Sustainable Operations Management Practices in the Textiles, Apparel, and Footwear Industry

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This paper reviews the current body of literature concerning the classification of frameworks, models, strategies, and practices in the textile, apparel, and footwear (TAF) industry. It organizes and unifies frameworks, models, strategies, and practices of sustainable TAF within various domains of operations management: freight transport, warehousing, purchasing and procurement, reverse logistics, product design, production, and packaging. Based on the review and analysis, we present suggestions with the goal of assisting TAF businesses in achieving long-lasting success in their sustainable operational oversight.

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I. INTRODUCTION

The textile, apparel, and footwear (TAF) industry is highly globalized, involving production, supply chains, and trade between multiple countries and regions. This industry comprises clothing and footwear design, creation, and distribution. Meanwhile, this is an innovative and fashion-driven industry. Consumers' needs for fashion and style constantly change, so designers and brands must continually innovate and create new designs and styles to meet market needs. Closely tied with the fashion industry, TAF is a $1.53 trillion industry and is expected to grow to $2 trillion by 2027 (Smith, 2023; United Nations Environment Programme, 2023). Products that are part of this industry include all kinds of clothing, footwear, and items made of cloth. This global industry makes up almost the entire world's population as everyone in society wears clothes. As such, the industry faces environmental and sustainability challenges. Because of the large consumer base of the industry, up to 17 million tonnes of waste is generated, with only 14.7% of the waste being recycled and the rest being put into landfills (US EPA, 2022). It's estimated that one garbage truck of clothes is thrown away every second and 25-70 pounds of textiles are thrown away per person per year in the U.S. and Europe (Ellen MacArthur Foundation, 2017; Whieldon et al., 2023). Along with the waste generation comes water, land, and air pollution generated by manufacturing and making apparel and footwear.

Today, the industry is committed to reducing its environmental impact, with the promotion of sustainable development and green manufacturing a priority. TAF companies have developed strategies to reduce chemical impact and material waste, improve water and energy management, source sustainable raw materials, drive circularity and innovation, promote sustainable brand marketing and communication, and improve employee and supplier well-being (NYU Stern Center for Sustainable Business, n.d.). The fashion industry could create economic opportunities of $560-700 billion by moving to a circular system (Ellen MacArthur Foundation, n.d.; United Nations Environment Programme, 2023).

Yet, only 8.4% of textile and associated retailing companies have publicly committed to avoid exaggerated sustainability claims, about half of fashion industry companies track and disclose at least one aspect of their Scope 3 indirect emissions, and only 49% have integrated environmental, social and governance information into their supply chain management strategy (Whieldon et al., 2023). The TAF industry has been moving much more slowly along its path to a circular economy than the plastics, glass, and metals industries (Östlund et al., 2020). The barriers to pursuing sustainability include but are not limited to high costs, complexity in integration and collaboration, unfavorable rules and regulations, limited access to sustainable materials, and the lack of knowledge, awareness, and technical expertise (Kazancoglu et al., 2020).

To remove barriers, researchers have conducted extensive research on the framework, models, strategies, and practices in achieving sustainability in the TAF industry (Köksal et al., 2017; Shen et al., 2017; Jia et al., 2020; Cai and Choi, 2020). However, to the best of our knowledge, none of the previous literature provided reviews and guidance on how practitioners can incorporate sustainability in different areas of operations management such as freight transport, warehousing, purchasing and procurement. Therefore, this paper aims to (i) provide a review of the existing TAF literature on the categorization of framework, models, strategies, and practices, (ii) categorize and consolidate TAF sustainability cases and examples based on different operations management areas, and (iii) offer suggestions on how TAF companies can achieve sustainable operations management (SOM).

The remainder of this paper is organized as follows. We provide a literature review on the categorization of TAF sustainability in Section 2. In Section 3, we discuss TAF sustainability cases and examples in various operations management areas. Then, we offer suggestions on how TAF companies can achieve SOM in Section 4. Section 5 concludes with a discussion of the limitations of our paper.

II. RELATED LITERATURE

Sustainability in the TAF industry has drawn wide attention among researchers recently. The fashion industry is lagging behind other industries in terms of sustainability practices (Yang et al, 2017; Rafi-Ul-Shan et al., 2018; Hugo et al., 2021). Rafi-Ul-Shan et al. (2018) pointed out that fashion supply chains are mainly aiming for higher margin profits without focusing on the long-term effects. Sustainability issues are a byproduct of the fast fashion because of the fast product-life cycle. The quick trend cycle discourages TAF companies from strategically integrating an organization's social and environmental goals in managing key organizational business processes for improving the long-term economic performance of the individual company. Although many TAF companies have implemented some circular economy initiatives such as consumption reduction, low waste practices, and reducing the amount of chemicals used in the production of clothing, Hugo et al.

(2021) noted the lack of transition to a more green supply chain and government regulation on the manufacturing of clothing and suggested a change on the consumer side in order for slow fashion to set in the industry and reduce the amount of waste being generated from clothes in landfills.

