a decision-support capability linking operational decisions with sustainability outcomes.

The framework proposes that AI creates value by transforming diverse operational and sustainability data into actionable insights that support decisions across product design, sourcing, manufacturing, logistics, retail operations, and end-of-life recovery. Rather than optimising isolated activities, AI enables coordination across the apparel product life cycle, recognising that upstream decisions frequently shape downstream environmental outcomes. For example, improved demand forecasting can reduce overproduction, while better material traceability supports product recovery, reuse, and recycling.

The framework further suggests that sustainability outcomes, including improved resource efficiency, reduced textile waste, enhanced circularity, and greater supply chain resilience, should not be viewed as automatic consequences of AI adoption. Instead, these outcomes emerge when AI-supported decisions are aligned with circular economy practices and organisational objectives. This perspective helps explain why similar AI technologies often produce different sustainability outcomes across organisations. Governance provides the enabling conditions that connect AI capability with sustainability performance. As illustrated in Figure 1, data quality, transparency, explainability, organisational capability, and regulatory compliance influence both the reliability of AI-generated insights and the extent to which they are translated into effective operational decisions. Weak governance can therefore limit sustainability improvements even when advanced AI technologies are available.

Finally, the framework incorporates a continuous feedback mechanism through which operational and sustainability outcomes generate new data that refine subsequent AI-supported decisions. This feedback loop highlights that sustainable supply chain transformation is an adaptive process in which learning, monitoring, and continuous improvement are integral to long-term performance. Overall, the framework shifts attention from evaluating individual AI technologies towards understanding how AI, governance, and circular economy practices interact to support sustainable apparel supply chains. It provides a conceptual foundation for interpreting the evidence reviewed throughout this paper and offers an integrated perspective for future empirical research.

8. Key Research Gaps

Despite the growing body of research on AI-enabled sustainable apparel supply chains, several important gaps remain. First, much of the literature relies on generic supply chain datasets or simulated environments, with limited use of apparel-specific data that capture the complexity of fashion demand, textile materials, product returns, and post-consumer waste. This constrains the applicability of many AI models to real apparel supply chains. Second, operational improvements are often used as proxies for sustainability. While many studies report gains in forecasting, production planning, or logistics, comparatively few examine whether these improvements lead to measurable reductions in textile waste, greater material recovery, or longer product life cycles.

Third, empirical evidence remains limited. Many AI applications, including automated textile sorting and AI-assisted recycling, have demonstrated promising technical performance but have rarely been validated under industrial conditions. Their scalability, long-term economic viability, and environmental benefits therefore remain uncertain. Finally, the literature pays relatively little attention to the organisational context of AI adoption. Issues such as explainability, data governance, organisational capability, and the challenges faced by small and medium-sized apparel manufacturers remain underexplored, despite their importance for successful implementation. Likewise, AI applications supporting reverse logistics and closed-loop supply chains continue to receive less attention than upstream operational optimisation.

9. Future Research Agenda

Future research should shift from demonstrating AI capability to evaluating its contribution to measurable sustainability outcomes. A priority is the development of apparel-specific data infrastructures that integrate information on product design, material composition, manufacturing, consumer behaviour, product returns, and end-of-life recovery. Such datasets would improve the robustness of AI models while facilitating collaboration between researchers and industry. Future studies should also integrate AI with life cycle assessment (LCA) and circular economy metrics to evaluate operational, environmental, and economic performance simultaneously. Moving beyond traditional indicators such as forecasting accuracy or production efficiency would provide stronger evidence of AI's contribution to sustainable supply chain management. Greater attention should also be given to implementation. Research is needed to examine how explainable AI, managerial trust, organisational capability, and digital governance influence technology adoption and decision quality. Comparative studies across developed and developing apparel-producing countries would further improve understanding of how institutional conditions, digital maturity, and infrastructure shape AI implementation. Addressing these priorities will strengthen the evidence base for AI-enabled sustainable apparel supply chains while providing more practical guidance for industry and policymakers.

