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A systematic review of mathematical programming models and solution approaches for the textile supply chain

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ABSTRACT

The textile industry is a complex and dynamic system where structured decision-making processes are essential for efficient supply chain management. In this context, mathematical programming models offer a powerful tool for modeling and optimizing the textile supply chain. This systematic review explores the application of mathematical programming models, including linear programming, nonlinear programming, stochastic programming, robust optimization, fuzzy programming, and multi-objective programming, in optimizing the textile supply chain. The review categorizes and analyzes 163 studies across the textile manufacturing stages, from fiber production to integrated supply chains. Key results reveal the utility of these models in solving a wide range of decision-making problems, such as blending fibers, production planning, scheduling orders, cutting patterns, transportation optimization, network design, and supplier selection, considering the challenges found in the textile sector. Analyzing those models, we point out that sustainability considerations, such as environmental and social aspects, remain underexplored and present significant opportunities for future research. In addition, this study emphasizes the importance of incorporating multi-objective approaches and addressing uncertainties in decision-making to advance sustainable and efficient textile supply chain management.

1. Introduction

The demand for textile products is expected to triple by 2050, driven by increasing consumption across fashion, healthcare, military, automotive, aerospace, and sports sectors (Li, Wang, & Ding, 2021; Shirvanimoghaddam et al., 2020). The textile industry uses a wide range of raw materials, including natural and synthetic fibers and blends. Global fiber production reached an all-time high of 124 million tons in 2023 (Textile Exchange, 2024). The textile supply chain is crucial to the global economy, with China, the EU, and India being the largest sellers (Lu, 2022). Millions are employed in the industry across emerging countries like Turkey, Brazil, Vietnam, Iran, and Pakistan (Galatti & Baruque-Ramos, 2022; Tseng et al., 2022).

Low labor costs and favorable South and Southeast Asian policies have driven the latest apparel manufacturing relocation (Lin et al., 2024). Many small, under-capitalized firms rely on low-skill labor, resulting in fragmented supply chains prioritizing employment over efficiency. A lack of investment in advanced technologies has slowed modernization, preventing these supply chains from effectively addressing challenges like reducing lead times and managing capacity (Cooper, 2010). Furthermore, rising demand for fast fashion – driven by low-cost production, frequent purchases, and short product life cycles – has made supply chains more complex (Camargo et al., 2020; Wen et al., 2019).

In addition, the textile supply chain is also one of the most polluting, leaving tons of waste in the environment, with estimates indicating that 45% of textile products, from fibers to clothing, are wasted (del Mar Barbero-Barrera et al., 2016; Li, Wang, & Ding, 2021; Xu et al., 2024; Zhu et al., 2022). These environmental impacts complicate the planning process, especially in light of high demand volatility, which became particularly evident following the COVID-19 pandemic (Abbate et al., 2023; Li et al., 2024). To promote sustainability, textile and apparel industries are increasingly adopting decarbonization practices, shifting towards circular business models, and investing in advanced technologies to improve production and distribution efficiency (Chen

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Table 1
Search strings.

Fiber production	Yarn manufacturing	Fabric manufacturing	Apparel manufacturing	Textile supply chain
"cotton production" OR "wool production" OR "silk production" OR "textile fibers" OR "synthetic fibers"	"spinning industry" OR "yarn production" OR "yarn manufacturing"	"knitting" OR "weaving" OR "dyeing" OR "fabric production"	"confection" OR "apparel"	"textile supply chain" OR "textile manufacturing" OR "textile production"
AND				
"mathematical programming" OR "linear programming" OR "nonlinear programming" OR "optimization" OR "mixed integer programming" OR "integer programming"				

et al., 2024; Xu et al., 2024).

Managing the complex textile supply chain requires significant effort to develop effective management plans. Mathematical programming models can be a valuable tool for decision-making, allowing managers to improve differing performance measures: (costs Zhou et al., 2020, profits Tsai, 2018), operational (machine utilization Zhang et al., 2017, assembly line balance Zhang & Chen, 2019, production quantity Pimentel et al., 2011), environmental (carbon emissions Moreno-Camacho et al., 2020, and water consumption Jafari et al., 2017).

Previous reviews have conducted analyses of using mathematical programming in the textile sector. In a conference paper, Toledo et al. (2022) provided a brief overview of optimization models used in the textile industry based on twelve papers. Wen et al. (2019) reviewed operational research models for the fashion retail supply chain, including simulation and game theory. Lorente-Leyva et al. (2024) proposed a conceptual framework to support the sustainable and smart planning of textile supply chains in uncertain contexts. However, neither work offers an extensive or comprehensive classification of mathematical programming models across all stages of textile manufacturing, from fiber production to the integrated supply chain. This paper addresses the identified literature gaps by systematically reviewing mathematical programming models applied to all stages of textile production. Such analysis yields a two-folded benefit. On the one hand, by classifying existing research based on the textile processes, this review provides a valuable resource for developing new models by referencing similar works that align with specific characteristics. On the other hand, this review highlights underexplored research areas, offering clear directions for future investigations to promote integration, sustainability, and efficiency in the textile industry.