Some studies have reviewed and categorized research on the TAF sustainability. Yang et al. (2017) identified five major sustainability areas of the retail fashion industry: sustainable retailing in disposable/fast/slow fashion, green branding and eco-labeling, retailing of secondhand fashion, reverse logistics in fashion retailing, and emerging retailing opportunities in e-commerce. Thorisdottir and Johannsdottir (2019) reviewed business models of the fashion industry and categorized relevant articles into three themes: the integration of sustainability-related practices within fashion business models, measurement and reporting, and sustainability drivers influencing fashion business models. Their findings suggest that, to promote sustainability, consumers would have to change their purchase behavior in order to create more sustainable practices. Islam et al. (2020) conducted a systematic literature review of 483 articles on environmentally sustainable practices in the TAF industry. Based on the theme analysis, they determined the topics and research directions of sustainable practice and sustainable development in the TAF industry, including product design, fiber processing, yarn and fabric manufacturing, textile dyeing, finishing, apparel washing and dyeing, fabric spreading, cutting, sampling and apparel assembly, printing and embroidery, and trims and accessories manufacturing, finishing, and packaging. The study maps the practices of various manufacturing processes in the TAF industry and develops a conceptual framework to identify sustainable practices for studying the TAF industry from an environmental perspective. Moreover, the study by Luján-Ornelas et al. (2020) delineated seven life cycle stages for textile products, namely fiber production, textile production, design, clothing production, commercialization, use, and end-of-life. The study also categorized the origins of sustainable initiatives and innovations into three levels (textile life cycle stages, initiators, and technological advances). The research underscores the imperative of addressing issues across all stages and engaging various stakeholders while emphasizing the significance of initiatives and innovations in facilitating the textile sector's transition towards sustainable production and consumption patterns in the future. Jia et al. (2020) conducted a systematic literature review of 109 articles on circular economy (CE) in the TAF industry. Based on the thematic analysis, they identified three types of CE adoption drivers (organizational, institutional, and customer drivers), three types of CE adoption barriers (organizational, financial, and policy barriers), four types of CE practices (product design, product stewardship, pollution prevention, and closing the loop), and two key CE performance indicators (ecological and environmental performance). The study highlighted the need for future research on examining the relationship between social sustainability and CE and emphasized the importance of supplier networks for innovations in adopting CE. Jestratijevic et al. (2022) reviewed 478 sustainable packaging solutions that have been advertised by international retail brands in the TAF industry. Based on thematic content clustering applied to iterative data analysis, they analyzed the theoretical and practical evidence for sustainable packaging progress. This analysis revealed three distinct groups of brands, each exhibiting varying degrees of transition from traditional packaging to sustainable packaging. They also identified seven different strategies to enhance sustainable packaging: rethink, refuse, reuse, reduce, recycle, repurpose, and rot. This study

emphasizes the need for future research to focus on replacing traditional packaging materials with more sustainable alternatives and to consider the potential impacts of packaging disposal. It underscores the significance of sustainable packaging initiatives in the TAF industries. Mesjar et al. (2023) studied how the use of technology can improve early designing and manufacturing by digitizing these processes, enhancing customer experience, facilitating second-hand and digital fashion, and helping upcycle clothing with the use of augmented reality. The paper highlighted the lack of empirical studies in the fashion industry, making it hard to measure how innovative technology can be sustainable in the TAF industry.

Researchers have acknowledged and reviewed the important role of operations and supply chain management to achieve sustainability in the TAF industry. For example, Köksal et al. (2017) conducted a literature review on a research sample of 45 papers on supply chain analysis in the TAF industry. They identified the main categories (enablers, drivers, and barriers) to study sustainable supply chain management (SSCM). The study highlights the relationship between social risk management practices and positive outcomes in stimulating the drivers of SSCM. Additionally, it emphasizes the importance of integrating sustainability into the globally fragmented supply chains of the TAF industry. Karaosman et al. (2017) reviewed 38 articles on sustainability integration in the fashion industry. They categorized sustainability practices according to a three-dimensional concurrent engineering (3DCE) framework with three stages: product design, production processes, and supply chain. They concluded that the breakdown of environmental and social sustainability practices in various 3DCE stages needs to be homogenous and strategic priorities need to be taken to advance sustainability in fashion operations. Rotimi et al. (2021) reviewed articles concerning post-consumer textile waste (PCTW) in the fashion industry's supply chain. The study identified four sustainable practices: education and engagement, recovery and redistribution, reuse, and recycling. The research emphasizes the importance of future investigations focusing on end-of-life practices for clothing, extending beyond retailers and consumers to include other agents in the supply chain. Furthermore, the study highlights that retailers play a crucial role in encouraging recycling practices to close the loop in the supply chain. By obtaining an adequate supply of clothing for reuse, recovery, redistribution, and recycling, these practices effectively divert PCTW from ending up in landfills. Cai and Choi (2020) categorized 108 papers on sustainable fashion supply chain management into four areas: sustainable supply chain management, forward activities, reverse activities, and closed loop supply chain/life cycle assessment. Chowdhury et al. (2022) identified 22 sustainable practices in the TAF industry from recent literature and synthesized 14 antecedents in the context of the TAF industry. The study emphasizes how sustainable practices can help practitioners in apparel companies improve sustainability in their supply chain performance. The literature review and analysis on fashion sustainability by Daukantienė (2023) revealed various aspects of fashion sustainability. Specifically, the environmental aspect of sustainability encompasses fibers and materials, design methods and approaches, impact of clothing technologies, washing of textile products, and waste utilization. The study emphasized that sustainability in the fashion industry encompasses three equally significant dimensions (the interplay between the environment, society, and the economy) and underscored the significance of sustainability capabilities throughout the global supply chain and across the entire product life cycle. A summary of the categories of SOM research in

the TAF field is provided in Table 1. However, none of the above studies reviewed or categorized the sustainable practices in the TAF industry based on various functions of operations management. Thus, this paper contributes to the existing literature by narrowing this research gap.

