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Potential factors affecting organizational readiness for the industry 5.0 for the Sri Lankan apparel industry: a systematic literature review

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Abstract Industry 5.0 in the apparel sector represents a transformative shift towards a human-centric and sustainable production model compared to Industry 4.0, which mainly focuses on technology-driven digitization. By leveraging advanced technologies including artificial intelligence (AI), robotics, and the Internet of Things (IoT), Industry 5.0 enables hyper-customization, real-time data analysis, and seamless integration of human expertise with machine capabilities. This shift enhances product quality, optimizes resource utilization, and prioritizes ethical manufacturing practices, focusing on both worker well-being and environmental responsibility. These changes fundamentally redefine the garment production landscape, positioning the industry for long-term sustainability and competitiveness. This systematic literature review (SLR) aims to identify the key readiness potential factors influencing the Sri Lankan apparel industry's transition to Industry 5.0. Specifically, the research explores the domains affecting readiness, including technological advancements, human-machine collaboration, sustainability practices, and resilience within the supply chain. The findings reveal that the Sri Lankan apparel industry is transitioning from Industry 4.0 to Industry 5.0, focusing on human-machine collaboration, integrating AI and robotics, and enhancing sustainability efforts. The readiness potential factors in this transition are categorized into four main domains human-centric, sustainability, resilience, and technological advancements. Despite notable progress in automation and sustainable practices, gaps persist, particularly in fully realizing human-machine collaboration and achieving complete supply chain transparency. Finally, this acknowledges certain limitations and suggests areas for future research.

Keywords: Apparel industry, Human-centric, Organizational Readiness, Resilience, Sustainability, technological

Introduction

The Sri Lankan apparel industry plays a pivotal role in the country's economic development, contributing significantly to export revenues and serving as a driver of national growth (Mirza & Ensign, 2021). By 2022, apparel exports reached US$5.9 billion Munasinghe (2024b) with key products including undergarments, outerwear, and activewear. The export market is led by knitted apparel, which generated US$3,100 million, and non-knitted apparel, contributing US$1,800 million. The apparel industry consists of 350 firms and employs 350,000 workers directly, with an additional 600,000 indirect employment, of whom 78% are women (Vidanage et al., 2024). This sector plays a vital role in reducing poverty by offering income-generating opportunities to unskilled workers.

The sustainability challenges confronting the Sri Lankan textile and apparel industry are significant and multifaceted. These include high levels of carbon emissions due to energy-intensive production processes and improper chemical management, which leads to environmental contamination and poses risks to human health. Waste management is another critical concern, as large volumes of off-cuts and defective garments contribute to ecological degradation. Additionally, water scarcity, stemming from the industry's high demand for water in production, remains a persistent operational challenge. These sustainability issues underscore the imperative for the industry to adopt sustainable development practices that not only reduce environmental impact but also enhance social responsibility and ensure long-term economic viability (Samudrika & Samarawickrama, 2024).

Despite its central economic importance, the Sri Lankan apparel industry faces substantial challenges compromising its global competitiveness. Technological gaps within the sector have resulted in inefficiencies in quality and productivity, particularly as global competitors increasingly adopt advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), and collaborative robots (cobots) (Abbate et al., 2024). Furthermore, shifts in consumer preferences toward sustainable fashion, including recycled and reusable apparel, have exposed the industry's limitations in meeting these expectations. These challenges are compounded by hazardous working conditions, low wages, and high employee turnover, particularly among technically skilled workers, highlighting the industry's struggles to retain and develop talent. The limited educational qualifications of many employees further increase these issues, creating additional barriers to sustained growth and stability (Maduranga & Harshani, 2024c; Wellagiriya et al., 2024).

Industry 5.0 marks a key advancement from the automation focus of Industry 4.0, which introduced innovations including big data, AI, augmented reality, and the IoT (Sarıoğlu, 2023). While Industry 4.0 optimizes manufacturing through data-driven automation, Industry 5.0 takes a more human-centric approach, integrating technologies such as human-machine interfaces, wearable devices, and augmented reality to enhance collaboration between humans and machines (Jahromi & Ghazinoory, 2024b). Cobots are central to this, enabling communication across the supply chain, factory, and end-users, fostering more efficient and interactive production processes (Sarıoğlu, 2023). Industry 5.0 prioritizes inclusivity, sustainability, and improving the quality of life for workers, focusing on human creativity, problem-solving, and emotional intelligence as drivers of innovation and value creation (Jahromi & Ghazinoory, 2024b). Furthermore, the digital transformation of Industry 5.0 extends beyond technology, impacting broader societal and cultural dimensions, and creating a more personalized and sustainable future (Sarıoğlu, 2023).

Existing literature mainly addresses the transition from Industry 4.0 to Industry 5.0, emphasizing the core principles of human-centricity, sustainability, and resilience. However, there is a limited amount of research papers exploring the application of these principles within the global apparel industry. In the Sri Lankan context, the adoption of Industry 4.0 remains in its early stages. Therefore, many current research papers focus on assessing the readiness for Industry 4.0 across various sectors. Notably, there is a significant gap in the literature concerning implementing of Industry 5.0 principles within the Sri Lankan apparel industry. Therefore, this research aims to identify the key potential readiness areas and factors influencing organizational readiness for Industry 5.0 within the Sri Lankan apparel industry.

Methodology

Search Strategy

The search strategy employed for this review was designed to ensure a comprehensive collection of literature related to Industry 5.0 readiness in the Sri Lankan apparel industry. Databases and other sources such as IEEE Xplore, ScienceDirect, SpringerLink, Wiley Online Library, and Google Scholar were selected for their relevance to the fields of Industry 4.0, Industry 5.0, and related technological advancements. Keywords including "transition to Industry 4.0 to 5.0," "Industry 5.0 readiness," "human-centric practices," "apparel industry," "sustainability," and "resilience" were systematically used across the databases.