We contribute to the state of the art by reviewing 163 papers within this scope published in journals, conferences, and books up to October 2024. This study focuses on studies that apply mathematical programming models, including linear, nonlinear, stochastic, robust, fuzzy logic, and multi-objective programming, to textile supply chain decisions. The review demonstrates how mathematical models can support decision-making processes in the sector. We identified several optimization strategies to address problems in production planning, transportation planning, network design, order allocation, product quality, sustainability, and social responsibility. Furthermore, by identifying future research gaps, we highlight areas where mathematical programming can be applied to address pressing problems in this critical industrial and economic sector.

This paper is organized as follows. In Section 2, we present the methodology and structure used in this review. In Section 3, we show the analyzed textile manufacturing models. In Section 4, we analyze the integrated textile supply chain models. In Section 5, we conclude this review by summarizing the principal findings and pointing out opportunities for future research.

2. Methodology

We conducted a systematic literature review of analytical works that apply mathematical programming models to support decision-making in textile manufacturing based on the systematic literature review methodology for operations management proposed in Thomé et al. (2016), explained as follows.

2.1. Search process

Regarding the searching and selection criteria, we searched for papers in the following databases: Elsevier SCOPUS, Google Scholar, IEEE, Informs, Oxford, Science Direct, Springer, Taylor & Francis Online, and Web of Science. The searches were performed from June 2022 to October 2024 without limitation on publication year and for only texts in English as the search criteria. The search strings are exhibited in Table 1.

We combined keywords for each stage of the textile manufacturing process with terms related to mathematical programming or optimization models. Qualitative or simulation models were excluded, and the word "models" was not used as a search term. We applied three exclusion criteria to refine the textile scope: (i) studies without optimization models (e.g., qualitative approaches, frameworks, simulations); (ii) studies not directly related to the textile industry (e.g., optimization models for other industries without textile applications); (iii) studies on specific textile topics without optimization problems (e.g., cloth structure geometry, pattern design tools). Fig. 1 illustrates the literature review search process. Following the initial database search, duplicate entries were removed. The abstracts of the remaining articles were screened to assess their relevance to the scope of this review, narrowing the selection to 210 papers for full-text reading. Based on the exclusion criteria mentioned, the final review included 163 papers.

Fig. 2 shows the numerical distribution of reviewed articles over the years. We can see that most publications were made from 2010 to 2024. Moreover, 58% of the papers were published in the last ten years, showing the recent increase in the relevance of the theme. Fig. 3 shows the leading journals for the reviewed papers. The European Journal of Operational Research has the highest number of publications, with ten articles, followed by Computers and Industrial Engineering, with eight articles. Other prominent journals focus on industrial engineering, operations research, management science, mathematical modeling, computing, and textile manufacturing. This distribution underscores the interdisciplinary nature of research in the textile supply chain. Table 2 highlights leading authors in textile industry studies, their countries, affiliations, and publication counts. Contributions are globally distributed across textile engineering, industrial engineering, and mathematics institutions.

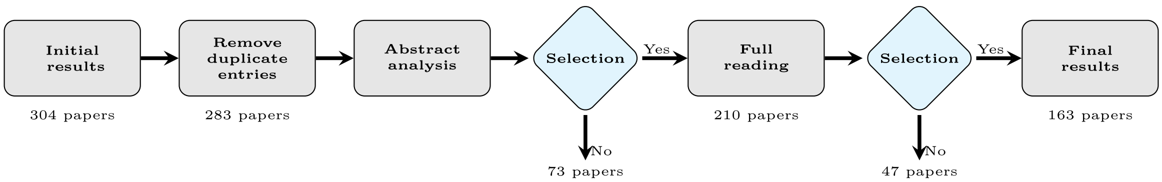


Fig. 1. Literature review search process.

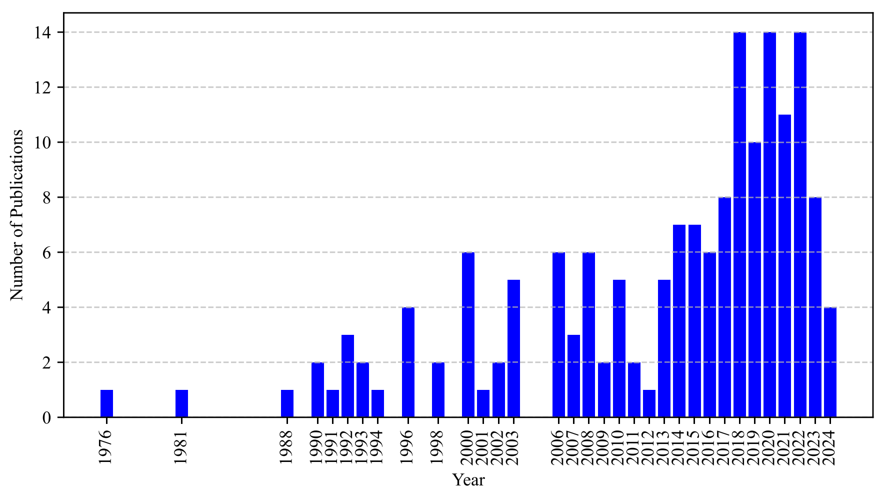


Fig. 2. Number of publications during the years.