TABLE 1. CATEGORIZATION OF SOM RESEARCH IN THE TAF INDUSTRY.

Articles	Categorization
Köksal et al. (2017)	Social risk management-related drivers, enablers, and barriers of stakeholders and focal firms, respectively
Karaosman et al. (2017)	Three stages of the three-dimensional concurrent engineering framework: product, process, and supply chain
Cai and Choi (2020)	Four specialized areas: sustainable supply chain management (strategic and operational), forward activities (sustainable design, sustainable dyeing, sustainable sourcing, sustainable production, and sustainable retailing and consumption), reverse activities, and closed loop supply chain and life cycle assessment
Rotimi et al. (2021)	Four significant sustainable themes: education and engagement, reuse, recovery and redistribution, and recycling
Chowdhury et al. (2022), Daukantienė (2023)	Three sustainable dimensions: environmental (fibers and materials, design methods and approaches, impact of clothing technologies, washing of textile products, and waste utilization), economic, and social
Sinha et al. (2023)	Eight themes: sustainable fashion supply, circular supply chain management, sustainable business model, sustainability frameworks and models, marketing, consumer behavior, slow and fast fashion, and corporate social responsibility
Harsanto et al. (2023)	Three types of innovation: product innovation (eco-design, life-cycle analysis, ecolabel, material, organic, ethics, and packaging), process innovation (cleaner production, eco-efficiency, waste handling, supply chain management, technology, and enzyme-based textile processing), and organizational innovation

III. ANALYSIS

In this section, we discuss TAF sustainability cases and examples in various operations management areas: (1) freight transport, (2) warehousing, (3) purchasing and procurement, (4) reverse logistics, and (5) other operations management areas. For each operations management area, we provide a brief overview of its business importance, the environmental impacts, and the strategies to achieve sustainability. We search relevant articles and reports between 2018 and 2023 using a combination of keywords, one keyword from each of the following three sets. Set 1:

freight transport, warehousing, purchasing, procurement, reverse logistics, product design, manufacturing/production process, packaging. Set 2: textiles, apparel, footwear, fashion. Set 3: sustainability, sustainable, environmental. These keywords are searched in both Scopus and Google Scholar. Table 2 summarizes the strategies discussed in this section.

TABLE 2. STRATEGIES TO ACHIEVE SUSTAINABLE OPERATIONS MANAGEMENT IN THE TAF INDUSTRY.

OM Areas	Examples of Strategies to Achieve Sustainability
Freight transport	Onshare factories, clean vehicles, and alternative fuel, logistics optimization
Warehousing	Class-based storage policy, adopting more environmentally sustainable policies and automation technology
Purchasing & procurement	Purchase of sustainable materials, adopting ISO 20400
Reverse logistics	Collection programs, route optimization, resell, donation
Product design	Use of personalized products to decrease returns, a circular design, creation of more sustainable or durable materials
Production	Switching to resource-efficient technologies and technical innovations, complying with production-related certifications and standards
Packaging	A closed-loop recycling system for plastic packaging, use of recyclable, reusable, or compostable packaging alternatives, responsible packaging disposal

3.1. Sustainable Freight Transport in the TAF Industry

In the TAF industry, freight transport is responsible for delivering the goods from production plants to the logistics warehouse and from logistics warehouses to the final destination (Rina et al., 2019). Transport personnel determine the timing and quantity of products shipped from logistics warehouses to stores, using sales data, demand forecasts, and inventory reports to prevent overstocking or understocking (Rina et al., 2019). Also, shipping products too early from the logistics warehouse can result in excess inventory in stores, leading to the return of unsold goods for disposal (Rina et al., 2019). Freight helps ensure that products are delivered on time, which is crucial as it helps maintain customer satisfaction and loyalty. In terms of distribution networks, transportation combines multiple modes of transportation, such as sea and air, to provide services based on just-in-time delivery (Ben Abid et al., 2022). Traffic volumes, regularity of shipments, and prioritization of deliveries remain critical for companies to improve responsiveness and ensure service levels for desired customers (Ben Abid et al., 2022). Regarding on-time delivery, demand variability appears to have a more pronounced impact on overall costs and customer satisfaction (Ben Abid et al., 2022).

Freight transport in the TAF industry has a carbon footprint as every mode of transportation of goods produces carbon emissions. Air freight is the most CO2-emitting mode of transport, but road freight is the most widely used. Since the pandemic, demand for freight has only increased due to increased demand for online shopping. Wool from the TAF industry generates the most carbon emissions from manufacturing and shipping. Wool has been found to generate significant carbon emissions during its transport from the farm to the manufacturing company, mainly via transoceanic freight (Wiedemann et al., 2020). Furthermore, the majority of big TAF companies such as Nike, Adidas, and H&M have their factories overseas. They have offshore factories because of the cheap labor cost, so they are able to save money. In order for it to reach around the world, they use freight transportation, including sea freight. The biggest problem with sea freight is oil spills and air pollution. In the last 25 years alone, the U.S. has had 256,024,001 gallons of oil spilled in the ocean (Petroleum Oil Spills Impacting Navigable U.S. Waterways, n.d.). This leads to lasting effects on the ocean ecosystem, which harms marine birds, sea turtles, and mammals and can harm fish and shellfish. Not only the oil spills, but sea freight also leads to air pollution. Moreover, TAF companies generally have low ESG scores. Manufacturing companies in the TAF industry come from raw materials for making textiles such as cotton, silk, and fabrics, and transport vehicles require a lot of energy to maintain the proper temperature and humidity levels necessary to maintain the quality of cotton, silk, and fabrics. They are initially transported by road from the farm to the nearest auction and port location and then transported across the ocean by container ship on the normal trade route from Australia to China; the greasy wool is then transported by road from the port in China to the mill for processing (Wiedemann et al., 2020). Therefore, transport vehicles in this industry are energy-intensive. In addition, roads, rail, port logistics warehouses, and freight infrastructure also negatively impact land use, including habitat loss, fragmentation, and degradation. Manufacturers store new products in one logistics warehouse per supply chain (Rina et al., 2019). This land-use change involves clearing trees and other vegetation, grading land, and constructing logistics buildings and infrastructure.

