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Into the Revolution of Industry 5.0 in Ensuring Ethical Fashion: A Review on Conceptual Framework

Industrija 5.0 - revolucija v zagotavljanju etične mode: pregled pojmovnega okvira

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Abstract

The global fashion industry faces numerous ethical concerns. The Global South, in particular, suffers from unethical practices in the fashion industry due to the complexity of the supply chain and the lack of regulations governing workers' welfare. Additionally, the rapid growth of the fashion industry has also caused a negative impact on the environment. Ethical fashion prioritizes transparency, accountability and the well-being of workers, while ensuring environmental and social sustainability. This study suggests Industry 5.0 as a suitable approach to ensure ethical fashion due to its focus on human centricity. Industry 5.0 values human well-being with a synergy of technologies such as artificial intelligence, blockchain, digital twin and energy-efficient automation. The proper implementation of Industry 5.0 in the fashion industry can promote ethical fashion practices by ensuring fair labour practices, transparency and accountability, by and minimizing environmental impacts. Through an in-depth review of literature regarding Industry 4.0, Industry 5.0 and ethical fashion, this study develops a framework for ethical fashion. A logical, human-centred framework for Industry 5.0 in the context of ethical fashion is produced by searching peer-reviewed literature for specific keywords, applying inclusion criteria and thematically analysing the content to extract significant concepts, technologies and ethical issues. This study also highlights the challenges of integrating Industry 5.0 with ethical fashion, such as building the skills of labourers, the consideration of socio-centricity and policy changes due to the emergence of Industry 5.0.
Keywords: Industry 5.0, ethical fashion, sustainable, transparency

Izvleček

Globalna modna industrija se sooča s številnimi etičnimi izzivi. Globalni jug je zaradi kompleksnosti dobavnih verig in pomanjkljivega urejanja na področju varstva delavcev še posebno izpostavljen neetičnim praksam v modni industriji. Hitra rast modne industrije ima poleg tega izrazite negativne vplive na okolje. Etična moda poudarja preglednost in odgovornost ter dobrobit delavcev ob sočasnem zagotavljanju okoljskih in družbenih vidikov trajnosti. Raziskava opredeljuje industrijo 5.0 kot primeren pristop k zagotavljanju etične mode, saj temelji na človeku usmerjenem pristopu. Industrija 5.0 poudarja blaginjo človeka v sozvočju s tehnologijami,

kot so umetna inteligenca, veriženje blokov, digitalni dvojček in energetsko učinkovita avtomatizacija. Ustrezna uvedba industrije 5.0 v modni industriji lahko prispeva k spodbujanju etičnih praks v modi, saj omogoča zagotavljanje pravičnih delovnih razmer, preglednosti in odgovornosti ter zmanjševanje okoljskih vplivov. Na podlagi poglobljenega pregleda literature o industriji 4.0, industriji 5.0 in etični modi raziskava oblikuje pojmovni okvir etične mode. Smiseln in človeku usmerjen okvir industrije 5.0 v kontekstu etične mode je razvit s sistematičnim pregledom recenzirane literature, ki vključuje iskanje po ključnih besedah, uporabo vključitvenih kriterijev ter tematsko analizo vsebin za določitev ključnih konceptov, tehnologij in etičnih vprašanj. Raziskava dodatno opozarja na izzive združevanja industrije 5.0 in etične mode, med katerimi so razvoj kompetenc delavcev, upoštevanje sociocentričnega pristopa ter potreba po spremembah načel zaradi vzpona industrije 5.0.

Ključne besede: industrija 5.0, etična moda, trajnostnost, preglednost

1 Introduction

The complexity of global fashion supply chains poses significant ethical issues, especially within the context of accountability, transparency and the multi-layered structure of networks [1]. Fashion supply chains frequently span multiple layers, incorporating several intermediaries and lower-tier manufacturers, with the majority of production taking place in the Global South, where cheap labour is easily available. These areas are usually characterised by institutional voids, such as a lack of regulatory frameworks, insufficient oversight and uneven labour standard enforcement [2]. To implement truly ethical procedures, the fashion industry must go beyond its employees and emphasize the welfare, safety and prosperity of its suppliers and workforce, the most vulnerable element in the fashion supply chain. The fashion industry is currently facing ethical challenges such as sweatshop working conditions, child labour and modern slavery, where workers face minimal safety measures, minimum wages, long working hours with unpaid overtime, exploitative contracts and a lack of workers' rights [3-6]. Despite international anti-corruption regulations, fashion supply chains remains prone to corruption and conspiracy that compromise fair practices and raise operational costs [7]. Immoral procurement practices between fashion brands and suppliers at the cost of workers' rights and safety manifest corruption. For example, suppliers may en-

