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Managing Deadstock in the Fashion and Apparel Industry: An Exploration of Causes, Solutions and Technological Interventions †

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Abstract: The fashion and apparel (FA) industry faces a critical challenge in the form of deadstock. There are various causes for deadstock, and some may be traced to supply chain and inventory management inefficiency. This research paper aims to understand the issue of deadstock, its root causes, its implications for business and strategies to mitigate it. This paper also aims to investigate the potential of adopting artificial intelligence (AI), machine learning (ML) and data analytics to reduce the issue of deadstock. This research paper uses a systematic bibliographic literature review of the relevant literature in this subject area. In conclusion, this research paper aims to comprehensively study deadstock in the FA industry. It highlights the potential of using AI, ML and data analytics in supply chain management (SCM) to increase efficiency and mitigate the deadstock issue. There is, however, a lack of sufficient research papers that focus on deadstock in the FA industry and strategies and technological interventions to overcome it. Therefore, this research paper aims to serve as an overview that can be beneficial for researchers, business stakeholders and process engineers in the FA industry to create deployable technology-based solutions to address the problem of deadstock.

Keywords: deadstock; fashion and apparel industry; supply chain management

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1. Introduction

The fashion and apparel (FA) industry is one of the biggest economic contributors, contributing 38% to the economy of the Asia–Pacific, 26% to that of Europe and 22% to that of North America [1]. The volume of unused inventory in this industry is estimated at a value of USD 120 billion [2]. Over the past decade, the apparel industry has experienced enormous growth both domestically and internationally. But deadstock still continues to be one of the biggest problems in this industry. "Deadstock" refers to unsold clothing items that sit in warehouses with no sales for a predetermined period of time and impede business expansion. It interferes with a company's cash flow, consumes warehouse space, and stagnates profits that might otherwise be used to buy goods that generate income. Deadstock can be found as finished goods produced by the apparel industry or as raw materials. Dead inventory is frequently the result of bad purchasing choices. If distributors do not set up controls during the purchasing process, they may have trouble avoiding dead inventory supplies. By classifying deadstock and relocating stock using data analytics, deadstock can be controlled [3].

Bypassing conventional retail channels and forging direct ties with customers, D2C brands are serving as game-changers. They can obtain profound insights into customer preferences, which improves demand forecasting and inventory control. D2C brands produce things based on actual demand to reduce the danger of deadstock and optimise their operations [4].

Due to issues like overproduction and product returns, the FA sector also acts as one of the biggest contributors to garbage on the planet. To reduce waste creation and improve management, the industry must use sustainable production methods. Utilising state-of-the-art AI tools to build a sustainable digital supply chain is one strategy to achieve this. The FA sector has acknowledged the use of AI during numerous phases, including the designing of clothing, making of patterns, forecasting of sales, production, and SCM. Every instance in which a new garment is designed, made and sold, there is the generation of new data, proving how dynamic the FA industry is. As a result, the adoption of new AI approaches in the industry is necessary to gain a competitive edge and boost company profitability. A comprehensive overview of the many AI strategies utilised in research to tackle diverse business problems in the FA supply chain is crucial for accomplishing this [1].

The objectives of this study are threefold: first, to obtain an understanding of deadstock and its implications for business and operations; second, to find proposed solutions to mitigate the problem of deadstock, focusing on the FA industry; and third, to understand technological interventions such as AI, ML and data analytics to reduce deadstock as well as improve operations in the supply chain. To this end, this study aims to conduct a comprehensive literature review focusing on the three objectives mentioned above. The purpose of this review article is to provide an overview of the issue of deadstock in the FA industry and strategies and technology-based solutions to mitigate this problem. This article also tries to place emphasis on the less explored utilisation of AI and ML in the FA industry and can benefit business stakeholders, process engineers and researchers involved in this industry by acquiring an understanding of the subject area and finding scope for future work.

2. Review of Existing Literature

A systematic review of the literature was performed and the articles were filtered based on inclusion/exclusion criteria (see Figure 1).