There are many practices and strategies to mitigate the negative environmental impacts of freight transport in the TAF industry. For example, having onshore factories can cut carbon emissions by 20% (Northcott et al., 2019). Nike's distribution center in Ham, Belgium is close to a network of canals, which allows 99% of inbound containers to be transported by water and eliminates the need for 14,000 truck journeys a year (Forde, 2019). Another strategy is that the industry may switch to liquid natural gas, which includes advantages such as a 95% reduction of sulfur oxides and fine particulate matter, a 90% reduction in nitrogen oxide emissions, and lastly a 25% reduction in carbon emissions (The DeWitt Companies, n.d.). Lastly, using optimization tools such as Transportation Management Systems (TMS), companies can better plan their shipments to reduce empty miles, optimize routes, and consolidate shipments. Efficient trip planning and optimized utilization of payload capacity could transform commercial goods flow in the TAF industry and reduce emissions from production vehicles to 2/3 of current levels (Dhonde & Patel, 2020).

3.2. Sustainable Warehousing in the TAF Industry

Most of the leading mass fast clothing retailers do this by bringing new products into their stores as often as possible, so large quantities of clothes of all sizes, shapes, and colors are produced in the warehouse and as quickly as possible and centralized distribution to make them readily available in sufficient

quantities to serve on store shelves (Corinna Cagliano et al., 2011). Boxes from Italian clothing company Muroglio's suppliers arrive at their distribution center to be unloaded by a designated team of workers and placed on the incoming product floor area, and then sent to the sortation system; After sorting, each box contains items with a uniform combination of items, sizes, and colors, and finally, all types of boxes are loaded onto outgoing trucks for delivery to the designated retail outlets (Sainathuni et al., 2019). Warehousing allows for fast and efficient production and distribution of apparel products. At the same time, this ensures that the latest and sufficient products reach stores on time for sale. Also, for fashion products, it is common practice in the TAF industry for sellers to negotiate with the buyers to specify the arrival window for fashion products to be shipped to the warehouse (Sainathuni et al., 2019). Muroglio's warehouse operations are structured in such a way that supplies from factories and fashionistas are delivered directly or via an intermediate platform located in central Italy to the distribution center; At the distribution center, the supplies are counted, stored, picked, sorted, boxed, and delivered to retail stores (Corinna Cagliano et al., 2011). For the transportation and delivery of fashion products, warehouses serve as the goods handover point for both parties to store and manage goods and provide multiple functions and services such as storage, distribution, handling, handling, packaging, and labeling. Warehousing helps appropriately manage inventory and product sales by tracking products, quantity, and location. The warehouse-keeping stock allows for the flexibility of restocking at the initial observation of sales. (Gallien, 2015). According to Gallien (2015), Zara's inventory is observed at its centralized warehouse in Spain as it is restocked after the initial sale. Warehousing makes the industry easier to know when to reorder products and identify slow or fast-moving ones.

However, the industry is constantly changing and innovating, introducing new fashion trends, design concepts, and technologies. With ever-changing consumer demands and market shifts, fashion companies must continuously adapt their products and services to maintain a competitive advantage. This causes the warehouses holding the products not to be able to assess how much inventory they have to hold or ship to stores. Due to the wide variety of products and the high frequency of shipments, it is a big challenge for TAF companies to efficiently and accurately track all sales, which could lead to excess inventory and a major environmental concern. (Tanaka et al., 2019). In turn, the rate of disposal causes more land to use to create landfills of products that warehouses have to throw out if there is no proper way to dispose of textile products. Landfills can negatively impact the environment as the product simply sits out on the land and causes possible pollution to the nearby soil and water. Besides, warehouses generally consume a high amount of energy and indirectly contribute to emissions from other parts of the supply chain, such as reverse logistics and transportation. According to Lewczuk et al. (2021), energy consumption is an important design and operating factor for most material handling systems (MHS) that operate in industrial or distribution warehouses. Facilities in TAF industry warehouses, including lighting, heating, ventilation, and air conditioning, consume energy. Additionally, logistics equipment, such as shelves, elevators, and trucks, also requires energy. Shelf energy consumption mainly comes from the energy consumed during its manufacturing and transportation processes. Warehouses use water to help produce and manufacture clothing and for other purposes like cleaning and machine maintenance to run. According to The Impact of Textile Production and Waste on the Environment (Infographic) (2022), over 79 billion cubic meters of water were used by the TAF industry. TAF products require water for

manufacturing and processing. Warehouses storing TAF products need to be cleaned and maintained, which requires a lot of water. In addition, warehouses may use groundwater or water from municipal water systems. Water consumption in warehouses can harm local water resources as water supply systems may face shortages or contamination. The high use of water causes the local water sources to become polluted, decreasing the amount of usable water in the world.