sure transactions through unlawful payments instead of fair and transparent selection procedures [8]. In numerous scenarios, vulnerable legislative surroundings, notably in emerging finances, create possibilities for the exploitation of private authorities, bribery and unfair practices [9]. Furthermore, global textile consumption has risen to an estimated 62 million tons of clothing per year, with a projection of 102 million tons by 2030, resulting in an epidemic increase in air, water and microplastic pollution from discharge into the food chain, as well as textile waste [10-15]. The development of low-cost textile production has resulted in fast fashion, in which consumers frequently acquire trendy clothing and discard them before the product's lifecycle is complete [16, 17]. Cost, financial status, perception of oneself, risk perceptions, consumerism, beliefs/attitudes, peer groups and fashion awareness all play a role in fast fashion purchasing decisions. Fast fashion purchases are often driven by consumers' desires such as becoming trendy, gaining respect, displaying dominance, blending in with a social group and establishing a personal identity [18-20]. Fast fashion meets consumers' desires for high-end clothes at a cheaper cost, despite its detrimental socioeconomic and environmental consequences. Along with standard sustainability considerations, transformational and collaborative design approaches may enhance positive design processes [21].

This phenomenon has raised a quandary because while fast fashion helps the economy, it also leads to difficulty in the disposal of textiles, as the recycling industry must handle all of the waste generated by the textile industry [22]. In contrast to fast fashion, ethical fashion or "fashion with conscience" implies a noble strategy to attract socially concerned or young mainstream customers by manufacturing trendy garments free of unethical practices. Its primary objective is to supply stylish, contemporary apparel while ensuring equitable compensation, safe working conditions and sustainable material sourcing. Ethical fashion companies prioritise open supplier chains, cruelty-free production methods and environmentally friendly materials over wasteful waste, environmental harm and exploitative labour practices. This tactic appeals to a growing segment of the consumer base that values aesthetic appeal in addition to social and environmental impacts and demands greater accountability from companies. Ethical fashion promotes values such as sustainability, human rights and conscientious consumption through marketing, storytelling and community service. It backs global campaigns for economic equality, social justice and climate action. Ethical fashion offers trendy clothing that allows people to express their uniqueness without compromising their morals. The proposed concept is to procure garments ethically while ensuring beneficial employment guidelines and circumstances to labourers, and to offer a sustainable business model. In addition, organic substances are utilized to minimise the impact on surroundings. Ethical fashion can therefore be identified as fashionable garments that integrate fair trade standards with sweatshop-free labour situations while not affecting the environment or labourers [23, 24].

The Industrial Revolution has revolutionized workplaces to satisfy society's needs, with an increasing emphasis on implementing green practices due to environmental concerns [25, 26]. This emphasis on sustainability is a distinguishing aspect of Industry 5.0, the most recent chapter in industrial evolution. Industry 4.0, while still being implemented in some countries, lays the framework for this transformation. It highlights technical breakthroughs such as data analytics, forecasting, the Internet of Things (IOT) and blockchain to fulfil rising demand for supply flexibility and productivity [27, 28]. Industry 5.0 builds on Industry 4.0's technological base, but with a key difference: it prioritizes sustainability and human well-being over efficiency [29]. This human-centred approach recognizes existing environmental issues while stressing innovation for a more sustainable future [30]. Industry 5.0 and recycling are inextricably linked, fostering sustainability and innovation centred on human needs. This notion combines modern technology such as AI, robots, the Internet of Things (IoT) and smart sensors with human creativity and decision-making. This integration improves efficiency and precision at every stage of the recycling process, including trash sorting and material processing. The recycling of polyester, particularly recycled polyester (rPET), has gained popularity, as it involves melting existing plastic to create new polyester fibres. While consumer plastic bottles are often highlighted, rPET can also be sourced from post-industrial materials. The demand for recycled polyester continues to rise due to population growth and economic development. Polyester is widely used across various industries, benefiting from its high strength, transparency and safety properties, which are deemed to be linked to Industry 5.0, while recycling fosters sustainability [31].