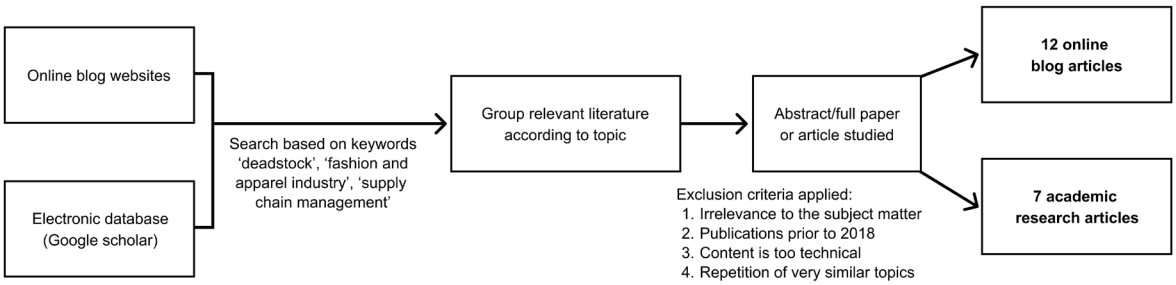


Figure 1. Flowchart of inclusion/exclusion criteria for selecting articles (author-made).

2.1. Deadstock in the Fashion and Apparel Industry

Unsold goods or supplies that the original producers never used are referred to as deadstock. These goods can include everything from completed garments to fabric remnants. Generally, deadstock clothing is any excess inventory that companies and retailers were unable to sell, whereas leftover fabric that is not suitable for its intended use is known as deadstock fabric. These could include fabrics from orders that were cancelled, fabrics that were miscut or dyed, slightly damaged textiles, or even cutting waste that was left over from the manufacturing of clothing [5].

Causes of deadstock in the FA sector include inaccuracies in the dyeing or printing process, excessive brand ordering, textile mill overproduction, and materials rejected for not meeting quality criteria [6]. Deadstock accumulates in retail settings as a result of consumer returns, soiled or damaged merchandise, faulty size runs or one-offs, outdated merchandise, unsuccessful designs, and even social justice campaigns [7].

Approximately fifteen percent of each textile production run is wasted. This implies that USD 120 billion worth of wasted textiles are disposed of, burned, or just left in

warehouses unutilized each year [8]. Fast fashion adds to textile pollution by needing less yardage and offering financial incentives for large orders, which increases waste. Fast fashion is driven by rapid market development and accelerated sampling [2]. Adding to this problem is the unfortunate short shelf life of certain deadstock textiles in warehouses. Products kept in warehouses are susceptible to mildew, mould, and insects. Cotton and other natural fibres are especially vulnerable, and keeping lace and elastic in unsuitable environments for an extended period of time might affect the product's longevity and quality [9].

Deadstock can cost retail businesses in terms of capital investment that could be put to profitable use, storage costs that could be used to warehouse better-selling products, the depreciation and obsolescence of seasonal or trend-based products, the risk of damage to or the expiry of unsold products, opportunity costs, negative impacts on cash flow and impacts on business analytics, making it difficult to make business decisions [10].

There is a common practice amongst fashion retailers where they burn unsold goods, resulting in harmful environmental consequences. Burberry, Louis Vuitton, Nike, Zara, Gap and H&M group have been exposed recently for their improper disposal of deadstock. Companies burn their deadstock due to various reasons. Luxury brands incinerate their unsold inventory to prevent them from being sold at discounted prices and retain the exclusivity and scarcity of the products. Fast fashion retailers burn their products due to overproduction. Excessive purchasing by consumers has also led to fashion retailers producing more, leading to a significant amount of waste. Certain countries even give tax write-offs to fashion firms for getting rid of unsold products. This incentivizes the incineration of unsold goods in a negative way [11].

For retailers and brands that are interested in disposing of their unsold inventory and returns, second-hand markets have become a limited channel since worn clothing also gets sent there that has low value. There are technological and operational limitations when it comes to recycling garments since they are often made of different blends of fibres, materials and other components. This affects their recyclability and acts as a barrier [12]. A flowchart to represent the flow of worn garments is shown in Figure 2.