Many practices and strategies exist to effectively mitigate the negative environmental impacts of warehousing in the TAF industry. In 2021, the European Union introduced several organizational standards to maintain environmental sustainability. ISO 9001 and 14001 are management policies designed to guide TAF companies on their environmental impact. Companies already familiar with and benefiting from ISO 9001 can utilize its processes and benefits to improve warehouse management (Zimon et al., 2022). ISO 9001 is a quality management system that specifies requirements for companies to comply with, while ISO 14001 provides requirements for an environmental management system. Zimon et al. (2022) demonstrated how ISO 9001 and 14001 can have a positive impact on sustainable supply chain management in the textile and fiber industries in Poland, Slovakia, and the Czech Republic. The completed survey was conducted among 105 organizations engaged in textile or garment manufacturing. The study found that the benefits of certification include improved environmental performance and reduced consumption and costs. By adopting these two new policies, the TAF industry can improve its warehouse sustainability. Another sustainable warehousing project to consider is a Leadership in Energy and Environmental Design (LEED) green building certification program, which can yield substantial economic benefits in water conservation, with a payback period typically within just 3.5 years. (Peng et al., 2020). Brands such as Levi Strauss & Co., Nike, REI, and Skechers have one or more of their distribution or logistics centers LEED certified (U.S. Green Building Council, n.d.). Moreover, automation technology can help warehouses improve efficiency, reduce labor waste and energy consumption, and thereby reduce environmental pollution. Therefore, adopting automation technology is an important way to achieve warehousing sustainability in the TAF industry. The HIVE Grid machine, created by British e-commerce retailer Ocado, is a highly automated design used in warehouses today that can handle more than 3.5 million products, equating to 65,000 orders in a week; the automated robots used make the work more fuel-efficient and reduce waste ("Is Green Warehousing the Only Criticality for Sustainable Businesses?" 2021). Class-based storage policy significantly shortens the travel distance of pickers, thereby reducing the energy consumption of the picking process. (Ene et al., 2016). It efficiently manages inventory, reduces inventory loss and waste, and thereby reduces resource consumption and environmental impact. For example, storing similar products in the same area can make it easier for employees to quickly find and pick them up, reducing handling time and energy consumption. Therefore, adopting a category-based storage strategy is an important way for the industry to achieve warehousing sustainability and reduce energy consumption.

3.3. Sustainable Purchasing and Procurement in the TAF Industry

In the TAF industry, sourcing is one of the most important functions that affect supply chain sustainability because it not only impacts supply chain output but also alters the structure of the entire supply chain (Niu et al., 2017). Purchasing decisions not only affect the raw material output but can also change the structure and operations of the entire supply chain. Procurement departments can choose environmentally friendly materials, factories,

and equipment and establish long-term cooperation with suppliers to ensure the sustainable development of the entire supply chain. By selecting products and services that meet environmental protection requirements, procurement departments can incorporate sustainability considerations into corporate business decisions to improve corporate social responsibility and economic efficiency. Therefore, both Wal-Mart and Kate Spade & Co. choose to purchase materials themselves instead of using agents to better control inventory and avoid resource waste (Niu et al., 2017). On the one hand, purchasing plays a crucial role in quality control and in ensuring that materials meet the required standards. The purchasing department is responsible for coordinating with suppliers and ensuring that purchased materials, and products meet the specified quality standards. Failure to do so can lead to product quality issues. For example, correct TAF such as surgical gowns and drapes are essential in hospital settings as they prevent the spread of bacteria and other pathogens, thereby protecting patients and hospital staff from contamination and infection (Nowack et al., 2012). The European Committee for Standardization (CEN) standard 13795 1-3 defines the specifications for such operating room textiles, and these textiles must meet specific hygienic requirements. This standard enables the comparison of different systems, such as disposable and reusable textiles (Nowack et al., 2012). Therefore, procurement is responsible for ensuring that the purchased materials and suppliers undergo strict quality control and validation processes, to guarantee that the purchased materials meet the required standards and that the products are of consistent quality and safety. On the other hand, effective purchasing and procurement planning help companies reduce procurement costs and inventory costs, thus lowering total logistics costs. A global sourcing strategy allows companies to purchase from a broader base of suppliers, leading to reduced procurement costs. Long-term relationships with suppliers can also optimize inventory levels, resulting in lower inventory costs. The TAF industry, which has complex supply chains, often employs global sourcing to reduce costs and improve profits. Low wages in developing countries are a major reason why companies in this industry seek global sources of affordable materials (Ghasemy Yaghin & Darvishi, 2020). Global clothing brands such as Gap (USA), H&M (Sweden), and Uniqlo (Japan) have successfully implemented a global sourcing strategy without relying on domestic production (Ghasemy Yaghin & Darvishi, 2020).