The objective of this study is to address Industry 5.0 and its feasibility to ensure ethical fashion. It observes the literature gap between two topics, proposes a conceptual framework for utilizing Industry 5.0 in ethical fashion, and addresses challenges and limitations. The definitions of key terms extracted from the relevant systematic review are presented in Table 1.

Table 1: Definition of key terms used in this study

Key term	Definition
Ethical fashion	Ethical fashion is the concept of consuming clothes that are socially and environmentally conscious [32].
Industry 5.0	A collaborative industrial revolution in which humans and automation work together to increase production and efficiency, and eliminate waste with the core value of human-centricity, sustainability and resilience [33].
Circular economy	The circular economy is a closed loop manufacturing and purchasing structure that emphasizes reusing, repairing and recycling existing materials and products for as long as possible [34].

2 Literature review

2.1 Ethical fashion practice

The ethical fashion practice comprises a multidisciplinary approach. Ethical sourcing and decision-making can promote ethical practices by focusing on individual supply chain employees. The employees' perspectives on ethical sourcing and broader ethical concerns influence their moral agency to make ethical sourcing decisions [32, 35]. Ethical fashion businesses can create impactful multimedia marketing strategies on social media that align with conceptual ideals [36]. Ethical fashion practices can also be ensured by consumer awareness. Consumers are increasingly aware of ethical norms and demand collective action against immoral behaviour in society. This has led to the increased scrutiny of ethical fashion practices [37]. Upcycling, which involves transforming old clothing or waste commodities into valuable objects, is an effective strategy to promote ethical fashion. The present conceptualizations of sustainable organization are insufficient because they undermine the interpersonal perspective that sustainable organization requires. A synchronic, interpersonal approach accommodates multiple perspectives regarding ethical fashion practices [38]. Circularity in fashion consumption, as well as virtuous morality when shopping for second-hand clothing, can contribute to ethical fashion. Pleasure, shame and guilt can drive moral decision-making towards reuse and sustainability. Seduction and conversion can also support moral decision-making by overcoming aversions and desires that hinder progress in circularity and ethical fashion [39].

Industry 5.0 principles complement Industry 4.0 by promoting ethical supply chains in the fashion goods sector. While Industry 4.0 literature predominantly refers to automation, data-driven optimisation and efficiency, various studies pay insufficient attention to the ethical tensions of worker displacement, algorithmic opacity and sustainability trade-offs, highlighting the contradiction between technological advancement and social responsibility [28]. These are addressed through the integration of Industry 5.0 knowledge, focusing on human-centricity, sustainability and resilience, with a demonstration of how this developing paradigm directly fills the vacuum left by Industry 4.0 [40]. As a complement to Industry 4.0, Industry 5.0 is expected to enhance rather than replace digital capabilities with human creativity, emotional intelligence and stakeholder engagement in order to foster ethically aligned decision-making throughout sourcing, production and distribution [41]. The analytical leap is further demonstrated on the basis of a comparative synthesis; such a comparison supports our contention that Industry 5.0 offers a more balanced and ethically responsive framework than that of the techno-centred paradigm of Industry 4.0, especially in terms of labour dignity, circularity and responsible innovation [42]. Identified voids in previous literature involve the lack of adequate attention to ethical AI governance, the lack of models aimed at integrating human creativity with digital intelligence and the insufficient exploration of community-orientated supply chain resilience. With the embedding of such assessments, the revised chapter goes beyond mere summarisation in providing a coherent cri-

tique, and situates Industry 5.0 as a transformative paradigm capable of strengthening ethical fashion practices by overcoming the inherent socio-ethical limitations of Industry 4.0. Table 2 presents a comparison of Industry 4.0 and Industry 5.0 in ethical fashion supply chains.