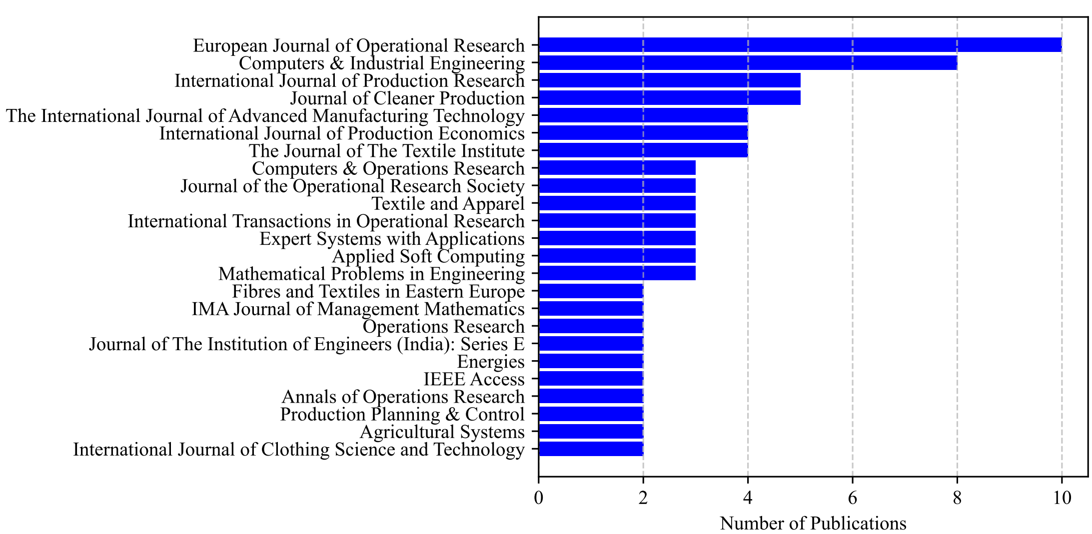


Fig. 3. Leading journals for the reviewed papers.

Table 2
Authors associated with textile industry studies, including country, affiliation, and publication count.

Author	Country	Affiliation	Publications
Reza Ghasemi Yaghin	Iran	Clothing Engineering and Management Group, Department of Textile Engineering, Amirkabir University of Technology	9
Yunus Demir	Turkey	Department of Industrial Engineering, Bursa Technical University	5
Houssem Felfel	Tunisia	National Engineering School of Sfax (ENIS), University of Sfax	4
Omar Ayadi	Tunisia	National Engineering School of Sfax (ENIS), University of Sfax	4
Faouzi Masmoudi	Tunisia	National Engineering School of Sfax (ENIS), University of Sfax	4
Paolo Serafini	Italy	Department of Mathematics and Computer Science, University of Udine	3
Suleyman Karabuk	United States	School of Industrial Engineering, University of Oklahoma	3
Emanuela Guerriero	Italy	Dipartimento di Ingegneria dell'Innovazione, Università degli Studi di Lecce Via per Monteroni	3
Fateme Darvishi	Iran	Clothing Engineering and Management Group, Department of Textile Engineering, Amirkabir University of Technology	3
Eric Papain Mezatio	France	Institut français du textile et de l'habillement	3
Lionel Amodeo	France	University of Technology of Troyes	3
Gianpaolo Ghiani	Italy	Dipartimento di Ingegneria dell'Innovazione, Università degli Studi di Lecce Via per Monteroni	3
A Gürsoy	Turkey	Ege University, Department of Mathematics	3