Products provided by TAF companies have significant environmental impacts throughout their life cycle, including during raw material procurement (Oelze, 2017). Cotton is a continuously procured and widely used raw material in the industry, but its cultivation and production often involve the use of large amounts of chemical pesticides and fertilizers. Additionally, the TAF industry extensively uses synthetic, toxic, and chemical materials, and cotton is one of the most chemically intensive crops, consuming 24 percent of the world's insecticides and 11 percent of pesticides (Hiller Connell & Kozar, 2012). During its cultivation, a large number of pesticides and herbicides are used, causing chemical pollution to the environment. Purchasing materials increases carbon emissions in transportation. One of the procurement processes involves resource allocation for targeted procurement. Fabric suppliers deliver the raw materials required for procurement to multiple distribution centers within the planning period to meet the needs of customers, and different transportation options in the transportation system have different carbon dioxide emissions (Yaghin & Sarlak, 2022). The fuel and energy used in the production and transportation of materials release carbon dioxide and other greenhouse gases. As the quantity of materials and transportation distance increases, the emission of carbon dioxide also increases. Therefore,

carbon emissions are generated throughout the entire life cycle of materials in the procurement process, from suppliers to final consumers. To encourage retailers to purchase, clothing manufacturers often offer buy-back contracts to retailers to incentivize them to purchase their products, which means that manufacturers will buy back unsold clothing from retailers; such practice can lead to a significant amount of waste during production (Niu et al., 2017). While buyback contracts are a business strategy that allows manufacturers to take risks and sell their products, they also have negative environmental impacts. Manufacturers may overproduce to meet potential demand, leading to waste of resources such as raw materials and energy, as well as creating large amounts of unsold inventory that may end up being disposed of or burned, further exacerbating environmental concerns.

Using sustainable materials can help reduce environmental pollution. For example, one sustainable option is purchasing organic cotton. Organic cotton is produced using certified organic or untreated seeds and farming methods that avoid synthetic chemical inputs (Han, 2018). This means that organic cotton is grown without the use of chemical fertilizers, pesticides, and herbicides, which reduces the emissions of harmful chemicals in the production process. Several TAF companies, including H&M, Inditex, Carrefour, and Nike, already purchase organic cotton. On average, these companies use 29.6% organic cotton in their total cotton consumption (Han, 2018). In TAF, supply chain management for a circular economy can reduce water, energy, and chemical use in manufacturing and reconfigure supply chains for pollution prevention (Majumdar et al., 2022). This includes suppliers, manufacturers, and transporters to ensure the sustainability of the product throughout its life cycle. This integration includes not only departments within the organization but also a collaboration with external organizations to maximize the use of materials and commodities. By establishing a circular chain, including collection, sorting, separation, and recycling, the impact on the environment and the waste of resources can be minimized (Majumdar et al., 2022). Furthermore, when TAF brands establish distribution channels and collect post-consumer TAF waste, awareness of the circular economy increases among consumers and other stakeholders, encouraging their participation and collaboration. Thus, in addition to circularity, economic sustainability is also enhanced, leading to overall business sustainability. Therefore, adopting ISO 20400 can assist in environmental sustainability. It is an international standard for sustainable sourcing that can be implemented across various industries, including textiles, clothing, and footwear. ISO 20400 aims to aid organizations in establishing and implementing sustainable procurement policies and practices, which include ensuring ethical behavior by suppliers, purchasing sustainable products and services, and making procurement decisions that contribute to addressing social, economic, and environmental issues (“ISO 20400 Guides Sustainable Purchasing”, 2017). The standard also involves assessing supply chains to understand each supplier's environmental and social impact, including energy efficiency, chemical usage, and waste disposal, in order to reduce pollution and waste. This information can be used to determine sustainable procurement priorities and targets. The case study by the Czech Republic Masaryk University (2018) shows an example of ISO 20400 adoption, where the university aimed to provide more sustainable solutions for producing sweatshirts from natural materials by purchasing green products, such as organic cotton. ISO 20400 provided direction to ensure the production process and material sourcing are sustainable and ethical.

3.4. Reverse Logistics in the TAF Industry

The increasing consumption of TAF in the world is becoming an increasingly serious environmental problem. An example of this can be seen in the United States, where textiles make up to 4.5% of the overall amount of garbage found in landfills (Subramanian et al., 2020). Reverse logistics and recycling can help reduce these negative impacts of the industry on the environment. For example, by recycling old clothes and shoes, the amount of TAF waste that ends up in landfills and incinerators can be reduced, further reducing environmental pollution. Then, reverse logistics and recycling are essential components of corporate social responsibility for the fashion industry. This industry generates a vast amount of waste during the manufacturing process, and implementing such practices can help companies deal with waste effectively, reduce negative impacts on society, and enhance their social image. H&M is an example of a company that implemented sustainable practices. In 2013, H&M started a program in their stores to collect used clothes. The following year, they released their first batch of products made from 20% recycled materials. By 2015, they had collected 19,000 tons of clothing. These efforts resulted in H&M being chosen to design and provide uniforms for Sweden's Olympic and Paralympic athletes in 2016 (Muthu, 2016). By implementing reverse logistics and recycling practices, H&M demonstrated its commitment to environmental sustainability and corporate social responsibility. In terms of Economics, reverse logistics and recycling are also important to the economics of a business. For example, recycling old clothes can provide recycled materials to make new products, which can help reduce costs and increase profits. As recycled TAF fiber is increasingly used as raw material for new products, retailers, and manufacturers are also customers of the reverse apparel supply chain (Sandberg et al., 2018). In addition, reverse logistics and recycling can also help companies better manage Inventory, reduce inventory costs, and improve the economic benefits of enterprises.