10. Conclusion

The apparel industry faces persistent sustainability challenges driven by overproduction, inefficient resource utilisation, textile waste, and increasingly complex global supply chains. This review examined how AI can support sustainable apparel supply chains by improving decision-making across forecasting, production planning, sourcing, logistics, quality management, and end-of-life recovery. The evidence indicates that AI has considerable potential to enhance operational efficiency while supporting waste reduction and circular resource management. However, the review also demonstrates that AI should not be viewed as a technological solution to sustainability in isolation. The environmental benefits of AI depend on how its capabilities are integrated with circular economy principles, effective governance, transparent data systems, and organisational decision-making. Improving predictive accuracy or operational efficiency alone is unlikely to deliver meaningful sustainability outcomes unless these improvements translate into changes in production, resource utilisation, and material recovery.

This review contributes by integrating AI-driven optimisation, waste reduction, and circular economy practices into a single conceptual perspective, highlighting that sustainable apparel supply chains emerge from the interaction between intelligent decision-making and circular resource management. Future research should prioritise industrial validation, apparel-specific datasets, and responsible AI implementation to ensure that digital technologies generate measurable environmental and operational benefits. Such efforts will be essential for accelerating the transition towards more resilient, resource-efficient, and circular apparel supply chains.

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References

[1] Akter, M. M. K., Haq, U. N., Islam, M. M., & Uddin, M. A. (2022). Textile-apparel manufacturing and material waste management in the circular economy: A conceptual model to achieve sustainable development goal (SDG) 12 for Bangladesh. *Cleaner Environmental Systems, 4*, 100070.

[2] Almelhem, M., Buics, L., & Süle, E. (2025). Comparison of sustainability and circularity indicators: downstream vs. upstream supply chain strategies. *Discover Sustainability, 6*(1), 302.

[3] Altekar, R. V. (2023). *Supply chain management: Concepts and cases*. PHI Learning Pvt. Ltd.

[4] Amjad, A. I., & Joshi, S. (2025). Technological advancements and the role of artificial intelligence–a review of textile material, machine manufacturing, and stakeholder experiences. *International Journal of Clothing Science and Technology, 37*(5), 903-932.

[5] Arora, R., Aggarwal, M., Agarwal, A., & Babbar, E. (2022). The Environmental Price of Fast Fashion. *International Journal of Applied Marketing & Management, 7*(2).

[6] Awaad, S., Mansour, D. M., Mahdi, I., & Abdelrasheed, I. (2024). Impact of material supply chain on the productivity optimization for the construction of roads projects. *Scientific Reports, 14*(1), 3294.

[7] Baryannis, G., Validi, S., Dani, S., & Antoniou, G. (2019). Supply chain risk management and artificial intelligence: state of the art and future research directions. *International Journal of Production Research, 7*(7), 2179-2202.

[8] Belhadi, A., Mani, V., Kamble, S. S., Khan, S. A. R., & Verma, S. (2024). Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: an empirical investigation. *Annals of operations research, 333*(2), 627-652.

[9] Bin Makhashen, Y., Rafi-ul-Shan, P. M., Bashiri, M., Hasan, R., Amar, H., & Khan, M. N. (2020). Exploring the role of ambidexterity and coopetition in designing resilient fashion supply chains: a multi-evidence-based approach. *Journal of Enterprise Information Management, 33*(6), 1599-1625.

[10] Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of industrial and production engineering, 33*(5), 308-320.

[11] Bruce, M., Daly, L., & Towers, N. (2004). Lean or agile: a solution for supply chain management in the textiles and clothing industry? *International journal of operations & production management, 24*(2), 151-170.

[12] Chowdhury, A. R., Limon, G. Q., & Arifur Rahman, M. (2024). Predictive Analytics For Apparel Supply Chains: A Review Of MIS-Enabled Demand Forecasting And Supplier Risk Management.

[13] Dissanayake, D., & Weerasinghe, D. (2022). Towards circular economy in fashion: Review of strategies, barriers and enablers. *Circular Economy and Sustainability, 2*(1), 25-45.

[14] Dissanayake, H., Manta, O., & Khan, S. (2025). Enhancing Supply Chain Transparency and Traceability in Waste Management Practices Through Blockchain Technologies and Digital Innovations. In *Blockchain Technologies for Smart Circular Economy and Organisational Sustainability* (pp. 177-193). Springer.

[15] Erhun, F., Kraft, T., & Wijnsma, S. (2021). Sustainable triple-A supply chains. *Production and Operations Management, 30*(3), 644-655.