Screening and Selection Process

The screening and selection process for the literature review followed a systematic, multi-step approach. The process began with an initial review of titles and abstracts to identify studies relevant to the core themes of Industry 5.0 readiness. This initial phase ensured that only studies addressing key elements such as human-centric practices, sustainability, resilience, and technological advancements were considered for further analysis. Subsequently, full-text reviews were conducted to evaluate each study’s detailed relevance and alignment with the review’s objectives. To maintain the quality and rigor of the selection process, the SciSpace tool was utilized to confirm that the chosen papers met the required content standards. The literature review was conducted from June 2024 to September 2024, ensuring a focused and

comprehensive analysis within the defined time frame. This methodical approach ensured the inclusion of studies that provided valuable insights into the transition to Industry 5.0.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria ensured that only studies of high relevance and quality were considered. The Table 01 below outlines the criteria that guided the selection of studies.

Table 1: Inclusion and Exclusion Criteria

Characteristic	Inclusion Criteria	Exclusion Criteria
Type of Publication	Peer-reviewed journal articles, conference papers, and book chapters indexed in reputable databases such as Scopus, IEEE, and others	Studies published in non-peer-reviewed sources or unpublished literature
Language	English	Non-English publications
Time Period	Studies published from 2016 to 2024 to capture recent developments in Industry 5.0	Studies published before 2016, which primarily focus on theoretical aspects of Industry 4.0
Research Focus	Studies focusing on organizational readiness, technological readiness, human-centric practices, sustainability, resilience, strategies and practices adopted by foreign apparel industries for transitioning to Industry 5.0 and the Sri Lankan apparel industry	Studies do not directly address the transition to Industry 5.0

Synthesis of Results

The reviewed research papers identified several potential factors and drivers that significantly influence organizational readiness for Industry 5.0. The factors in the existing papers are categorized under the three core values of human-centricity, sustainability, and resilience or the TOE (technology, organizational, and environmental) framework (Huy & Phuc, n.d.). Each core value plays a pivotal role in facilitating an organizational transition to Industry 5.0, emphasizing the integration of advanced technologies with human involvement, a commitment to environmental sustainability, and enhanced resilience to disruptions. The identified potential factors are particularly relevant for the Sri Lankan apparel industry, providing critical insights for implementing Industry 5.0 principles and maintaining competitiveness in an increasingly dynamic and technologically advanced global environment.

Results and Discussion

Selection of Evidence

According to the PRISMA guidelines, the selected papers focus on the transition from Industry 4.0 to Industry 5.0 within the Sri Lankan apparel industry, emphasizing the core values of Industry 5.0. The research filtration process, represented in Figure 1, narrowed the relevant literature to studies that explore implementing these principles in the Sri Lankan apparel sector focusing on the potential factors driving the industry's evolution.

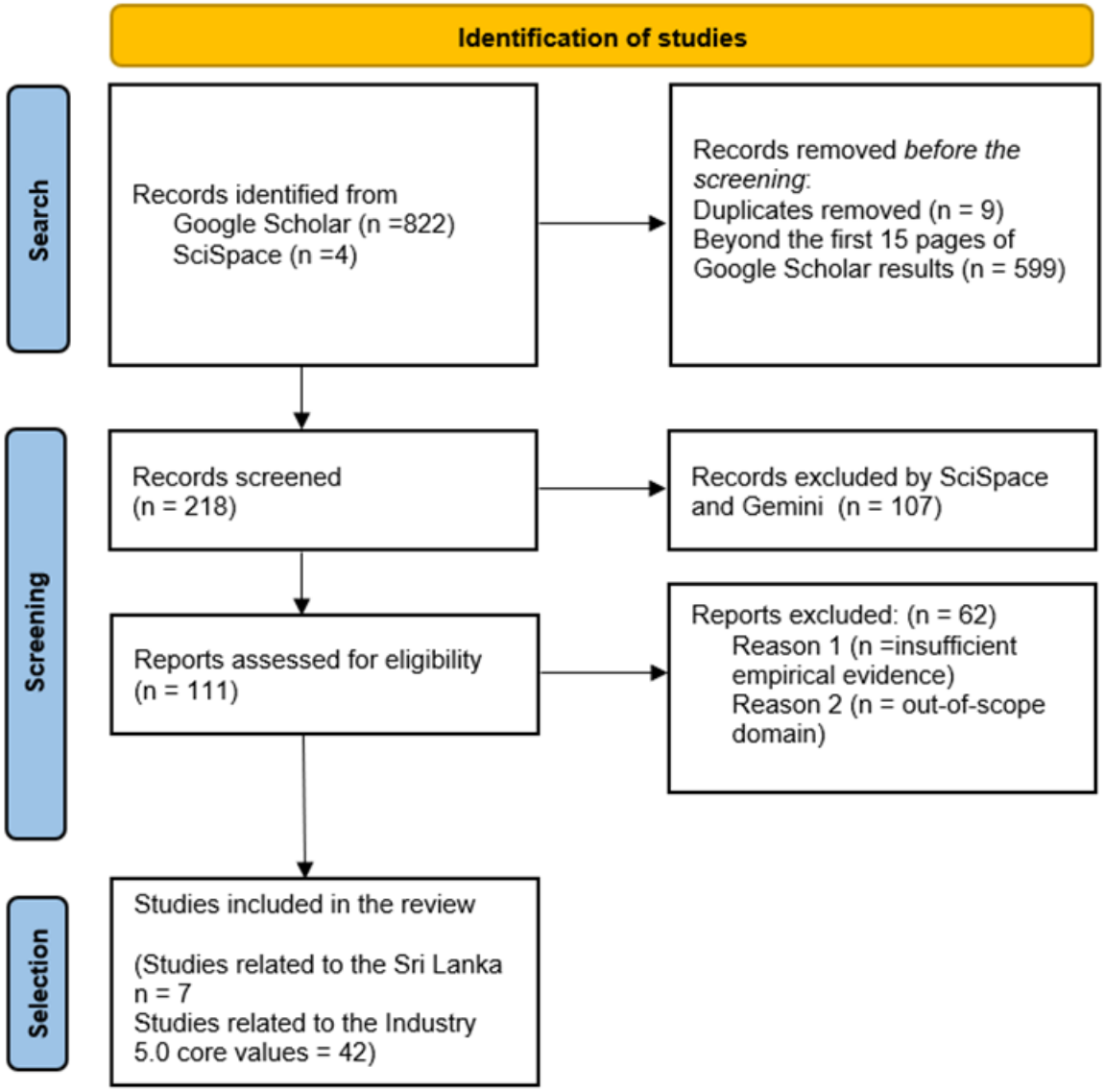

Figure 1. Article Screening Process

Potential Factors that Affect Organizational Readiness for Industry 5.0 for the Apparel Industry