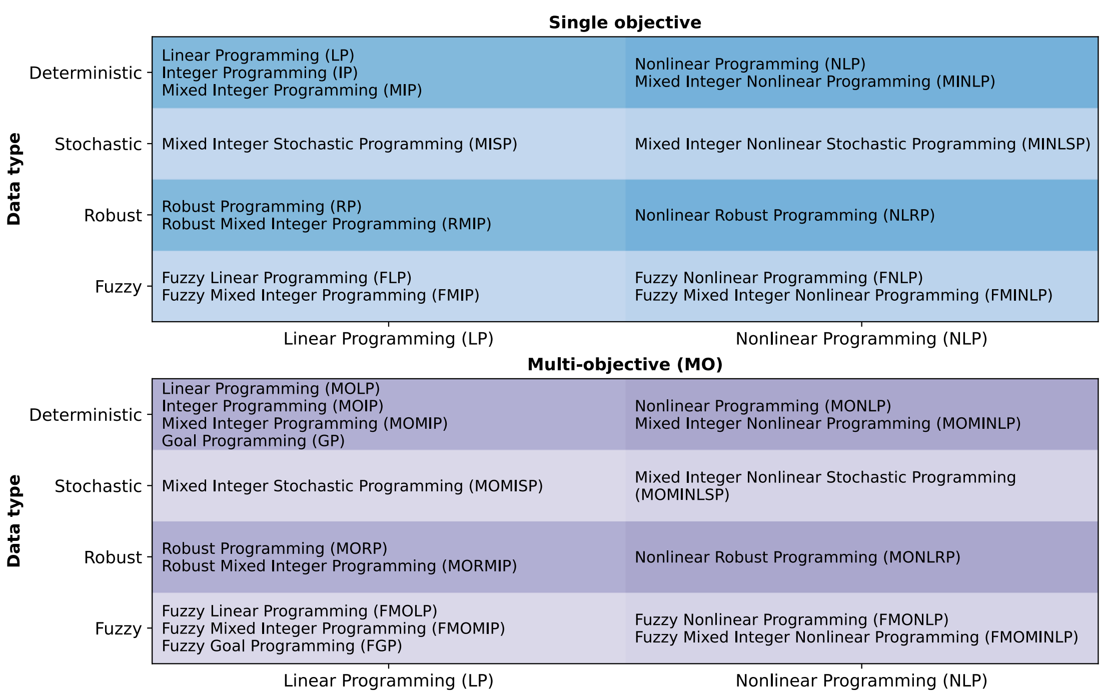


Fig. 4. Optimization approaches present in the papers.

2.2. Data analysis, synthesis, and interpretation

At each stage of textile production, the contents of the papers were summarized in tables showing the types of problems addressed, the presence or absence of multiple items, multiple machines, multiple periods, the type of objective function, and uncertainty in parameters. Furthermore, we highlighted the significant characteristics used in models and the solution methods. According to Fig. 4, we categorize optimization models by objective function type (single or multi-objective) and data type (deterministic, stochastic, robust, or fuzzy). The acronyms provide a standardized reference for the models discussed.

2.3. Structure of the literature review

Textile manufacturing consists of many processes, from obtaining and processing the raw materials to the final goods. Fig. 5 presents a general production process of the textile supply chain. The main steps of yarn manufacturing are cleaning and fiber preparation, blending, combing, carding, roving, and spinning. In the first stage, fibers are cleaned and blended. The textile production system uses various raw materials, including cotton, wool, silk, flax, and synthetic fibers, which can be blended. This process removes impurities, mixes different types of fibers, and feeds the combing machines, where the materials are aligned. Next, slivers are combed onto carding to strengthen and reduce

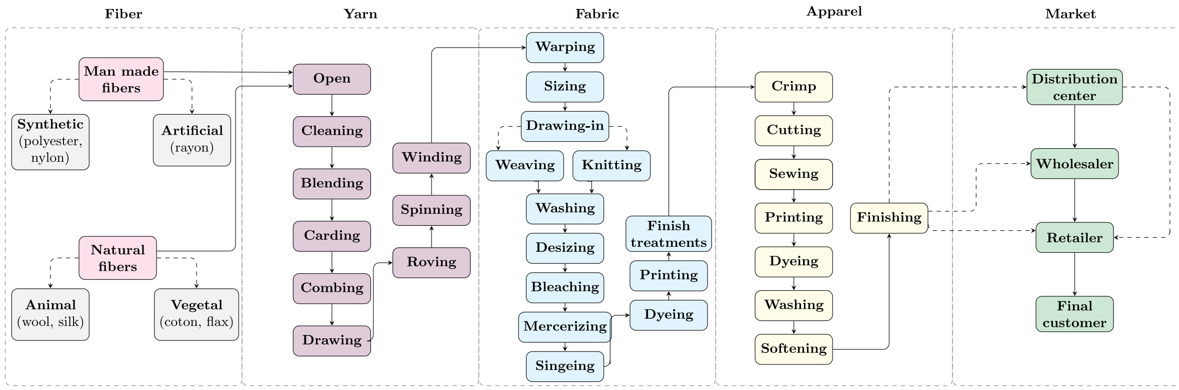


Fig. 5. Production process of the textile industries.

thickness. The roving process twists and strengthens the yarn, preparing it for spinning. When the desired characteristics are obtained, the yarns are wound in bobbins during the spinning process. These processes require a machine configuration for each blending type.