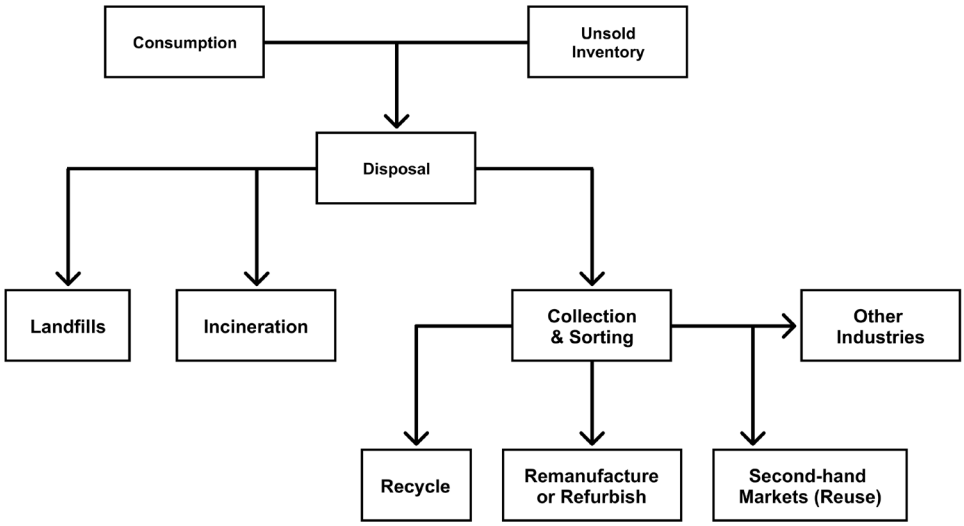


Figure 2. Flow of worn garments [12].

A throwaway culture has emerged as a result of the fast fashion industry's mass production and excessive consumption, where clothes are seen as transient objects that are swiftly discarded and replaced with the newest styles. Pre-consumer waste, or apparel that was overproduced and never even reached the consumer, accounts for 10 to 20 percent of textile waste [5]. Disposing of deadstock is a major source of fabric waste, and burning it contributes to the increase in carbon footprints and greenhouse gases released in the environment, which aggravates global warming [9,13].

2.2. Current Strategies Used to Deal with Deadstock

Deadstock materials are taking centre stage in the sustainability discourse as the sector looks for methods to apply circular solutions and decrease waste. The industry is welcoming deadstock with open arms, from designers creating their collections using other brands' leftover materials to sourcing platforms making it easier to obtain fabrics. There are now many sites accessible for sourcing deadstock worldwide. Queen of Raw is the most well-known platform as of right now. The portal functions similarly to eBay in that businesses can upload their extra fabrics rather than holding onto their inventory. Queen of Raw is leveraging technology not only to make sourcing easier but also to prevent the overproduction or overordering of materials by keeping track of how many textiles are published on the site by each brand or mill each season. They can then get in touch with the business directly if they detect something strange [6]. Using deadstock fabric can have some advantages as well as limitations, which are shown in Table 1.

Table 1. Advantages and limitations of using deadstock fabric [9].

Advantages	Limitations
• Make unique styles of clothes that truly stand out. • Carbon footprint is reduced and a significant amount of waste is saved. • Small designers benefit from a reduced price tag, a smaller order quantity and faster availability.	• Ethical concerns regarding source of production. • Quality issues in fabric rejected during production.

In the fashion industry, discarded cloth from manufacturers and mills is a sustainable resource. For a longer period of time, more textiles can be kept out of landfill by being rescued, marketed, and incorporated into new designs. However, it appears that the sector is now undervaluing deadstock [8]. Some fashion businesses dispose of their deadstock by giving it to charities, selling it in bulk to non-competing markets, selling it through discounts and outlets, or destroying it in some other way [14].

There are some strategies D2C fashion brands can use to avoid deadstock, like data-driven demand forecasting, limited-edition and small-batch releases, pre-order and crowd-funding and, agile production and inventory management [4]. Inventory management problems in the apparel industry can be solved by strategies such as using inventory management software, IoT and RFID smart tags to smartly manage inventory, using logistics modelling and warehouse layout planning to streamline and optimise processes, using AI-powered style demand forecasts derived from data patterns and trends, and enhancing inventory management for clothing through the utilisation of cutting-edge technologies [15].

2.3. Technological Interventions to Mitigate the Problem of Deadstock

Figure 3 shows a data analytics model for managing deadstock in the apparel industry. The design brief specifies that the system receives data from the distributor's inventory management system. The data are then pre-processed to prepare them for analysis. A decision tree classifier is created utilising the training data after data preparation to categorise clothing as suggested or not. A prediction engine uses the classifier, based on the suggestions, to identify popular clothing items among customers as well as deadstock that needs to be swiftly sold. The last step is to generate pairs of deadstock and best-selling clothing using a gain optimisation algorithm.