One of the products with the highest rate of returns from online and retail stores is clothes. Whatever reason the consumer has to return the clothes, a large majority of what gets returned does not get resold by the retailer. As the increase in online shopping goes on, consumers' expectations for returning merchandise are set by companies like Amazon, which gives free returns on items. One solution to the problem of resource shortages and wasted clothing in landfills is textile recycling (Sandvik & Stubbs, 2019). When the clothing items are returned domestically, there is a lower chance of the items ending up in a landfill. Furthermore, the rate at which clothing is being bought and returned is higher than in years before online shopping became a big component of the consumer's shopping habits. The lifecycle of clothing trends has overall decreased with the increased trend of online shopping, which allows consumers to change styles quickly in several weeks, which causes the supply chain to slow down as it can't keep up with the rate of demand consumers have. Only in the United States, synthetic fibers burned in 2012 generated 1.1 million metric tons of CO2e, while textiles discarded in landfills resulted in a net of 8.5 million metric tons of CO2e emissions. (Muthu, 2016). The negative impact of the industry on the environment can be mitigated through the implementation of reverse logistics and recycling practices. Recycling old clothes and shoes, for instance, can significantly reduce the amount of TAF waste that ends up in landfills or incinerators, consequently reducing CO2 emissions and minimizing environmental pollution. Reverse logistics and recycling can help businesses better manage raw materials, finished goods, and inventory. For example, recycling old clothes can provide recycled materials to make new products, reducing the need to produce new raw materials. This helps reduce energy and raw material consumption,

further reducing the burden on the environment. TAF recycling can be combined with pulp mills to use green liquor as a pretreatment agent in the TAF recycling process. When industrial green liquor was used for pretreatment in a pulp mill, the textile recycling process had a success rate of approximately 70% (Sanchis-Sebastiá et al., 2021).

The industry can donate TAF to organizations that can give clothing to the impoverished when clothing or footwear is no longer wanted by a consumer. With volunteers and employees, the donations are sorted through and put on racks of clothes for people who need them in the local area of the organization. The TAF gets a chance to be reused by new owners of the TAF and items that would have been in a landfill get to be used by a person in need of them. In making more sustainable practices in the TAF industries finding more ways to efficiently make logistics flow. To make returns and exchanges more efficient, supply chains need to figure out how to optimize routing to reduce reverse logistics disposal rates. A study in a Pakistan manufacturing TAF company showed that the corporate social responsibility of the manufacturing country ties into the effectiveness of the course for reverse logistics (Javed et al., 2021). Due to the increase in product return flow, companies will need to create new practices to deal with the more significant amount of returned items. One way companies can reduce the amount of clothing sent back to manufacturers is to let lightly used clothes be resold in a second-hand section of their stores like Patagonia worn to wear. Importantly, recycling is one of the steps that is used in a circular economy with centers that can recycle TAF specifically. A study found that some companies use recycled material to make new clothes, such as H&M using recycled cotton, wool, and cashmere, and The Insecta Shoes Brand uses used clothing and fabric to make vegan shoes (Filho et al., 2019). H&M's Garment Collecting program, the world's biggest of its kind, offers customers a discount for in-store dropoff of unwanted clothing worldwide, with 55% reused as a product, 15% reused as material, 22% recycled, and 8% landfilled or incinerated in 2022 (H&M, 2023).

3.5. Other Sustainable Operations Management Areas in the TAF Industry

According to the European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE), product design is a critical process to determine TAF products' functionality, quality, popularity, lead time, durability, repairability, and recyclability (ETC/WMGE, 2022). Product design also profoundly influences product variety, supplier selection, and lead time, all of which are important aspects within a highly competitive industry such as TAF. The design need for low costs, high product variety, and shorter delivery time has many negative environmental impacts. TAF companies utilize artificial fibers such as polyester, nylon, and acrylic, which require centuries to break down naturally; and the washing of synthetic fabrics like polyester contributes to 35% of the total microplastics found in the ocean (Maiti, 2023). High product variety and constant changes in fashion trends lead to huge waste or obsolete stock. Many strategies can be adopted during the design stage to reduce environmental impacts. Adidas and similar retailers are exploring the use of personalized products to decrease returns, enhance customer contentment, and lower inventory levels (Masunaga, 2019). Another strategy is to choose a circular design, which has the potential for extended product life spans due to higher quality, reduced material consumption via improved material utilization, hazardous substances elimination, minimized toxic emissions and the release of microplastics, enhanced reusability and repairability, and increased opportunities for repurposing and recycling (ETC/WMGE, 2022).

The manufacturing processes play a crucial role in meeting the demands of TAF

companies. The production processes in the textile value chain include fiber production (raw material production, material processing & sorting, fiber preparation), yarn and fabric production (yarn preparation/spinning, weaving/knitting/bonding), and textile production (bleaching/dyeing and finishing, assembly (United Nations Environment Programme, 2023). The pretreatment process, coloration process, and special finishing process all add value to textile manufacturing (Uddin, 2019). According to the European Environment Agency's European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE), the global supply chain responsible for manufacturing the clothing, textiles, and footwear consumed within the EU-27 in 2020 employed nearly 13 million full-time equivalent workers, making TAF the third largest sector globally, trailing only food and housing sectors (ETC/WMGE, 2022). The environmental consequences during the production stage encompass issues such as land, energy, and water usage, utilization of fertilizers and pesticides, increased energy consumption, and the use of chemical feedstock (ETC/WMGE, 2021). In 2020, producing TAF products consumed in the EU required 4,000 million m^3 of blue water, 20,000 million m^3 of green water, and 180,000 km^2 of land, resulting in 121 million tonnes of carbon dioxide equivalent (CO2e) greenhouse gas emissions in total (ETC/WMGE, 2022). A study on Swedish clothing showed that the production steps account for 80% of its life cycle climate impact as a result of fossil fuel-based energy consumption (Sandin et al., 2019). Thus, to reduce the environmental impacts during the production stage, TAF companies need to switch to resource-efficient technologies and technical innovations such as clean energy, closed industrial systems, and process/technology optimization (Östlund et al., 2020). Certifications and standards such as Global Organic Textile Standard (GOTS), ECO PASSPORT by OEKO-TEX, Worldwide Responsible Apparel Production (WRAP), and Zero Discharge of Hazardous Chemicals (ZDHC) provide TAF companies with some of the best-recognized practices in sustainable production.