After spinning, the yarns pass on to weaving or knitting processes. Weaving is the stage at which the yarns are interwoven into flat fabric. The yarns form intertwining loops in the knitting stage, resulting in knitted fabrics. The difference between a flat and knitted fabric is how the yarns are woven together. Finally, the fabrics go through finishing operations such as dyeing, printing, chemical, and mechanical finishing to give them the desired colors and shape. The fabrics are then sent to the finishing department, where further operations, such as cutting and sewing, are carried out to produce garments, home textiles, automotive textiles, and technical textiles.

According to Eruguz et al. (2012, 2016), in a multi-echelon supply chain, each production or distribution stage represents a processing function of an item. Each production or distribution stage is an echelon with the potential to hold safety stock. In this representation, the arcs linking two echelons denote the supplier-customer relationship. In this sense, Fig. 5 can be seen as a multi-echelon supply chain, where the stages are fiber production, yarn production, fabric production, and apparel manufacturing. Based on Wen et al. (2019), we analyzed the existing problems in each stage of the textile supply chain.

Therefore, we have structured the systematic review into two primary sections. In Section 3, we focus on the problems encountered within a single textile and apparel industry echelon, encompassing the entire process from fiber production to apparel manufacturing. Next, in Section 4, we analyze the outcomes concerning an integrated multi-echelon supply chain, investigating strategic, tactical, and operational decision-making problems.

3. Mathematical programming and optimization for textile and apparel manufacturing

Production planning studies in the textile industry have faced significant challenges. However, many existing problem formulations only consider some of the constraints of the textile industry, given the complex environment in which these problems are embedded (Rabbani et al., 2016). For instance, to achieve the desired colors and characteristics for textile products, a sequencing of production orders is required to allocate resources better, use full production capacities, and simultaneously reduce cleaning times for different colors. These decisions involve identifying the time and nature of each machine configuration and production demands while considering operational costs, such as setup, transportation costs, and inventory costs (e.g., Camargo et al., 2014; Karabuk, 2008; Zhou et al., 2020). Moreover, efficient production planning becomes more challenging when environmental issues such as water consumption, carbon emissions, and energy savings are considered. Govindan et al. (e.g., 2015), Zhang and Chen (e.g., 2019).

3.1. Fiber production

Textile manufacturing begins with obtaining raw materials. Generally, natural fibers can be obtained from vegetables (e.g., cotton and flax) or animals (e.g., wool and silk). Man-made fibers can be semi-synthetic, like rayon made from natural sources of regenerated cellulose, or synthetics, such as polyamide, polyester, and acrylic. Desired attributes in textile goods, such as softness, good appearance, and thickness, are obtained from quality fibers (Lord, 2003). In this topic, we discussed problems related to cotton production. No papers were found associated with the other raw materials.

3.1.1. Cotton production

Cotton is the most common natural fiber in the textile supply chain (Esteve-Turrillas & de la Guardia, 2017). Producing high-quality cotton fibers begins with growing and harvesting cotton (Kelly et al., 2015). However, only a few papers consider cotton production. For instance, Hong et al. (2019), Salassi et al. (2013) and Wineman and Crawford (2017) all highlight the importance of crop rotation to achieve better yields in cotton production. Crop rotation is the regular succession of production of different crops on the same land, generating agronomic and economic benefits. Duffy et al. (1994) studied initial allocations for cotton planting. The objective function was the maximization of discounted before-tax net returns, and the computational results proved a pattern of increasing marginal returns for the initial cotton-base donors.

Furthermore, Khalili-Damghani et al. (2015) addressed another critical factor in cotton production: energy consumption. The authors proposed a method based on linear programming to evaluate the relative efficiency of homogeneous decision-making units (fertilizer, pesticide, and seed) to produce cotton and maximize input efficiency.

3.2. Yarn, fabric and apparel manufacturing

In this review, we have categorized the analyzed papers into the following problem groups: (i) blending problems (3.2.1); (ii) resourcing planning problems (3.2.2); (iii) lot-sizing problems (3.2.3); (iv) scheduling problems (3.2.4); (v) batch-processing machines scheduling problems (3.2.5); (vi) integrated lot-sizing and scheduling problems (3.2.6); (vii) cutting problems (3.2.7); (viii) cutting schedule problems (3.2.8); (ix) assembly line balancing problems (3.2.9); (x) product quality problems (3.2.10); and (xi) distribution problems (3.2.11).