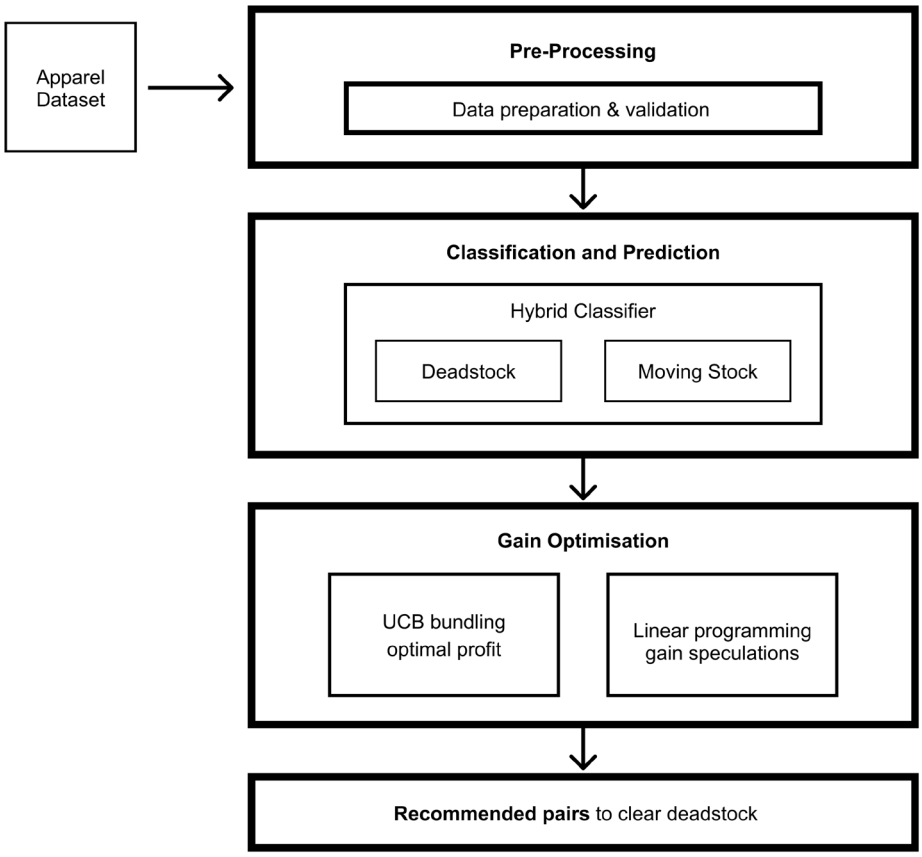


Figure 3. Framework to manage deadstock using data analytics model [3].

The management of deadstock is more impacted by the data analytics model. Clothes with the potential to become deadstock can be cleared by using customer purchasing patterns to inform decisions about how to move them. Finding the best possible bundle proposal benefits from analytics over profit optimisation. By effectively managing deadstock, this can increase the turnover of all small-scale, medium-scale and large-scale clothing industries. In the future, this work can be improved by using more best-practice algorithms for efficient deadstock management across various industries [3].

There are several ways by which AI can be applied in the FA supply chain. Machine Learning (ML) has been used for demand forecasting, colour prediction, sales prediction, fabric defect identification, trend analysis and mechanical property-based predictions of fabric behaviour. A Decision Support System (DSS) can be used to industrialise a variety of jobs by streamlining the supply chain's decision-making process. Expert systems are used in the manufacturing and production of clothing to choose the right procedures and machinery so as to produce the least environmental contamination. Optimisation using genetic algorithms (GAs) is widely used to solve scheduling and design layout issues with the production of garments. Image recognition and vision are used to automate numerous industrial applications, including process control and inspection, and are also popular for use in augmented reality, virtual try-ons and content-based image retrieval systems [1].

There are two main aspects from which AI can address problems in SCM, based on the analysis of the current implementation of AI in SCM. Firstly, using advanced automatic infrastructure AI can improve the decision-making process with supply chains and help in SCM both internally and between supply chain members. Secondly, AI can optimise business processes by facilitating in monitoring goods and operations in real-time, in analysing collected data to generate actionable insights and in taking actions to improve business and efficiency based on the valuable insights that are obtained [16]. However,

relevant data availability, knowledge of the AI field and the SC's capability to adopt AI are three broad factors that must be considered for successful AI adoption in SCM [17].