[16] Faghih, E., Saki, Z., & Moore, M. (2025). A systematic literature review—AI-enabled textile waste sorting. *Sustainability, 17*(10), 4264.

[17] Geissdoerfer, M., Kanda, W., & Kirchherr, J. (2026). Conceptualizing circular ecosystems: an analysis of 45 definitions. *Business Strategy and the Environment, 35*(2), 2368-2394.

[18] Giri, C., Jain, S., Zeng, X., & Bruniaux, P. (2019). A detailed review of artificial intelligence applied in the fashion and apparel industry. *Ieee Access, 7*, 95376-95396.

[19] Hossain, M. S., Sikdar, M. S. H., Chowdhury, A., Bhuiyan, S. M. Y., & Mobin, S. M. (2025). AI-driven aggregate planning for sustainable supply chains: A systematic literature review of models, applications, and industry impacts. *American Journal of Advanced Technology and Engineering Solutions, 1*(01), 382-437.

[20] Huang, D., Zhan, Y., & Lonsdale, C. (2025). Utilising artificial intelligence to enhance firm circular economy maturity: a thematic review via machine learning. *Business Strategy and the Environment, 34*(5), 6135-6158.

[21] Huo, J., & Peng, C. (2023). Depletion of natural resources and environmental quality: Prospects of energy use, energy imports, and economic growth hindrances. *Resources policy, 86*, 104049.

[22] Imtiaz, N., & Rahman, K. (2026). From global EdTech adoption to AI-driven learning equity: A cross-cultural framework for U.S. higher education. *Journal of Adaptive Learning Technologies, 3*(3), 55–69. https://scientificbulletin.com/index.php/JALT/article/view/1979

[23] Imtiaz, N., Kundu, T. R., Roy, A., Bhuiyan, M. I., Rahman, K., & Islam, M. K. (2025). Governance readiness beyond predictive performance: An empirical benchmark for higher-education early warning systems. *Frontiers in Computer Science and Artificial Intelligence, 4*(5), 49–65.

[24] Imtiaz, N., Zannat, F., Vengaladas, M. K., Mahmud, S., & Hasan, M. A. (2025). Transforming business analytics: The impact of machine learning on performance prediction in U.S. financial sectors. *Journal of Business Insight and Innovation, 4*(1), 61–72. https://insightfuljournals.com/index.php/JBII/article/view/45

[25] Islam, A., Miah, M., Akhir, A., Munni, A., Jahan, I., & Nashid, S. (2026). Benchmarking machine learning models for real-time fraud detection in digital banking transactions. *Journal of Posthumanism, 6*(4), 97–135. https://doi.org/10.63332/joph.v6i4.4159

[26] Ivanov, D., Dolgui, A., Das, A., & Sokolov, B. (2025). Digital Supply Chain Twins: Managing the Ripple Effect, Resilience, and Disruption Risks by Data-Driven Optimization, Simulation, and Visibility. In *Handbook of Ripple Effects in the Supply Chain* (pp. 407-432). Springer.

[27] Jia, F., Yin, S., Chen, L., & Chen, X. (2020). The circular economy in the textile and apparel industry: A systematic literature review. *Journal of cleaner production, 259*, 120728.

[28] Jonsson, P., Öhlin, J., Shurrab, H., Bystedt, J., Sheikh Muhammad, A., & Verendel, V. (2024). What are the root causes of material delivery schedule inaccuracy in supply chains? *International journal of operations & production management, 44*(13), 34-68.

[29] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling, 127*, 221-232.

[30] Köksal, D., Strähle, J., Müller, M., & Freise, M. (2017). Social sustainable supply chain management in the textile and apparel industry—A literature review. *Sustainability, 9*(1), 100.

[31] Leal Filho, W., Dinis, M. A. P., Liakh, O., Paço, A., Dennis, K., Shollo, F., & Sidsaph, H. (2024). Reducing the carbon footprint of the textile sector: an overview of impacts and solutions. *Textile Research Journal, 94*(15-16), 1798-1814.

[32] Madden, A., Bailey, C., Alfes, K., & Fletcher, L. (2018). Using narrative evidence synthesis in HRM research: An overview of the method, its application, and the lessons learned. *Human Resource Management, 57*(2), 641-657.