Table 2: Comparison of Industry 4.0 and Industry 5.0 in ethical fashion supply chains

	Industry 4.0	Industry 5.0	Ethical fashion implication	References
Sustainability	Compliance-driven environmental management	Regenerative, circular and restorative sustainability models	Moves the industry from harm reduction to long-term ecological stewardship	[28, 40–42]
Transparency and traceability	Blockchain/IoT-enabled data tracking	Technology enhanced by human-centric accountability and ethical AI	Enhances trust, traceability and social justice in sourcing	
Social responsibility	Limited integration of human values	Integration of well-being, inclusion, co-creation and stakeholder values	Addresses persistent gaps in labour rights, equity and community impact	

2.2 Consumers' concerns

Ethical buyers are aware of certain difficulties and seek safeguards for production chain workers, such as safe working conditions and a minimum salary. They also minimise their influence on the environment and choose cruelty-free items. Companies that have joined the Fur Free Alliance and prohibited the use of fur in their designs include Giorgio Armani, Michael Kors and Gucci. Additionally, Chanel has recently discontinued the use of exotic leathers and furs. Companies including Gucci, Michael Kors and Giorgio Armani have joined the Fur Free Alliance, despite anti-fur campaigns in the 1980s and 1990s [43]. Although there are a growing number of ethical consumers, it is difficult to predict how this will impact consumer behaviour and if they are willing to spend more on ethical goods. Because of the inconsistent results, it is still unclear whether customers prefer socially conscious businesses or steer clear of those that are manufactured carelessly [44]. Numerous rivals in the fashion industry are dedicated to doing business ethically and have included environmental considerations in their business plans. Examples of this include companies such as Patagonia and The North Face, while others emphasise animal rights and kindness. Numerous initiatives for improved sustainability and ethical

behaviour have sprung from this. However, buyers interested in ethical clothes find it challenging to make educated judgments due to the lack of transparency and the abundance of projects. Because there are so many such projects, it is difficult for customers to make wise decisions [45]. Customers are increasingly looking for labels on apparel that ensure it is made responsibly. The composition of raw materials, the place of origin, labour conditions and the environmental circumstances may all be found on these labels. An increasing number of companies are looking for certificates that say their goods are "green", "ethical" or "free of animal cruelty". While social certifications establish minimal requirements for worker rights and animal welfare, environmental certifications guarantee that dangerous chemicals are not used in manufacturing. Customers may feel more secure selecting brands that don't utilise animal products thanks to these certifications [46, 47].

2.3 Industry 5.0

Industry 5.0 refers to a collaborative industrial environment where humans and automation work together to increase production and efficiency, and eliminate waste [33]. This strategy combines the benefits of human intellect and machine capabilities, providing high precision through

human control and optimal automation for efficiency [48]. It is motivated by the desire to address consumers' distinct and individualized needs by merging human ingenuity with technological capabilities. Industry 5.0 is a dynamic, resilient, and human-centric approach to industrial development in which intelligent digital ecosystems augmented by human interaction streamline operations and improve user experiences [49]. However, sustainable development is a multidisciplinary concept that integrates environmental, economic and social factors into decision-making and action. It focuses on managing societal concerns in an environmentally and economically sustainable manner while ensuring that our actions meet present needs without jeopardizing future generations' ability to meet their own [50]. Sustainable development in the Bangladeshi RMG industry should be framed around environmental responsibility, economic growth and improving garment workers' social well-being [51, 52].

The Industry 4.0 era utilized cyber-physical production systems (CPPS) to make intelligent decisions through real-time communication and cooperation among automation, thereby facilitating the flexible and efficient production of high-quality personalized inventories [53–55]. As firms embraced Industry 4.0, the Fifth Industrial Revolution (Industry 5.0) emerged. Industry 5.0 aims to achieve societal goals beyond jobs and growth by respecting the environment and prioritizing worker well-being in the production process [29, 56]. Industry 5.0 is predicated on the notion that Industry 4.0 prioritizes modernization and artificial intelligence-driven innovations over social fairness and sustainability, resulting in greater production efficiency and flexibility. Industry 5.0 emphasizes the need for research and innovation to support the industry's long-term contribution to humanity within global boundaries [52]. Before the formal implementation of Industry 5.0, there had been debates about the "Age of Augmentation", where humans and machines collaborate in synergy [57].

Industry 5.0 conjugately centres around human and environmental well-being at its core. Industry 5.0 prioritizes human demands and interests in manufacturing, transitioning from technology-driven advancement to a more societal-centric approach. Industry personnel will take on new tasks as their worth shifts from "cost" to "investment". Manufacturing technology should adapt to the requirements and diversity of workers to serve individuals and society. The goal is to establish an inclusive and secure workplace that prioritizes physical and mental welfare while also protecting workers' fundamental rights, such as autonomy, dignity and privacy. Upskilling and re-skilling are essential for industrial workers to further their careers and maintain a work-life balance [28, 29, 58]. To protect the environment, industry must be sustainable. It must create circular processes that reuse, repurpose and recycle natural resources, thereby reducing waste and environmental impacts, and eventually leading to a circular economy with greater resource productivity and efficacy [29].