There are also several applications of ML that can be seen in SCM. Supplier selection can be carried out using a combined decision tree (DT) and Potential Vector Machine (P-SVM) technique (e P-SVM-DT), and using Reinforcement Learning. Supplier segregation can be performed using Multi-Criteria Decision Making–Machine Learning (MCDM-ML) to evaluate and segment suppliers. Chain risks can be managed using Multi-Criteria Decision Analysis (MCDA) and Mathematical Modelling and Optimisation. Demand or sales estimation can be performed using a fuzzy forecasting system since it works well under scenarios like the strong seasonality of sales, volatile demand and a wide range of items with a short life cycle or a lack of historical background data. Inventory management can be performed using ML tools that can find hidden inventory patterns from warehouse datasets and help in decreasing and saving costs. Transportation and distribution can be performed using ML algorithms that can generate better delivery routes by exploring the pattern of transportation, vehicles, infrastructure and consumer vehicles. Production carried out using ML tools can help to improve the accuracy of production planning and factory scheduling and reduce supply chain latency for components and parts. Sustainable development can be achieved using ML as it provides better production planning, and because of its high potential for tackling uncertainty, it can help conserve industries. Circular economy (CE) can be established by applying ML techniques to design circular materials, components and products, to operate circular business models and to optimise circular infrastructure [18].

3. Discussion, Implications and Future Scope

The FA industry is certainly of economic significance as it significantly contributes to the economies of the Asia–Pacific regions, Europe and North America. But this industry is troubled by the problem of deadstock. The value of deadstock in the FA industry is estimated at a whopping USD 120 billion. Deadstock occurs mostly due to errors during production, overproduction, excessive ordering or unsuccessful designs. This constitutes about fifteen percent of every textile production run. Deadstock causes retail businesses to suffer financially and hinders their growth. Now in the FA industry, some luxury brands burn their deadstock to maintain the value and scarcity of their luxury products. This practice again is incentivised in countries that give tax write-offs to companies for getting rid of their unsold inventory. Such a practice is not only unsustainable but also significantly contributes to environmental pollution. For those companies looking to get rid of their unsold inventory and returns, second-hand markets have become a limited channel. The availability of low-value worn garments acts as a barrier. Furthermore, since garments are a mix of various raw materials, their recyclability is affected and this becomes a barrier to their recycling. There are various strategies businesses can use to get rid of deadstock or turn deadstock into sales. There are companies like Queen of Raw that are trying to create a marketplace for deadstock fabric and prevent it from being disposed of. However, strategies that can help avoid deadstock should be prioritised since this will help bring down waste and financial loss. To avoid deadstock, some D2C fashion brands are already using strategies such as data-driven demand forecasting, limited-edition and small-batch releases, pre-order and crowdfunding, and agile production and inventory management. The framework for managing deadstock using data analytics models can help in increasing the turnover of small-scale, medium-scale and large-scale clothing industries. This framework analyses the purchasing patterns of customers and differentiates the deadstock from the moving stock. This helps in the early detection of deadstock, which can be bundled with high-selling products to improve sales. When it comes to the application of AI in the FA supply chain, ML, DSS, expert systems, optimisation and image recognition and vision are used. But the implementation of AI can also help address problems in SCM in general, from two main aspects—advanced automatic infrastructure and optimised business processes. For AI to be successfully adopted into SCM, the availability of relevant

data, knowledge of the AI field and the capability of SCs to adopt AI are three broad factors that must be considered. In SCM, ML methods can be used for supplier selection, supplier segregation, managing chain risks, demand/sales estimation, inventory management, transportation and distribution, production, sustainable development and circular economy. There are three main advantages of using ML over traditional methods in SCM. First, ML methods can handle non-linear problems in supply chains. Second, ML methods are specifically developed to handle big and unstructured data. Third, ML methods have been proven to be stronger in recognising and predicting the most effective factors in supply chain performance. However, there are two main criticisms faced when using ML methods in SCM. Firstly, the unavailability of historical data in cases of big revolutionary changes can reduce the effectiveness and efficiency of AI methods. Secondly, there can be instances when the validity and fairness of ML techniques can be doubted due to the duplication of problems that were meant to be solved by calculating optimal models. Hence, ML methods can be considered to be used in SCM for the advantages they provide, but at the same time, the criticisms of using such methods need to be equally considered and addressed if possible.