Fig. 6 presents the distribution of reviewed papers across the fiber, yarn, fabric, and apparel manufacturing stages. The fabric stage dominates, with scheduling and lot-sizing and scheduling being the most studied topics. The apparel stage also receives significant attention, particularly in scheduling and batch-processing machine scheduling problems. In comparison, research on the fiber stage is limited, focusing

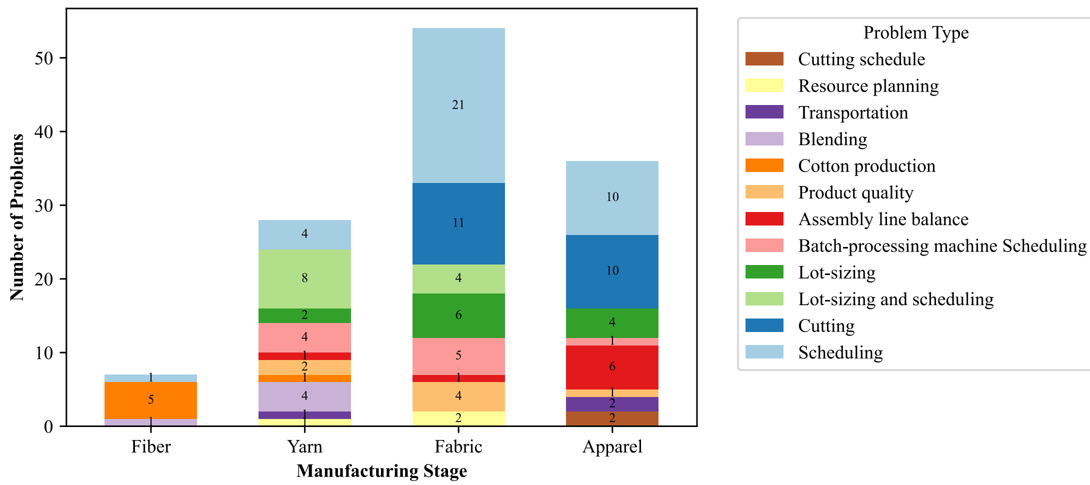


Fig. 6. Problem types by textile manufacturing stage.

mainly on cotton production. It also provides insights into the specific problem types explored within each stage, emphasizing key problems in textile manufacturing.

3.2.1. *Blending problems*

Blending different raw materials is crucial in determining clothing softness, comfort, thickness, and strength. High-quality yarns are obtained by mixing different types of fibers. Ballestero (2006), Bhattacharyya et al. (2008), Biadgligne et al. (2020) and Mogahzy (1992) have addressed cotton-blending problems and determined the right mix required for manufacturing at the minimum cost. Zhang et al. (2014) formulated a nonlinear model to determine a suitable blending ratio of cotton yarns.

3.2.2. *Resource planning problems*

Wong et al. (2001) analyzed a strategic production planning to optimize the use of capital-intensive equipment in the apparel industry. A two-level model was applied to determine the number of spreading and cutting machines to minimize the payback time. Rabbani et al. (2016) presented a MIP model for technology and capacity planning in textile manufacturing that considered water consumption, workforce constraints, and setup times to maximize profits. The model decides the amounts of each type of available technology and capacity planning allocated for each product at each period to maximize profits. Regarding energy consumption, Kousar et al. (2022) presented eight models to determine energy source allocation in a multi-stage textile facility.

3.2.3. *Lot-sizing problems*

The lot-sizing problem (LSP) consists of determining the amount to be manufactured for each product to meet customer demands while respecting resource constraints. Bhatnagar (1981) discussed the implementation of LP to determine the optimal product mix, showing the challenges and the advantages of using the LP formulation for textile manufacturing. Also, Gunasekaran et al. (1993) dealt with economic LSP in a multi-stage, multi-facility, and multi-product, production–inventory textile system, considering setup and in-process inventory carrying costs.

Motivated by financial planning decisions for a mixed make-to-order/make-to-stock environment when demand exhibits predictable fluctuations, an MIP model for LSP is proposed in Elmehanny et al. (2018) for the apparel industry. The model must decide the production amount in regular time and overtime, the inventory levels, and the fabric dimensions kept in stock over a season. Furthermore, an LP model was presented by Ghosh et al. (2020) to solve an LSP considering manufacturing lead times.

Research dealing with single objective functions can sometimes ignore some critical aspects of the textile industry. Malik et al. (2022) addressed LSP for a small apparel industry, considering eight different objectives simultaneously. The authors analyzed reducing machine and operation times, maximizing demand fulfillment, and efficiently using raw materials. The proposed model determined the number of products to be manufactured, achieving a pre-determined profit while reducing costs and machine times and meeting production requirements.

To address the labor shortage and environmental issues, Tsai and Jhong (2019) proposed a model combining workforce planning, carbon emission reductions, energy recycling, and waste reuse. Similarly, Tsai (2018) addressed a lot-sizing problem while improving environmental sustainability. Tayyab et al. (2020) looked at production planning in a multi-stage system considering effluent treatment and carbon emission costs. Also, Wu and Chang (2003a, 2003b) proposed NLP models for determining textile dyeing amounts respecting waste minimization alternatives, environmental regulations, and the limitations of production resources.

3.2.4. *Scheduling problems*

Scheduling involves determining the job sequence and allocating necessary resources. An example of resource allocation can be found in Sumathy and Amirthalingam (2021), which tackles workforce scheduling in the textile industry. Mainly, scheduling in the textile processes is crucial to maintaining the desired features of the products, using materials and resources efficiently (Srinath et al., 2022; Zhou et al., 2020).