Industry 5.0 focuses on integrating automation from Industry 4.0 with Sustainable Development Goals (SDGs) in a human-centred approach [59]. Due to Industry 5.0's priorities on human well-being instead of automation, there is a shift of paradigm on the concern of achieving sustainability [60]. Industry 5.0 comprises complex systems that combine sustainable technologies with social well-being, as shown in Figure 1.

Interactive human-machine technologies such as neural implants, human-centric artificial intelligence (AI), Augmented Reality (AR) and Virtual Reality (VR) can combine the efficiency of humans and machines [61–63]. Bio-inspired technologies with embedded smart materials in industries can enhance the manufacturing process while being recyclable [28, 64, 65]. Technologies such as digital twins and virtual simulation can maintain human centricity and operational safety [66]. Technologies for energy efficiency, renewables, storage and autonomy are required to
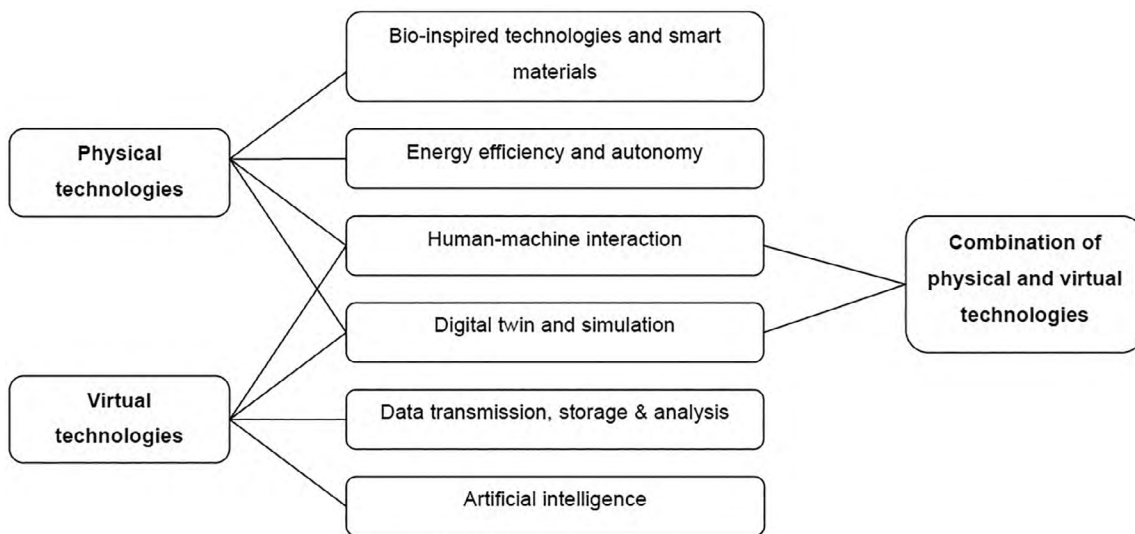
Figure 1: Technological advancements in Industry 5.0

achieve emission neutrality, including the integration of renewable energy sources and low-energy data transmission and analysis [67]. The most distinguished breakthrough in Industry 5.0 is blockchain technology, which can ensure ethical practices in industries, including the supply chain of textile industries. Transactions recorded in blockchain are transparent, traceable and cannot be falsified, thereby reducing the risk of social exploitation [68, 69]. Additionally, incorporating AI in the supply chain can reduce risk by predicting potential obstacles and taking necessary measurements through contingency plans [70].

This study observes a literature gap between ethical fashion practices and Industry 5.0. Although both topics focus on human well-being and sustainability, there is a lack of studies regarding the implementation of Industry 5.0 to ensure ethical practices in the fashion industry. This study therefore proposes a framework to fill the gap and highlights how the application of Industry 5.0 can impact ethical fashion practices.