These key readiness areas and potential factors were identified based on the filtration of studies according to the above-mentioned article selection criteria. The findings from the review are organized under four primary categories human-centric, sustainability, resilience, and technological potential factors (Table 2). Each category underscores the critical elements required for achieving organizational readiness within the Sri Lankan apparel industry as it transitions to Industry 5.0.

Potential Human-Centric Readiness Factors

This section discusses seven key essentials required for prioritizing human needs while integrating collaborative robots to enhance human-machine collaboration.

Continuous Learning

Continuous learning is essential for the workforce to adapt to technological advancements in Industry 5.0. Ghobakhloo et al. (2024b) emphasize the importance of employees possessing expertise in digital technologies to integrate them effectively

into operations and business models. Olsson et al. (2024b) accentuate the challenges of maintaining and continuously broadening the knowledge base, advocating for structured upskilling initiatives to avoid scattered efforts. Similarly, Dai et al. (2024) address that learning provides essential knowledge, while training enhances competency. Maharana et al. (2024) explain the need for technological literacy, focusing on the critical importance of AI, cobots, and augmented reality skills. George et al. (2023) describes lifelong learning, pointing to curiosity and adaptability as key to continuous education outside formal programs. Nousala and Metcalf (2024) reinforce the necessity of complementing technical skills with human-centered capabilities such as problem-solving and emotional intelligence, while Harish and Nayyar (n.d.) focus on the demand for digital literacy, data analysis, and problem-solving further stressing the role of continuous learning in adapting to new technologies. Collectively, these studies reveal that continuous learning must address both technical expertise and soft skills to meet the evolving demands of Industry 5.0.

Training and Development

Training and development are crucial to prepare employees for Industry 5.0's technological demands. Verma (2024) focuses on the use of VR (Virtual Reality) and AR (Augmented Reality) technologies for immersive skill-enhancing training, but Nair (2024) discusses the importance of behavioral training alongside technical skill development, especially for human-robot interaction. Maharana et al. (2024) elaborate on the need for retraining employees in data analytics, machine learning, and robotics to collaborate effectively with machines, aligning with Ghobakhloo et al. (2024b) emphasize the role of continuous learning initiatives to adapt to evolving technologies. Alves et al. (2023) explain the importance of developing multifaceted skills, including technical and socio-technological capabilities. Olsson et al. (2024b) reinforce that upskilling can drive innovation by strategically integrating human abilities with technology. Emma-Ikata and Doyle-Kent (2022) focus on the fact that even long-standing manufacturing workers must be open to learning and adapting further elaborated by George et al. (2023) address retraining in cognitive and creative skills as automation replaces routine tasks. These studies reinforce that training programs in Industry 5.0 must combine technical, behavioral, and cognitive elements to prepare employees for the future workplace.

Organizational Senior Management Involvement

Senior management plays a critical role in guiding organizations through the digital transformation required by Industry 5.0. Olsson et al. (2024b) emphasize the need for clear ownership of responsibilities to avoid fragmented management and rebuild trust. Ghobakhloo et al. (2024b) explain the capabilities required from leaders to navigate the complexities of digital transformation, including fostering innovation and strategic execution. Patil and Kulkarni (n.d.) accentuate the role of emotional intelligence in ensuring human-centric collaboration, while Alves et al. (2023) elaborate on the importance of strategic leadership to guide transformation efforts. George et al. (2023) reinforce the need for decentralized decision-making and inspire continuous improvement among teams, emphasizing the humanization of emerging technologies. Thomas et al. (2024b) focus on the importance of continuous leadership growth, where managers must collaborate across departments and invest in new technologies. These perspectives reveal that strong, emotionally intelligent leadership is essential to drive successful digital transformation and innovation in Industry 5.0.

Safety of Workers

Worker safety is a central concern in Industry 5.0, particularly in environments involving human-robot collaboration. De Fonseka (2024b) emphasizes the importance of safety in embedding environmental sustainability practices, focusing on hazardous conditions in manufacturing as a key factor. Damaševicius et al. (2024) focus on the role of safety sensors and features in cobots to prevent injury and ensure safe operations. Similarly, Maharana et al. (2024) address the need for safety awareness in collaborative robot workspaces, advocating for risk management protocols and procedures. Emma-Ikata and Doyle-Kent (2022) discuss the necessity of proximity sensors and kill

switches as critical safety measures, especially given the potential injury risks posed by cobots. Bi et al. (2021) accentuate the need for safety assurances through additional mechanisms such as force monitors in human-robot collaborative environments. George et al. (2023) explain that regulatory updates are essential to address the integration of human-robot collaboration while balancing cybersecurity and privacy concerns. Together, these studies reinforce that ensuring safety in human-machine collaboration requires advanced technological solutions and robust safety protocols to protect workers.

Human-Machine Collaboration

Human-machine collaboration is a core attribute of Industry 5.0, where humans and machines work together to enhance productivity and innovation. Sindhwani et al. (2022) emphasizes the role of collaborative robots (cobots) equipped with sensors that enable active interaction with humans. Dai et al. (2024) explain that while Industry 4.0 focuses on automation, Industry 5.0 centers on intelligent collaboration, ensuring cobots support human tasks without replacing them. Nair (2024) underscores the human touch in production, where cobots play a complementary role, maximizing both productivity and well-being. Damaševicius et al. (2024) explain cobots' adaptability, arguing that they must effectively communicate and collaborate with human operators. Tóth et al. (2023) focus on the need for a truly integrated human-AI collaboration model, where human-centered processes drive innovation and productivity. Together, these studies reinforce that the future of Industry 5.0 depends on the seamless and intelligent collaboration between humans and machines, ensuring that human workers remain central to production processes.