Jobs can be seen as items that should be manufactured, like yarns, fabrics, or clothing. Each job has attributes like color, weight, fibers, processing times, and other characteristics that determine the product family. Typically, items from the same family can be processed in the same production batch. However, setup times and costs can significantly impact the allocation of resources required to switch from one family to another.

Setup times and costs can be categorized as sequence-dependent or sequence-independent. A setup is sequence-dependent if it depends on the current and previous jobs processed. A setup is sequence-independent if it depends only on the current job, regardless of the prior one (Allahverdi, 2016). Mathematical programming models considering setup times and/or costs are applied in Berthier et al. (2022), Demir and Inan (2022), El Hachemi et al. (2018), Eroglu and Ozmutlu (2014), Frendewey and Sumichrast (1988), Guinet (1991), Guo et al. (2006), Hsu et al. (2009), Li, Wang, et al. (2021), Maldonado et al.

(2000), Morales et al. (1996), Mourtos et al. (2021), Qiu et al. (2002), Serafini and Speranza (1992), Srinath et al. (2022), Sumihartati et al. (2011), Wong et al. (2000), Zhang et al. (2017) and Zhou et al. (2020).

Performance measures are important for evaluating scheduling production. Common performance measures include makespan, total processing time, tardiness, and earliness. The completion time (C_j) of job j is the instant at which its processing is completed. Makespan deals with the total processing time required to complete all jobs. MIP models and metaheuristics for minimizing makespan in textiles are in Berthier et al. (2022), Huang and Yu (2013), Jungwattanakit et al. (2008) and Wong et al. (2000). Croft et al. (2021) proposed models to minimize makespan while also considering water consumption. Unlike most studies, Wang et al. (2022) treated makespan as a constraint rather than an objective in an energy consumption-focused scheduling problem. The authors investigated energy-efficient scheduling on unrelated parallel machines with position-based deterioration in the textile industry.

Tardiness occurs when a job is completed after its due date (d_j). The number of tardy jobs represents late completed jobs. Tardiness (T_j) is the difference between the completion time of tardy jobs and their due dates ($T_j = \max C_j - d_j, 0$). Early completed jobs may incur inventory-carrying costs. Earliness (E_j) is the difference between the early completion due dates ($E_j = d_j - C_j$). To minimize tardiness and earliness, Tomastik et al. (1996) used an IP model and Lagrangian relaxation in a circular, automated material handling system. MIP models and genetic algorithms (GA) have been applied in Celikbilek et al. (2016), Hsu et al. (2009), Jungwattanakit et al. (2008) and Min and Cheng (2006) to minimize costs related to earliness and tardiness. Huang and Yu (2013) analyzed a cutting and sewing flow shop to minimize the sum of weighted earliness, tardiness, and makespan. Azadeh et al. (2010) investigated three textile sub-processes (dyeing, printing, and finishing operations) to minimize makespan and total tardiness. Sánchez-Herrera et al. (2019) suggested a MIP model and greedy search procedure to minimize maximum tardiness, emphasizing human resource importance.

Sometimes, job splitting is required to process sub-jobs on separate machines to meet due dates. Eroglu and Ozmutlu (2014) focused on scheduling jobs with splitting and sequence-dependent setup times across nonidentical and unrelated parallel machines to minimize makespan in weaving. Job splitting and preemption are have also studied in previous works by Serafini (1996) and Stern and Avivi (1990). Li, Wang, et al. (2021) and Srinath et al. (2022) explore machine eligibility by assigning specific machines to certain colors. Furthermore, Srinath et al. (2022) introduced scheduling preferences and shade differences as new objectives, alongside traditional ones like makespan, tardiness, and total setup time.

LP models in Cooper and Saydam (2003) and Saydam and Cooper (2002) maximize machine utilization and generate optimal loads for scheduling jobs on multi-port dyeing machines. In a different scheduling application, Zaharie et al. (2017) used an IP model to determine order acceptance, scheduling, and allocation to work teams in the apparel industry, considering penalties for delays or rejections. Du et al. (2018) addressed robust order scheduling in apparel by assigning orders to production lines, considering preproduction events and daily production uncertainties to minimize preproduction events and tardiness.

3.2.5. Batch-processing machine scheduling problem

The scheduling model that best fits the dyeing process in literature is the batch-processing machine scheduling problem (BPMSP). BPMSP integrates the batch and the scheduling problems. In textile dyeing, the batch problem involves grouping yarn or fabric with different characteristics and due dates for processing in dyeing boilers. Uzsoy (1994) showed that the BPMSP is equivalent to a bin-packing problem. A classical bin packing problem aims to pack a finite set of objects into a minimum number of equal-sized bins. BPMSP was formulated as MIP models and solved with heuristics in Puigjaner et al. (1996) to minimize costs and in Demir (2023), Demir and Inan (2022) to minimize the total tardiness and the total number of boiler washings. Zhang et al. (2017), proposed multiobjective formulations and metaheuristics to minimize tardiness and machine finishing time, while Demir (2022, 2024), focused on optimizing over-capacity usage and boiler costs. Duran et al. (2024) maximized jobs processed while minimizing machine usage. Li et al. (2022) proposed a bi-objective model to minimize maximum lateness and pollution cost on parallel batch-processing machines with varying capacities.