3 Framework for implementing Industry 5.0 in ethical fashion

Industry 5.0 in ethical fashion must increase customer awareness in order to foster long-term transformation. By placing a strong focus on sustainability, ethics and transparency, this human-centred approach enables consumers to make moral purchasing decisions. Technologies that provide thorough provenance information, such as blockchain and QR code tagging, enable consumers to make informed judgments. Immersion technologies and digital twins encourage mindful consumption. Behaviour can also be influenced by social media and educational programs. As consumers become more aware of the social and environmental effects of fashion, manufacturers are being pressured to adopt more ethical methods. Raising consumer knowledge increases brand accountability and fosters a cyclical, inclusive fashion industry where ethics and innovation coexist [71].

This study proposes a conceptual framework for integrating Industry 5.0 with ethical fashion practices. The framework is structured around three mutual cores of Industry 5.0 and ethical fashion: human-centricity, sustainability, and transparency and accountability. The human-centric core of the

framework emphasizes ethical labour practices, inclusive design and production, and prioritizes human well-being and ergonomics by leveraging Industry 5.0-enabled technologies, such as human-machine interaction and Artificial Intelligence. The sustainability core promotes circular economy principles by applying closed-loop systems for the reuse of materials, recycling and the use of bio-inspired technologies and smart materials enabled by Industry 5.0 [34, 72]. It also promotes the reduction of environmental impacts by using energy-efficient and autonomous technologies of Industry 5.0, and by using blockchain to promote sustainable supply chain management. Finally, the core pillar of transparency and accountability in ethical fashion can be achieved by supply chain transparency, ethical governance and consumer empowerment through Industry 5.0, as shown in Figure 2.
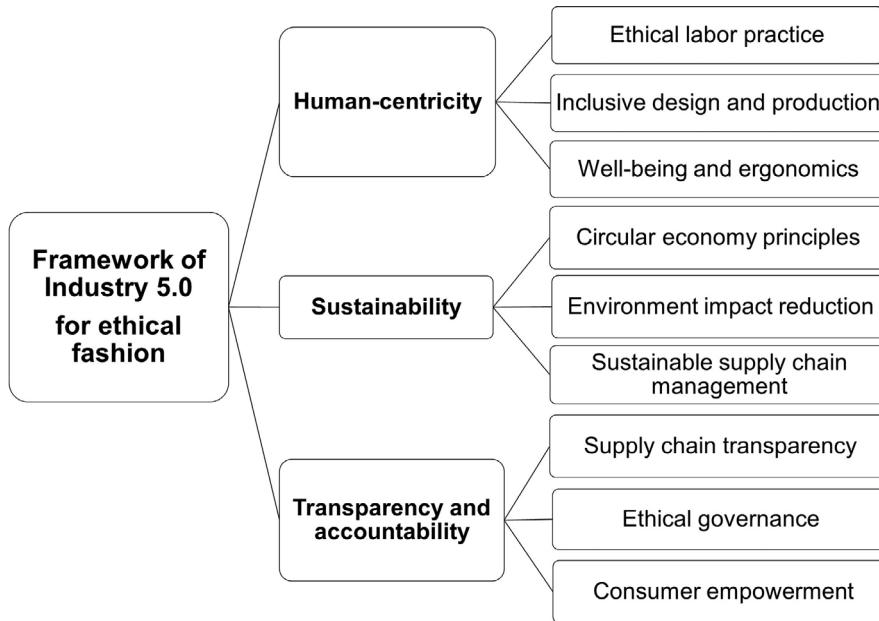

Figure 2: Conceptual framework for implementing Industry 5.0 in ethical fashion

The original theoretical basis of the conceptual framework can be found in the incorporation of stakeholder theory, the TBL framework and STS theory. The result is a more robust and unique interaction model between Industry 5.0 principles and ethical fashion practices. By combining these, however, it provided a multi-faceted basis that went beyond simply restating Industry 5.0 characteristics, such as transparency, sustainability and human-centricity; rather, it created a dynamic model to show how these ideas work in tandem to achieve ethics in fashion. Industry 5.0 conceives a humanistic vision, which resonates with the stakeholder theory that champions the inclusive creation of value among multiple actors, such as designers, workers, suppliers, consumers and policy-makers, who co-operatively interact through digital technologies and co-creation platforms, thereby ensuring transparency and ethics along the value chain [73].The TBL theory underpins the sustainability foundation of the framework, positioning Industry 5.0 technologies such as blockchain, artificial intelligence and circular manufacturing systems as facilitators of a balance between social wellbeing (people), environmental preservation (planet) and profitability (profit) [74]. STS theory extends the framework by addressing the interplay between the social and technological aspects in fashion systems, guaranteeing that automation and AI increase human creativity, empathy and moral judgment, instead of replacing