This research paper aims to provide a foundational overview of the problem of deadstock in the FA industry, its causes and strategies to address this problem. It also explores the use of data analytics to manage deadstock in the clothing industry, use of AI to improve SCM in the FA industry, and the application and implementation of AI and ML in SCM in general. An overview of strategies to mitigate deadstock in the FA industry is shown in Figure 4. Since this study discusses the mentioned technological interventions in a non-technical manner, it can help business stakeholders and process engineers in the FA industry to understand how such interventions can help them mitigate the problem of deadstock by improving their SCM. This will greatly help them to reduce losses, grow their businesses and also reduce environmental pollution. This study can also help researchers interested in this subject area to obtain an overview of the current knowledge base of the available research. Since much of the work associated with the implementation of technology-based solutions in SCM is technical in nature and lacks the consideration of nuances involved in the FA industry, there is a need for collaborative research work between researchers with a technical background and those with a background in the FA supply chain and business. This would help create deployable technology-based solutions that can benefit not only large-scale fashion brands and manufacturers but also small- and medium-scale businesses in the FA sector that may not have an in-house research and development team. Since most of the technology-based research deals with the supply chain side of things, there is scope for future work on the use of AI, ML and data analytics in assisting apparel designers to create designs based on the latest trends and customer demand. This would help in reducing the number of unsuccessful apparel designs and help improve sales, thereby helping in reducing deadstock.

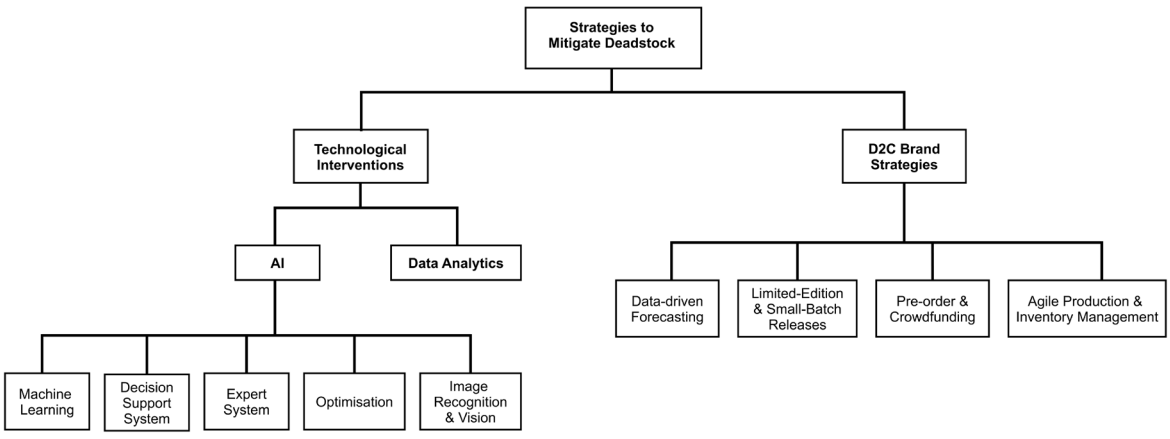


Figure 4. Overview of strategies to mitigate deadstock in the FA industry (author-made).

4. Conclusions

Deadstock continues to be one of the biggest problems faced by the FA industry. It affects retail businesses financially and can hinder them from growing. The disposal of deadstock also harms the environment as it mostly gets destroyed by incineration. The causes of deadstock are rooted in sales or supply chain issues. Supply chain issues are mostly linked with problems in production and inventory management. D2C brands use strategies like data-driven demand forecasting, limited-edition and small-batch releases, pre-order and crowdfunding, and agile production and inventory management to avoid deadstock. There are various strategies to get rid of existing deadstock or turn deadstock into sales, but it is equally necessary to reduce the generation of deadstock during the production phase and help bring down the fifteen percent textile waste that is produced. This can be achieved through the use of a data analytics framework and AI application in SCM, such as ML, DSS, expert systems, optimisation and image recognition and vision, in order to manage and reduce the issue of deadstock. When it comes to SCM, there are clear advantages of using ML methods in SCM instead of traditional methods for more efficient functioning and to reduce the generation of deadstock. There is a need for collaborative work to be conducted by researchers with a background in big data science and technology, and the FA industry, respectively, as this would help in creating deployable technology-based solutions that can be implemented in real-life scenarios. In conclusion, this study aims to spread awareness and evoke interest among researchers, brands and labels, process engineers and business stakeholders in the FA industry to conduct research and find more effective solutions to tackle the problem of deadstock through a collaborative effort.

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