Change of Culture

A cultural shift is necessary for organizations transitioning to Industry 5.0, as technological changes require new approaches to work and collaboration. Olsson et al. (2024b) explain the need for transparent communication and avoiding unplanned digital initiatives, ensuring employees are engaged in the transformation process. Maharana et al. (2024) emphasize the adaptive nature of co-bot workspaces, where employees must be ready to adjust to new workflows. Tóth et al. (2023) underscore the social management of digital collaboration cultures, advocating for the inclusion of all stakeholders in knowledge creation and collaboration. Patil and Kulkarni (n.d.) emphasize the importance of fostering a culture of innovation that promotes sustainable products and improved processes, while George et al. (2023) accentuate the need for data transparency and decentralized authority to foster collective success. Harish and Nayyar (n.d.) explain that a supportive workplace culture can reduce stress and improve working conditions while generating new job opportunities. These studies highlight the importance of building an adaptable, transparent, and innovative workplace culture that can thrive amidst Industry 5.0's technological disruptions.

New Job Roles Design

Industry 5.0 not only transforms technology but also redefines job roles to align with new collaboration models between humans and machines. Maharana et al. (2024) emphasize the need for human resources (HR) departments to redesign job roles to incorporate cobots, focusing human employees on more complex and strategic tasks. Verma (2024) explains the potential for creating new roles in human-robot collaboration management, data analysis, and system optimization. Tóth et al. (2023) clarify the creation of roles such as plant knowledge engineer and robot coordinator, driven by AI services, that will support integrated collaboration processes. Harish and Nayyar (n.d.) underscore emerging roles such as digital twin experts and augmented reality technicians, who will ensure the proper operation and optimization of production processes. Collectively, these studies reinforce that Industry 5.0 will lead to the creation of highly skilled roles that integrate human expertise with advanced technological systems, shifting the workforce toward more intellectually demanding and collaborative positions.

Potential Resilience Readiness Factors

This section examines four key potential factors necessary for adapting to and recovering from disruptions or unexpected events.

Manufacturing Resilience

Manufacturing resilience in Industry 5.0 emphasizes adaptability and the ability to respond swiftly to disruptions. Martín-Gómez et al. (2024) explain the importance of resilience, defining it as the capacity to adapt to changes and recover from disruptions quickly. George et al. (2023) emphasize the role of smart, resilient manufacturing systems that are agile, reconfigurable, and capable of responding in real-time to operational changes, enabled by integrated supply chains with enhanced visibility. Leng et al. (2023b) emphasize the role of modular design and predictive maintenance in building resilience, suggesting that resilience differs from robustness by focusing on quick recovery from disruptions rather than minimizing performance fluctuations. Van Erp et al. (2024) accentuate the importance of circular design and flexible adaptation of manufacturing strategies in response to geopolitical and environmental uncertainties. Similarly, Aheleroff et al. (2022) focus on how decentralized manufacturing enhances resilience by enabling flexibility and mass personalization. Collectively, these perspectives reinforce the evolving nature of resilience in Industry 5.0, where real-time adaptation, modular design, and decentralized systems form the core of resilient manufacturing.

Supply Chain Flexibility

Supply chain flexibility in Industry 5.0 is crucial for maintaining resilience and agility in the face of disruptions. Ejjami and Boussalham (2024) describe the potential of AI-driven technologies to enhance resilience by optimizing processes and enabling proactive management. George et al. (2023) emphasize that Industry 5.0 technologies, such as blockchain, AI, and IoT, allow real-time monitoring and predictive measures, thus enabling greater resilience and sustainability within supply chains. Dacre et al. (2024) explain the role of resilience in meeting evolving customer demands for mass personalization, while Agrawal et al. (2023) underscore the integration of resilience and sustainability to achieve the UN Sustainable Development Goals (SDGs). Dai et al. (2024) elaborate on the concept of "Operator 5.0," where human creativity and resourcefulness are unleashed through the use of information and technology, further reinforcing the human-centric approach in supply chain management by allowing quick, cost-effective responses to disruptions. Villar et al. (2023) elaborating on the human-centric focus of Industry 5.0 supply chains, prioritizing ethical and social essentials, such as workplace safety and sustainability. Susitha et al. (2024) emphasize that digital capabilities (DCs) and strategic flexibility are essential for achieving supply chain agility and adapting to technological changes. Overall, these perspectives demonstrate that supply chain flexibility in Industry 5.0 is driven by the integration of digital technologies, real-time visibility, and a focus on resilience and sustainability.

Stakeholder Collaboration

Stakeholder collaboration is essential for the successful implementation of Industry 5.0 technologies and principles. Ghobakhloo et al. (2024b) emphasize the importance of active engagement among various stakeholders, including customers, partners, and governmental entities, to foster cooperation and embrace Industry 5.0. In contrast, Ghobakhloo et al. (2022a) focus on the shift from the horizontal integration of supply chains in Industry 4.0 to the horizontal integration of smart components and stakeholders within a value network in Industry 5.0, which includes smart factories, suppliers, and technology providers. Patil and Kulkarni (n.d.) explain the importance of building strong relationships with stakeholders, suggesting that resilient organizations collaborate with vendors and partners to adapt to market shifts. These studies collectively reinforce how Industry 5.0 transforms stakeholder collaboration from traditional supply chain integration to a more holistic and collaborative network, which enhances organizational resilience and innovation.