them [75]. These concepts taken together demonstrate that ethical fashion in the Industry 5.0 era is a socio-ethical development where intersections between sustainability, stakeholder participation and human-machine cooperation will take place, rather than just technology advancement. A schema of such an improved conceptual framework that binds these theoretical pillars in generating the quantifiable ethical objectives of the fashion ecosystem, such as inclusion, justice, traceability and resilience, is presented in Table 3 below. Our new model thus fills the gap between theory and practice by providing a fresh interaction mechanism that interlinks technical progress with ethical imperatives. By casting out an integrated theoretical framework that may inspire empirical validation in future research, it also furthers academic discourse. The improved framework now depicts the ethical fashion ecosystem as a stakeholder-driven socio-technical system based on sustainability principles, as the ethos of Industry 5.0 lies in digital ethics and human-centric advancement [76, 77].

Table 3: Conceptual framework linking Industry 5.0 and ethical fashion

Theory	Concept	Industry 5.0	Ethical fashion's application	Outcomes	References
Stakeholder	Shared value with multiple stakeholders and engagement	Human-centric	Collaboration with designers, workers and consumers through digital tools	Transparency and inclusivity	[73]
Triple bottom line	People, planet and profit	Sustainability	Circular fashion, blockchain and co-efficient production balance	Environmental protection, social equity and profitability	[74]
Socio-technical system	Social and technical system integration	Human-machine collaboration	Balancing craftmanship with creativity	Resilience, empowerment and ethics	[75]

4 Application of Industry 5.0-enabled technologies for ethical fashion practices

The emphasis on the human-centric sustainability of Industry 5.0 facilitates the integration of ethical practices in the textile industry. The interactive human-machine synergy implemented by Industry 5.0 ensures the efficiency of human labour rather than replacing it with automation, which promotes ethical labour practices in the textile industry. Technologies for energy efficiency and renewable resources promote sustainability and ethical practices. Industry 5.0 can also integrate ethical practices in the textile industry by adopting blockchain and digital twins to promote transparency, traceability and accountability.

Unlike Industry 4.0's priority to automate, Industry 5.0's human-centric approach can lead to stronger rules and enforcement measures in the textile industry to ensure ethical fashion practices [28]. As a result, governments and authorities in many countries can make a greater impact by enacting laws to improve the transparency of social sustainability claims.

Consumers are increasingly aware of environmental and social issues, leading to a growing demand for sustainable and ethical fashion. However, many consumers lack the knowledge and tools to scrutinize sustainability claims. This makes it easier for fashion brands to deceive consumers and exploit them as an opportunity for unethical practices [78, 79]. Implementing Industry 5.0 in the textile industry can help consumers to access transparent information about products, which helps them make ethical purchase decisions and encourages the textile industry to practice ethical fashion.

The supply chain in the textile industry is often obscure, with complex routes that make it difficult to

track the origin of materials and the working conditions of labourers, who suffer from low salaries, involuntary overtime, inconsistent hours and poor safety conditions [80, 81]. This obscureness allows textile industries to make misleading claims about their ethical fashion practices. Industries often use vague and misleading marketing claims to promote their products as sustainable without providing transparent proofs or certifications to support their claims of being "sustainable" or "ethical". This can be eliminated by integrating blockchain technology in the supply chain to transparently trace the sourcing of raw materials to production and overall operations, thereby ensuring social well-being and ethical fashion practices [68, 69]. AI-driven supply chains can forecast optimal inventory management to reduce waste generated in inventories through real-time data insights and the IoT (Internet of Things) [82]. AI can also optimize logistics by sourcing environment-friendly, sustainable materials and forecasting efficient routes and transportation modes [83]. Moreover, AI promotes ethical supply chain management and upholds fair labour

standards with the optimization of production operations and waste reduction [84].