[33] Martins, A., Branco, M. C., Melo, P. N., & Machado, C. (2022). Sustainability in small and medium-sized enterprises: A systematic literature review and future research agenda. *Sustainability, 14*(11), 6493.

[34] Mishra, A., Dutta, P., Jayasankar, S., Jain, P., & Mathiyazhagan, K. (2023). A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. *Benchmarking: an international journal, 30*(3), 975-1020.

[35] Modgil, S., Dwivedi, Y. K., Rana, N. P., Gupta, S., & Kamble, S. (2022). Has Covid-19 accelerated opportunities for digital entrepreneurship? An Indian perspective. *Technological Forecasting and Social Change, 175*, 121415.

[36] Mohammed, I. A., & Mandal, J. (2023). The impact of lead time variability on supply chain management. *International Journal of Supply Chain Management, 8*(2), 41-55.

[37] Mostaghimi, K., & Behnamian, J. (2023). Waste minimization towards waste management and cleaner production strategies: a literature review: K. Mostaghimi, J. Behnamian. *Environment, Development and Sustainability, 25*(11), 12119-12166.

[38] Munni, A. (2022). Artificial intelligence in project management: A systematic review of applications, challenges, and future directions. *Frontiers in Computer Science and Artificial Intelligence, 1*(1), 68–78.

[39] Munni, A., & Mashaka, G. P. (2026). Machine learning for environmental antimicrobial resistance risk prediction. *International Journal of Digital Health and Telemedicine, 2*(1). https://doi.org/10.51137/wrp.ijdht.550

[40] Nafiz Imtiaz, Zannat, F., Ahmed, S., Hasan, M. A., & Mahmud, S. (2025). Leveraging AI for data-driven decision making and automation in the USA education sector. *Journal of Economics, Management & Business Administration, 4*(1), 87–106. https://www.journals.airsd.org/index.php/jemba/article/view/551

[41] Naik, M. D. G., & Rashmi, M. (2024). OPTIMIZING SUPPLY CHAIN MANAGEMENT THROUGH INFORMATION TECHNOLOGY: A CASE STUDY OF ASKASH METAL FORMING, BELAGAVI. *INTERNATIONAL RESEARCH JORUNAL OF EDUCAITON AND TECHNOLOGY Учредители: International Research Journal of Education and Technology, 6*(10), 106-122.

[42] Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature reviews earth & environment, 1*(4), 189-200.

[43] Pal, R., Sandberg, E., & Paras, M. K. (2019). Multidimensional value creation through different reverse supply chain relationships in used clothing sector. *Supply Chain Management: An International Journal, 24*(6), 729-747.

[44] Papri, N. K., Haque, M. K. A., & Mouwa, Z. (2022). Climate-adaptive sustainable apparel supply chains: Integrating machine learning, digitalization, and circular economy. *Journal of Primeasia, 3*(1), 1–16. https://doi.org/10.25163/primeasia.3110730

[45] Ragava Raja, R., & Khanna, G. (2025). Life cycle-based sustainability assessment and circularity mapping for packaging materials: Integrating artificial intelligence. *Journal on Artificial Intelligence, 7*(1), 301-327.

[46] Rahman, M. (2026, March 20). *Sustainable textile materials and their role in shaping contemporary apparel design practices*. SSRN. https://doi.org/10.2139/ssrn.6653078

[47] Rahman, M., & Chowdhary, U. (2024, August 23). *Comparison of 100% cotton and blend for selected performance attributes*. SSRN. https://doi.org/10.2139/ssrn.6365698

[48] Rahman, M., & Forhad, M. R. (2021). Sustainable biomaterials for next-generation textile applications: Emerging fibers, biopolymers, and advanced fabrication strategies—A review. *Journal of Primeasia, 2*(1), 1–8. https://doi.org/10.25163/primeasia.2110698

[49] Rahman, M., & Lee, S.-E. (2024, February 5). *Luxury gaming experiences: An analysis of game design elements within luxury fashion brands* [Conference paper accepted for presentation at the International Textile and Apparel Association (ITAA) Annual Conference]. SSRN. https://doi.org/10.2139/ssrn.6351299

[50] Rejeb, A., Keogh, J. G., & Treiblmaier, H. (2019). Leveraging the internet of things and blockchain technology in supply chain management. *Future Internet, 11*(7), 161.