Packaging serves a vital role in safeguarding apparel and shoes, shielding them from potential harm, stains, and theft. Beyond protection, packaging facilitates the seamless containment and transportation of these products in a standard unit of loading. Moreover, packaging acts as a canvas for projecting a unique and appealing product identity, significantly enhancing its allure for the discerning TAF consumers. In 2022, approximately 21% of global fashion retail sales constitute e-commerce transactions (Statista Research Department, 2023), which underscores the extensive utilization of shipping mailers or boxes with a considerable portion ending up being discarded instead of being reused. The fashion industry's utilization of packaging contributes to a staggering 26% of the total global plastic production, and even more notably, it constitutes a significant 40% proportion of the world's plastic waste (Waldeck, 2023). TAF companies are taking action to address packaging issues. UK and European clothing retailers such as Superdry, George at Asda, Very.co.uk, and s.Oliver, have partnered with Mainetti to implement a closed-loop recycling system for plastic packaging (Mainetti, 2022). Toad & Co. is collaborating with LimeLoop to collect their reusable package of durable vinyl upcycled from billboards (Wiesendanger, 2022). Companies should build the capacity to return store packaging to the distribution centers for reuse and/or proper waste disposal, use recycled materials for packaging, convert to recyclable, reusable, or compostable packaging alternatives, and foster a culture of responsible disposal for both packaging and associated waste streams (NYU Stern Center for Sustainable Business, n.d.). For example, there are textiles made entirely from paper, recycled denim, fabrics redesigned to

minimize waste, and innovative technologies for waterless printing (United Nations Environment Programme, 2020).

IV. RECOMMENDATIONS AND CONCLUSIONS

This paper conducts an analysis of the current body of literature concerning the classification of frameworks, models, strategies, and practices in the TAF industry. We contribute to the existing literature by reviewing and categorizing the sustainable practices in the TAF industry based on various functions of operations management. To help industry practitioners to identify best operational practices, we organize and unify real-world instances of sustainable TAF within various domains of operations management.

While steps are being made to improve sustainability practices in the TAF industry, there is room for improvement to keep sustainable practices in place and to prioritize sustainability in this industry. Based on our analysis and summary, we put forth some recommendations aimed at guiding TAF enterprises in attaining enduring excellence in their sustainable operational management.

First, as highlighted in several studies that we reviewed, TAF companies should keep explore and adopt new technologies (Luján-Ornelas et al., 2020; Mesjar et al., 2023; Daukantienė, 2023; Harsanto et al., 2023). Technologies such as circular textile technology and 3D printing technology, to convert recycled textiles into new products, not limited to any TAF. For example, recycled polyester fibers are turned into garbage bags, shopping bags, raincoats, and recycled textiles are used to make furniture and car interior products. This can reduce waste and environmental pollution. Recycling textiles avoids these problems while also turning recycled textiles into valuable products. A large number of textiles are discarded every year, taking up landfills and dumps and causing severe environmental impacts, but the use of recycled textiles is currently limited to making new clothes and grocery bags. The use of recycled textiles could be extended to creating items made from recycled materials, so developing new applications, recycled textiles can be reused more and further reduce the consumption of natural resources.

Second, sustainable product design is a common strategy to achieve sustainability (Cai and Choi, 2020; Daukantienė, 2023) but it can be costly. A low-hanging fruit for TAF companies is to consider product identification during the product design and packaging stage. The TAF industry can use product identification to allow consumers to understand the product's ingredients and environmental impact and then choose more environmentally friendly products. Using packaging to promote product identification for sustainability means that consumers are provided with more product information related to sustainability and choices from the perspective of consumers so that they can make more informed purchasing decisions. As more and more consumers are paying attention to the importance of environmental protection, consistent green product identification for sustainability can boost consumer demand for environmentally friendly products and further drive the production and manufacturing industry toward a more environmentally friendly direction.

Third, TAF should make efforts to reduce returning items in order to minimize waste and other environmental impacts, which has not been extensively studied in the literature. Virtual dressing rooms, which are not new to the TAF industry, can help reduce product returns but retailers still need to decide the best technology to make the best use of the virtual dressing rooms. For example, AR is great for accessories such as hats, scarves, and gloves while AI-driven dressing rooms are better for apparel (Dietmar, 2021). Manufacturers should consider enhancing their product information by offering comprehensive

size and fit guides for each item by diversifying their model pool to include individuals with varying body types and sizes. TAF companies must also assume greater responsibility for educating consumers about the consequences of excessive product returns. Online stores can change a free return policy to a paid return policy so that consumers are more careful to purchase clothing in the future as returns will not be so hassle-free anymore.

In closing, we acknowledge the following limitations of our work. First, the frameworks, models, strategies, and practices mentioned in the TAF industry are not comprehensive or exhaustive. With the advent of new sustainability threats and technological innovation, more sophisticated strategies and practices can be invented. Second, the TAF industry is an interconnected sector with a long and complex supply chain. Many strategies can't be successful without the involvement of other supply chain members, which is not discussed in-depth in this paper. Third, almost every aspect of supply chain and operations management can have significant environmental impacts, far beyond the seven areas we presented in this paper. Studies on sustainable practices in other operations management areas can be a viable direction for future research.

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