Agile Manufacturing

Agile manufacturing in Industry 5.0 requires flexibility and the ability to quickly adapt to disruptions and market changes. Verma (2024) emphasizes the collaborative nature of Industry 5.0, which allows for rapid customization and response to market demands, enhancing flexibility in manufacturing processes. Patil and Kulkarni (n.d.) reinforce the need for flexibility and agility to

withstand disruptions such as natural disasters and pandemics, suggesting that agile manufacturing systems can maintain operations even in unpredictable conditions. Fraga-Lamas et al. (2024) elaborate on the need for Industry 5.0 factories to develop resilient value chains that can adapt quickly to geopolitical and natural crises, linking agility to the ability to handle global supply chain challenges. Harish & Nayyar (n.d.) emphasize that businesses in Industry 5.0 must be agile to respond to technological changes and fluctuating market conditions. Together, these perspectives emphasize that agile manufacturing in Industry 5.0 goes beyond flexibility, requiring resilience and the capacity to make rapid decisions in the face of uncertainty.

Potential Sustainable Readiness Factors

This section explores five key essentials critical for implementing environmentally friendly practices and maintaining a sustainable business environment.

Effective Resource Utilization

Effective resource utilization is a cornerstone of sustainability in Industry 5.0, aiming to reduce environmental impact and optimize material use. Jahromi and Ghazinoory (2024b) emphasize the significant consumption of natural resources in the clothing industry, stressing the need for better resource management. Ghobakhloo et al. (2022a) explain the positive impact of Industry 4.0 technologies on resource efficiency, suggesting that this trend will continue in Industry 5.0 with even more focus on sustainability. Abbate et al. (2024) describe eco-design and the use of ecological materials to reduce environmental impacts, emphasizing waste reduction as an essential component of resource efficiency. Patil and Kulkarni (n.d.) explain the role of sustainable procurement practices in minimizing environmental impact, while Dacre et al. (2024) accentuate energy-saving initiatives and carbon neutrality as key strategies for effective resource management. Collectively, these perspectives agree that resource efficiency in Industry 5.0 involves not only technological advancements but also strategic management of natural resources and sustainable practices.

Sustainable Regulations Creation

Sustainable regulations are crucial for driving environmental responsibility in Industry 5.0. Ghobakhloo et al. (2022a) emphasize the role of technology governance (TGV) in integrating environmental authority into the design and implementation of Industry 5.0 technologies, suggesting that regulatory frameworks are necessary for embedding sustainability into industrial practices. Aheleroff et al. (2022) emphasize that Industry 5.0 prioritizes environmental protection, aligning with increasing global regulatory demands. De Fonseka (2024b) elaborates on the global impact of government regulations, illustrating how apparel industries in countries such as Bangladesh, Sweden, and India are increasingly governed by environmental policies such as chemical taxes and bans on textile incineration. Rehman et al. (2024) explains the need for compliance with corporate governance codes and environmental standards, reinforced by internal audits and regulatory oversight. Together, these sources agree that regulations are a key driver of sustainability in Industry 5.0, with governments playing a critical role in enforcing environmental policies and promoting sustainable practices across industries.

Sustainable Business Model Creation

Sustainable business models in Industry 5.0 focus on circular production, collaboration, and long-term environmental impact. Ghobakhloo et al. (2022a) emphasize the reformation of value networks to enable circular production and the creation of sustainable business models, which are essential for achieving Industry 5.0 objectives. Abbate et al. (2024) discuss the shift toward slow fashion in the textile industry, where recycled materials, eco-compatible products, and short supply chains are vital elements of a sustainable business model, contrasting it with the fast fashion model. Zizic et al. (2022) accentuate the role of smart data in developing sustainable business models that account for rebound effects and environmental impacts. Martín-Gómez et al. (2024) reinforce that sustainable business model innovation (SBI) in Industry 5.0 promotes stakeholder collaboration to foster sustainable innovation. Overall, these perspectives converge on the importance of

developing business models that not only prioritize profit but also emphasize environmental sustainability and stakeholder collaboration.

Minimizing Waste or Recycling

Minimizing waste and promoting recycling are central themes in the Industry 5.0 sustainability framework. Abbate et al. (2024) emphasize using eco-design and ecological materials to reduce waste, addressing the importance of circular economy principles. Nair (2024) explains the application of lean manufacturing to eliminate waste in production processes, while George et al. (2023) describe the integration of AI and additive manufacturing techniques, such as 3D printing, to reuse materials and minimize waste. Patil and Kulkarni (n.d.) discuss the role of IoT sensors and data analytics in optimizing resource use and minimizing waste throughout the production cycle. Sindhwani et al. (2022) accentuate the importance of recognizing and eliminating waste-generating practices and promoting recycling as key steps toward industrial sustainability. Collectively, these studies reinforce that minimizing waste in Industry 5.0 requires the integration of advanced technologies, circular design principles, and strategic efforts to reduce material waste and environmental impact.

Renewable Energy Sources Usage

The use of renewable energy is a critical component of Industry 5.0 sustainability goals. Sindhwani et al. (2022) elaborates on the availability of renewable energy sources such as solar, wind, and geothermal energy, stressing their importance in reversing the damage caused by fossil fuel emissions. Patil and Kulkarni (n.d.) underscore the role of cutting-edge technologies in integrating renewable energy sources into manufacturing operations, reducing carbon footprints, and promoting eco-friendly practices. George et al. (2023) emphasize that Industry 5.0 prioritizes renewable energy as part of its circular production methods, focusing on optimizing logistics and inputs to reduce waste and environmental impact. Collectively, these perspectives agree that the integration of renewable energy sources is not only crucial for reducing environmental harm but also aligns with Industry 5.0's broader goals of sustainability and resource optimization.

Potential Technological Readiness Factors

This section explores four key essentials critical for establishing a solid technical foundation.