[51] Roberts, H., Milios, L., Mont, O., & Dalhammar, C. (2023). Product destruction: Exploring unsustainable production-consumption systems and appropriate policy responses. *Sustainable Production and Consumption, 35*, 300-312.
[52] Roemer, N., Souza, G. C., Tröster, C., & Voigt, G. (2023). Offset or reduce: How should firms implement carbon footprint reduction initiatives? *Production and Operations Management, 32*(9), 2940-2955.
[53] Russell, R. S., & Taylor, B. W. (2019). *Operations and supply chain management*. John Wiley & Sons.
[54] Sandin, G., & Peters, G. M. (2018). Environmental impact of textile reuse and recycling–A review. *Journal of cleaner production, 184*, 353-365.
[55] Sarker, A., Haque, M. K. A., & Mouwa, Z. (2022). Artificial intelligence for sustainable and climate-resilient apparel supply chains: A narrative review and integrative framework. *Frontiers in Computer Science and Artificial Intelligence, 1*(1), 79–92. https://doi.org/10.32996/fcsai.2022.1.1.9x
[56] Sauer, P. C., & Seuring, S. (2018). A three-dimensional framework for multi-tier sustainable supply chain management. *Supply Chain Management: An International Journal, 23*(6), 560-572.
[57] Sharma, R., & Mehta, K. (2024). Stock market predictions using deep learning: developments and future research directions. *Deep Learning Tools for Predicting Stock Market Movements*, 89-121.
[58] Shehun, M. T. F. (2022). SYSTEMATIC REVIEW OF INDUSTRIAL ENGINEERING APPROACHES TO APPAREL SUPPLY CHAIN RESILIENCE IN THE US CONTEXT. *American Journal of Interdisciplinary Studies, 3*(04), 235-267.
[59] Shirvanimoghaddam, K., Motamed, B., Ramakrishna, S., & Naebe, M. (2020). Death by waste: Fashion and textile circular economy case. *Science of the total environment, 718*, 137317.
[60] Singh, N. (2024). Building Sustainability in Textile and Apparel Supply Chains. In *Eco-Innovation and Sustainable Development in Industry 5.0* (pp. 198-222). IGI Global Scientific Publishing.
[61] Spieth, P., Breitenmoser, P., & Röth, T. (2025). Business model innovation: Integrative review, framework, and agenda for future innovation management research. *Journal of Product Innovation Management, 42*(1), 166-193.
[62] Suhaimi, Z. S., Suppatvech, C., Hadeed, R., & Azmat, M. (2026). Digital innovations in sustainable fashion supply chains: a SCOR-Driven synthesis. Supply Chain Forum: An International Journal,
[63] Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC medical research methodology, 8*(1), 45.
[64] Thorngren, S. (2025). Exploring Digital Product Passports in the Textile industry The Evolving Ecosystem and Implications for Circular Strategies among Brands and Retailers. *IIIEE Master Thesis*.
[65] Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of business research, 122*, 502-517.
[66] Turker, D., & Altuntas, C. (2014). Sustainable supply chain management in the fast fashion industry: An analysis of corporate reports. *European management journal, 32*(5), 837-849.
[67] van Gerven, T., Tsilionis, K., & Ozkan, B. (2025). Recommended Features for Digital Reporting Systems to Support Emissions Disclosures for Small and Medium-Sized Enterprises. International Conference on Software Business,
[68] Waltersmann, L., Kiemel, S., Stuhlsatz, J., Sauer, A., & Miehe, R. (2021). Artificial intelligence applications for increasing resource efficiency in manufacturing companies—A comprehensive review. *Sustainability, 13*(12), 6689.
[69] Xue, X., Dhumras, H., Thakur, G., & Shukla, V. (2025). Integrating artificial intelligence and sustainable materials for smart eco innovation in production. *Scientific Reports, 15*(1), 36942.
[70] Younus, M., Pathan, S. H., Amin, M. R., Tania, I., & Ouboucetta, R. (2024). Sustainable fashion analytics: predicting the future of eco-friendly textile. *Global Mainstream Journal of Business, Economics, Development & Project Management, 3*(03), 13-26.
[71] Zhang, A., & Seuring, S. (2024). Digital product passport for sustainable and circular supply chain management: a structured review of use cases. *International Journal of Logistics Research and Applications, 27*(12), 2513-2540.