Some companies may focus on one aspect of sustainability, such as using recycled materials or environmental impacts while neglecting other important factors such as fair labour practices [85]. Industry 5.0 utilizes human-centric technologies for energy efficiency, renewables and autonomy, while prioritizing human well-being and maintaining higher product accessibility, an improved customer experience and sustainable talent management. This can ensure genuine sustainability efforts and ethical fashion practices [67, 86]. Moreover, Industry 5.0's circular economy principles promote recycling, reprocessing and waste minimization measures, which reduce the rebound effect [41]. Industry 5.0 incorporates data-driven decision-making, innovative design and circular strategies to help corporations reduce overconsumption, reduce post-consumer waste and manage the rebound effect, resulting in more sustainable and ethical fashion practices (Table 4) [87, 88].

Table 4: Areas to apply Industry 5.0-enabled technologies

Technologies enabled by Industry 5.0	Areas to implement	References
Human-machine collaboration	Worker well-being, ethical labour practices, improved laws and regulations	[28]
Digital twins and virtual simulation	Operation safety in manufacturing	[66]
AI and blockchain	Transparency and traceability in supply chain	[68, 69, 82–84]
Bio-inspired smart materials	Recycling materials and enhanced manufacturing	[28, 64, 65]
Energy efficient automations	Waste minimization	[67, 86]

5 Challenges and future directions

Adopting Industry 5.0 in the textile industry presents obstacles in multiple interlinked categories. The human-centric core value of technologies enabled by Industry 5.0 will not gain its full potential without the two-way interaction of humans and machines. The skills required to adapt to Industry 5.0 must be envisioned through retraining and lifelong learning

concepts. Society must also integrate challenges such as youth unemployment, the ageing population and gender discrimination for the broader implementation of Industry 5.0. The heterogenic nature of society also hinders the harmonic prioritization of the values and needs of its members. While Industry 5.0 focuses its core value on individual human-centric well-being, it must integrate with the complete working environment of the textile

industry, requiring a socio-centric approach. The revolution of Industry 5.0 facilitated the addressing of technological by both governments and policymakers for setting appropriate rules and regulations, which is often a lengthy process due to the slow adaptability of governments and policymakers. The textile industry has not yet fully embraced Industry 4.0. In the meantime, implementing Industry 5.0 requires an overhaul of the skills and strategies of management as a whole in the textile industry. New technologies are also required to measure the social and environmental impacts of implementing Industry 5.0 in the fashion industry [67]. A collaborative transformation that combines technological advancements with socio-human integration is about to take place in the textile industry. This change will facilitate sustainable manufacturing, individualised innovation and improved worker well-being. Deliberate upskilling and lifelong learning are crucial for reducing youth unemployment and integrating marginalised groups. Policies must support inclusion, ethical governance and technological accessibility. Industry 5.0 offers opportunities to reconsider value chains through the use of AI-human collaboration, circular economy models and real-time social impact assessment tools. Governments, educational institutions and corporate leaders will be essential in overcoming regulatory barriers.

6 Conclusion

This study concludes that Industry 5.0 has the potential to advance ethical fashion by aligning technical innovation with human-centred and ecologically sensitive ideals. It draws attention to the shared goals of Industry 5.0 and ethical fashion, which include reducing environmental harm and promoting responsibility, openness and worker welfare. By combining cutting-edge technologies with human inventiveness and moral ideals, Industry 5.0 encourages a more sustainable and socially responsible apparel business. However, this study also identifies significant limitations on the fashion industry's use

of Industry 5.0. These include the industry's capacity to adapt to this new paradigm, the need for people to acquire new skills to facilitate effective human-machine collaboration and broader social implications that must be considered. Furthermore, the creation of frameworks and policies that are supportive is still necessary for the effective adoption of Industry 5.0 practices. This study lays the groundwork for future practices in the fashion industry, advocating for intersectoral collaboration, regulatory support for transparency and circularity, and pilot programs in smart-ethical manufacturing. It emphasizes the need for designers and manufacturers to adopt traceability technologies and embrace human-AI co-creation to enhance accountability. Governments are urged to foster ethical innovation through guidelines and funding, paving the way for a morally sound Industry 5.0 fashion ecology. Industry 5.0 creates new opportunities for fashion research and innovation despite these obstacles. Future research is required to examine how these technologies can be successfully scaled and integrated, as industry looks to move away from mass production and towards more individualised, moral and sustainable solutions. Ultimately, Industry 5.0 offers a route to a fashion ecosystem that is more moral, inclusive and progressive.

Data availability: The authors have cited the research data in the reference list at the end of article.

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