Adoption of New Advanced Technologies

Adopting advanced technologies is fundamental to Industry 5.0, emphasizing the integration of AI, IoT, robotics, and more. Wellagiriya et al. (2024) focus on developing collaborative robots and governing software that combines AI and IoT to enhance human productivity. Sindhwani et al. (2022) accentuate the role of AI and big data in hyper-customization, using real-time data to deliver tailored products, which aligns with Industry 5.0's focus on personalized production. Donmezer et al. (2024b) underscore the importance of Digital Human Modeling (DHM) in optimizing human-machine interactions across sectors such as textiles, robotics, and energy, further emphasizing the human-centric design that Industry 5.0 promotes. Verma (2024) explains the role of DARQ technologies (Distributed Ledger Technology, AI, Extended Reality, Quantum Computing) in enhancing predictive maintenance, immersive training, and advanced data analytics. Dai et al. (2024) explain that integrating these emerging technologies not only improves operational efficiency but also emphasizes human-machine collaboration. Huy and Phuc (n.d.) elaborate on Industry 5.0, which revolves around intelligent technologies such as edge computing and autonomous robots, positioning digitalization at its core. Collectively, these perspectives agree on the pivotal role of advanced technologies in Industry 5.0 but diverge slightly in their focus, with some emphasizing collaboration and personalization, in contrast, others underscore broader system integration and human-centric design.

Financial Requirements

Financial requirements are essential for the transition from Industry 4.0 to Industry 5.0 because they provide the foundation for adopting advanced technologies and reshaping manufacturing systems to align with human-centric, sustainable, and

resilient goals. Significant investments are needed to implement cognitive cyber-physical systems, collaborative robots (cobots), and blockchain, which enable seamless human-machine collaboration and operational efficiency. Without sufficient funding, organizations risk falling behind in testing and validating these emerging technologies through pilot projects, which are critical for ensuring their applicability and effectiveness in specific industrial contexts (Damaševičius et al., 2024; Slavic et al., 2024). Furthermore, infrastructure investments in 5G networks, renewable energy, and digital platforms are vital to supporting the hyperconnected ecosystems required for Industry 5.0 (Sarıoğlu, 2023). Financial readiness also allows organizations to access government subsidies, low-interest loans, and tax incentives, which offset high initial costs and ensure smoother transitions, particularly for industries in emerging economies where profitability and resource constraints pose significant challenges (George et al., 2023; Sahoo et al., 2024). Aligning financial investments with sustainability objectives is equally critical, as technologies that prioritize environmental responsibility and human-centric designs are necessary to meet global sustainability targets. Ultimately, without adequate financial readiness, businesses cannot achieve the transformative potential of Industry 5.0, nor can they remain competitive in a rapidly evolving global landscape.

Tech Policy Creation

Effective tech policy creation is essential for guiding the implementation of Industry 5.0 technologies while ensuring innovation and compliance. Ghobakhloo et al. (2024b) emphasize the importance of building technology governance capabilities to align the adoption of new technologies with strategic objectives. Huy and Phuc (n.d.) explain the need for new laws and regulations that support human-robot collaboration and differentiate between technologies, calling for flexibility in these policies to promote innovation. George et al. (2023) focus on developing technology standards that ensure interoperability but caution against excessive rigidity that could stifle innovation. They further elaborate on how data protocols must balance openness and security. Collectively, these perspectives align on the necessity of creating flexible and robust technology governance frameworks that promote innovation, ensure compliance, and maintain security, with notable differences in their emphasis on the balance between openness and regulation.

Information Security

Information security is a growing concern in Industry 5.0 as integrating advanced technologies increases the risks of cyber threats. Jahromi and Ghazinoory (2024b) illustrate new security capabilities enabled by edge computing, such as improved data security and intelligent wearables for health monitoring and personalized design in the clothing industry. Damaševicius et al. (2024) emphasize the privacy and data security concerns associated with cobots, noting the need to protect sensitive data while ensuring worker privacy. George et al. (2023) underscore the challenge of balancing data openness with cybersecurity, pointing out the need for visibility and interoperability without compromising security. Huy and Phuc (n.d.) discuss implementing comprehensive cybersecurity risk management processes, including identification, detection, protection, and recovery. Verma (2024) emphasizes the growing cyber risks in Industry 5.0 due to exponentially more connected systems, calling for integrated cybersecurity measures. While all perspectives agree on the importance of robust information security, they vary in focus, with some stressing the protection of worker privacy, and others emphasizing system-wide security measures, Still, others point to the challenges of balancing security with data transparency.

Table 2: Key Sources Supporting Industry 5.0 Readiness Potential factors

Main Domain	Factor	Source
Human-Centric Potential factors	Continuous Learning	Ghobakhloo et al. (2024b); Olsson et al. (2024b); Dai et al. (2024); Maharana et al. (2024); George et al. (2023); Nousala & Metcalf (2024); Harish and Nayyar (n.d.)
	Training and Development	Verma (2024); Nair (2024); Maharana et al. (2024); Ghobakhloo et al. (2024b); Alves et al. (2023); Olsson et al. (2024b); Emma-Ikata and Doyle-Kent (2022); George et al. (2023)
	Organizational Senior Management Involvement	Olsson et al. (2024b); Ghobakhloo et al. (2024b); Patil and Kulkarni (n.d.); Alves et al. (2023); George et al. (2023); Thomas et al. (2024b)
	Safety of Workers	De Fonseka (2024b); Damaševicius et al. (2024); Maharana et al. (2024); Emma-Ikata and Doyle-Kent (2022); Bi et al. (2021); George et al. (2023)
	Human-Machine Collaboration	Sindhwani et al. (2022); Dai et al. (2024); Nair (2024); Damaševicius et al. (2024); Tóth et al. (2023)
	Change of Culture	Olsson et al. (2024b); Maharana et al. (2024); Tóth et al. (2023); Patil and Kulkarni (n.d.); George et al. (2023); Harish and Nayyar (n.d.)
	New Job Roles Design	Maharana et al. (2024); Verma (2024); Tóth et al. (2023); Harish and Nayyar (n.d.)
Resilience Potential factors	Manufacturing Resilience	Martín-Gómez et al. (2024); George et al. (2023); Leng et al. (2023b); Van Erp et al. (2024); Aheleroff et al. (2022)
	Supply Chain Flexibility	Ejjami and Boussalham (2024); George et al. (2023); Dacre et al. (2024); Agrawal et al. (2023); Dai et al. (2024); Villar et al. (2023); Susitha et al. (2024)
	Stakeholder Collaboration	Ghobakhloo et al. (2024); Ghobakhloo et al. (2022a); Patil and Kulkarni (n.d.)
	Agile Manufacturing	Verma (2024); Patil and Kulkarni (n.d.); Fraga-Lamas et al. (2024); Harish and Nayyar (n.d.)
Sustainability Potential factors	Effective Resource Utilization	Jahromi and Ghazinoory (2024b); Ghobakhloo et al. (2022a); Abbate et al. (2024); Patil and Kulkarni (n.d.); Dacre et al. (2024)
	Sustainable Regulations Creation	Ghobakhloo et al. (2022a); Aheleroff et al. (2022); De Fonseka (2024b); Rehman et al. (2024)
	Sustainable Business Model Creation	Ghobakhloo et al. (2022a); Abbate et al. (2024); Zizic et al. (2022); Martín-Gómez et al. (2024)
	Minimizing Waste / Recycling	Abbate et al. (2024); Nair (2024); George et al. (2023); Patil and Kulkarni (n.d.); Sindhwani et al. (2022)
	Renewable Energy Sources Usage	Sindhwani et al. (2022); Patil and Kulkarni (n.d.); George et al. (2023)
Technological Potential factors	Adoption of New Advanced Technologies	Wellagiriya et al. (2024); Sindhwani et al. (2022); Donmezer et al. (2024b); Verma (2024); Dai et al. (2024); Huy and Phuc (n.d.)
	Financial Requirements	Slavic et al., (2024); Damaševičius et al., (2024); Sarıoğlu, (2023); George et al.,(2023); Sahoo et al., (2024)
	Tech Policy Creation	Ghobakhloo et al. (2024b); Huy and Phuc (n.d.); George et al. (2023)
	Information Security	Jahromi and Ghazinoory (2024b); Damaševicius et al. (2024); George et al. (2023); Huy and Phuc (n.d.); Verma (2024)

Technological Advancements and Sustainable Practices in the Sri Lankan Apparel Industry

The Sri Lankan apparel industry is still in Industry 4.0 and has leveraged advanced technologies to enhance both efficiency and sustainability. For example, 3D printing is used to test product quality and performance before mass production, which helps reduce waste and production costs. Additionally, big data analytics allows manufacturers to gather and analyze consumer data, improving product design and decision-making. Adopting of the IoT has further strengthened supply chain connectivity, enabling better insights into customer preferences and fostering personalized product development. Cloud computing optimizes product development and manufacturing processes, offering flexibility and enhancing productivity. Increased automation in the industry has also replaced many manual tasks, making operations faster and more cost-effective. Together, these technologies enable Sri Lankan apparel industry to stay competitive globally while fostering innovation and sustainability (Wijethunga et al., 2023b).

Vidanage et al. (2024) State that the Sri Lankan textile and apparel sector sustainability approaches have implemented several key strategies to address environmental and ethical challenges. Resource efficiency is a primary focus, with companies using water recycling systems, energy-efficient machinery, and methods to reduce material waste. The industry has also prioritized sustainable sourcing, utilizing eco-friendly materials such as organic cotton and recycled fibers while ensuring ethical labor practices across the supply chain. Waste reduction initiatives such as improved cutting techniques, demand-driven production, and recycling of unsold inventory are also key strategies. Adopting green technologies, including waterless dyeing, digital printing, and renewable energy sources such as solar and wind, has further advanced sustainability efforts in production processes.

Moreover, the Sri Lankan textile industry emphasizes regulatory compliance to uphold environmental and labor laws, ensuring ethical and eco-friendly practices. The industry engages in consumer education campaigns to raise awareness about responsible consumption, encourage sustainable purchasing habits, and reduce waste. Furthermore, the adoption of circular economy practices, such as second-hand shopping, clothing rentals, and upcycling, helps to extend the lifecycle of products, significantly reducing waste and promoting sustainability within the industry (Vidanage et al., 2024).

Gap Between Industry 4.0 and Industry 5.0 in the Sri Lankan Apparel Industry

According to the previous introduction and results of potential factor identification the Sri Lankan apparel industry is currently positioned within the framework of Industry 4.0, where automation, digitalization, IoT, and data analytics have been key drivers of efficiency, waste reduction, and improved decision-making processes. While these technologies have enhanced production, inventory management, and supply chain visibility, the transition to Industry 5.0 presents significant gaps that must be addressed for the industry to remain competitive and sustainable globally. One critical gap lies in integrating human-centric technologies, that are at the core of Industry 5.0. While Industry 4.0 emphasizes the automation of repetitive tasks, Industry 5.0 calls for deeper collaboration between humans and machines, exemplified by the use of collaborative robots (cobots). In Sri Lanka, the apparel sector has yet to fully adopt these technologies, essential for improving flexibility, productivity, and safety in manufacturing processes. Furthermore, Industry 5.0 introduces cutting-edge technologies such as digital twins, blockchain for real-time supply chain transparency, and AI-driven mass customization. These tools, critical for optimizing production and enhancing customer-centricity, are not yet widely integrated into Sri Lanka’s apparel sector, creating a substantial gap in the industry's readiness for Industry 5.0.

In terms of sustainability, while the Sri Lankan apparel industry has made progress in adopting energy-efficient systems, waste reduction strategies, and renewable energy sources, there remain significant gaps compared to the sustainability goals of Industry 5.0. The current sustainability efforts focus primarily on resource efficiency and waste minimization, such as water recycling and the use of eco-friendly materials. However, Industry 5.0 advocates for a fully circular economy model, where the entire lifecycle of

products is rethought, from design for durability and recyclability to systems of upcycling and take-back schemes. Although traceability systems similar to QR codes are in place to some extent, comprehensive supply chain transparency remains challenging, especially in tracking raw materials and ensuring ethical labor practices. Moreover, advanced sustainability technologies such as AI-driven resource optimization and blockchain to ensure full accountability across the supply chain are underutilized. These gaps specify the need for deeper integration of circular principles and advanced digital technologies to meet the human-centric, resilient, and sustainable demands of Industry 5.0. Addressing these issues will be crucial for the Sri Lankan apparel industry to evolve successfully and maintain its competitive edge in the global market.

Key Potential Factors for the Sri Lankan Apparel Industry's Transition to Industry 5.0

According to the previous gap identification the transition of the Sri Lankan apparel industry from Industry 4.0 to Industry 5.0 requires several key potential factors to ensure competitiveness and sustainability. Central to this transition is integrating advanced technologies such as AI, IoT, and robotics, alongside enhancing human-machine collaboration through technologies such as cobots. These innovations enable smarter, more efficient production while maintaining a human-centric approach. Continuous learning and upskilling are essential for the workforce to adapt to these new technologies, with a focus on both technical expertise and soft skills similar to problem-solving. Additionally, sustainability practices must evolve to align with Industry 5.0 goals, such as adopting circular economy models and optimizing resource efficiency through technologies identical to AI and digital twins. While the industry has progressed in areas similar to automation and digitalization, gaps remain in fully integrating collaborative technologies and achieving end-to-end supply chain visibility.

Government intervention plays a pivotal role in facilitating the transition to Industry 5.0 by creating a supportive ecosystem that integrates human-centric, sustainable, and resilient practices. Governments can drive this shift through financial incentives such as subsidies, low-interest loans, and tax benefits, which encourage industries to invest in advanced technologies and sustainable practices (Slavic et al., 2024; Huy & Phuc, n.d.). Furthermore, robust regulatory frameworks, inspired by initiatives similar to the Paris Agreement, the Sustainable Development Goals, and the Well-Being of Future Generations Act, embed Industry 5.0 values into national policies, emphasizing sustainability, resilience, and societal well-being (Damaševičius et al., 2024).

Furthermore, governments are also instrumental in addressing workforce challenges by funding education and professional training programs that upskill employees and promote lifelong learning, ensuring the workforce is equipped to handle technological advancements (Harish & Nayyar, n.d.). These efforts extend to providing mental health support, encouraging flexible work arrangements, and implementing ethical standards to safeguard employee data privacy and inclusion in a hyperconnected value ecosystem (Sharma, 2023). Collaborative efforts with industry stakeholders, including businesses and academia, enable the identification of skill deficits, foster talent pipelines, and ensure that employees thrive in a digitally transformed industrial environment (Enang et al., 2023; Harish & Nayyar, n.d.). This partnership between governments, industries, and society is critical not only for industrial transformation but also for societal progress, positioning Industry 5.0 as a catalyst for Society 5.0, which aligns industrial development with broader social and environmental goals (Bas et al., 2022; Sarıoğlu, 2023).

In addition, some foreign countries have adopted strategies to transition from Industry 4.0 to 5.0, enhancing value addition in the apparel industry. These approaches integrate advanced technologies, sustainability, and human-centric practices, enabling improvements in customization, resource efficiency, and circular economy adoption.

Conclusion

This systematic literature review examines the transition of the Sri Lankan apparel industry from Industry 4.0 to Industry 5.0, focusing on the industry's readiness to adopt advanced technologies while maintaining a human-centric approach and sustainability. A systematic literature review identified key potential factors affecting

organizational readiness and categorized them into four domains human-centric approach, sustainability, resilience, and technological advancements. The findings emphasize the need for continuous learning, upskilling, and effective human-machine collaboration to achieve Industry 5.0 readiness. Additionally, this points out the importance of sustainability, advocating for a shift toward circular economy models and leveraging advanced technologies including AI and digital twins to optimize resource efficiency. Despite progress made in adopting Industry 4.0 technologies, such as automation and IoT, significant gaps remain in integrating collaborative technologies and ensuring complete supply chain transparency. The research underscores the need for government support in the form of financial incentives and infrastructure development to facilitate the successful transition to Industry 5.0. These insights provide a strategic framework for policymakers and industry leaders to guide the Sri Lankan apparel industry toward a future that balances technological advancement with human-centric and sustainable practices.

This systematic literature review has several limitations that should be acknowledged. Most of the selected studies primarily focused on factors associated with the core values of Industry 5.0, such as sustainability, human-centricity, and resilience. However, aspects such as mass customization, which are related to Industry 5.0, were not addressed in this review as they are considered more applicable within the Sri Lankan apparel industry. Additionally, while the review included studies relevant to potential factors influencing Industry 5.0 readiness, the majority of these were not specific to the apparel industry. There is also a prominent scarcity of studies examining the technological background of the Sri Lankan apparel industry, including the specific technologies and machinery currently in use. This limitation suggests a potential variability in technological readiness factors for this sector. Furthermore, in terms of sustainability, more focus on environmental-friendly practices, whereas the Sri Lankan apparel industry already places considerable emphasis on employee welfare and social responsibility.

Future research should explore the essential need to conduct empirical research to assess the applicability of the identified potential factors within the Sri Lankan context, offering practical insights into their implementation and outcomes. Similarly, evaluating the economic and social sustainability of the Sri Lankan apparel industry is crucial, particularly in understanding how Industry 5.0 technologies could facilitate sustainable growth, enhance labor conditions, and promote social responsibility. A detailed analysis of the readiness potential factors, employing appropriate research methodologies, is necessary to assess the sector's preparedness for the technological and organizational transformations required by Industry 5.0. Furthermore, explores the effective distribution of Industry 5.0 principles across large, medium, and small-scale apparel companies in Sri Lanka, ensuring the entire sector can leverage the benefits of this transformative shift.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Author Contributions

The corresponding author takes primary responsibility for communication with the journal during the manuscript submission. All authors listed on the manuscript must have made significant contributions to the study. An author statement indicating the specific details of the contribution from each author (must be listed using their initials only) for the manuscript based on the relevant CRediT (Contributor Roles Taxonomy) roles should be included: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, review and editing.

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