3.2.6. Integrated lot-sizing and scheduling problems

Integrated lot-sizing and scheduling problems combine decisions regarding the amount of production (lot sizes) and scheduling of several products on single or multiple capacitated machines. Integrating the lot-sizing and scheduling problems aims for efficiency and cost reductions. This class of problems is well-known as NP-hard since lot-sizing and scheduling problems are typically NP-hard, and algorithms are developed to solve them. Different approaches have been used in Akinc (1993), Beraldi et al. (2008, 2006), Camargo et al. (2021, 2014), Dumoulin and Vercellis (2000), Frendewey and Sumichrast (1988), Gunasekaran et al. (1993) and Silva and Magalhaes (2006). Pimentel et al. (2008, 2011) studied an integrated lot-splitting and scheduling problem in knitting manufacturing. Each item can be split into one or several different sizes during production, and each lot will be produced independently on identical parallel machines.

Camargo et al. (2021) analyzed blending integrated with scheduling and lot-sizing in spinning production planning. In the first stage, the blending problem determines the number of cotton bales in each blend load to feed the spinning machine. The lot-sizing and scheduling problem in the second stage determines the timing, level, and production sequence to meet yarn demand over time.

In general, the productive environment of textile industries is characterized by unpredictable demand, meaning that companies need to adapt to demand fluctuations over the planning horizon. However, most literature on mathematical programming in textile manufacturing considers deterministic parameters. Few papers consider parameter uncertainty. Uncertain data are represented by stochastic programming in Beraldi et al. (2006) and Karabuk (2008) for yarn manufacturing. The most uncertain parameters for textile supply chain papers are discussed in Section 4.

3.2.7. Cutting problems

Cutting stock problems (CSP) involve cutting objects available to produce smaller pieces in specified amounts. In fabric production, CSP establishes cutting patterns to minimize waste and costs or maximize profits. MIP models in Degraeve and Vandebroek (1998) and Richter (1992) address one-dimensional cutting problems (1D-CSP) to minimize cutting operations and waste while maximizing profits. In 1D-CSP, a fabric roll is only cut into smaller pieces in one direction. Ozdamar (2000) handled the cutting-wrapping problem, cutting large fabric lengths into smaller pieces wrapped around rolls.

In the two-dimensional rectangular cutting stock problem (2D-CSP), small rectangular pieces are cut from a large quantity of fixed-sized rectangular sheets. For instance, Wuttke and Heese (2018) proposed a MIP model and heuristic to minimize trim loss in 2D-CSP for the weaving industry. de Armas et al. (2008) also addressed a 2D-CSP with a Graphical User Interface in the textile industry. Farley (1990) presented a variant of 2D-CSP to minimize waste over multiple stock plates for the canvas industry. Peric et al. (2009) and Li et al. (2016) aimed to reduce waste and production time in a multicriteria MIP model and stochastic quadratic programming, respectively.

Gonçalves (2015) applied a biased random-key genetic algorithm to solve 2D-CSP to minimize the total fabric quantity needed to fulfill all orders. Salem et al. (2023) proposed a 2D-CSP variant with variable cutting pattern lengths between company-defined limits. They presented MIP formulations to minimize the total fabric area and the number of cuts.

Irregular packing problems (nesting) involve allocating irregular and regular pieces to a larger sheet while minimizing material or space waste (Leao et al., 2020). For instance, Heckmann and Lengauer (1998) and Hu et al. (2020) considered the 2D nesting problem to minimize the length of the sheet.

Some papers address fabric spreading and assigning garment sizes onto a table before cutting. This problem is known as cut order planning (COP). Tsao et al. (2020) formulated COP as a MIP model to determine the length of used fabrics and the number of opened sections while minimizing the total cost. Moreover, Ünal and Yüksel (2020) and Shang et al. (2019) proposed formulations to minimize the total usage of fabrics for COP. Also, Xu et al. (2020) analyzed the cost-oriented garment COP system in the context of mass customization when products must deal with fit and design issues.

Silva et al. (2015) considered minimizing the material waste problem in a vertically integrated textile company. The authors analyzed the integrated production planning and cutting problem. The proposed MIP model defines fabric roll dimensions, the number of rolls from inventory or purchase, and cutting patterns for each piece.

3.2.8. Cutting schedule problems

In apparel manufacturing, the pieces produced in the cutting process are required as work in progress to avoid bottleneck downtime in the sewing process. However, due to the limited area for storage and inventory costs, holding high inventory levels of cut pieces is not appropriate. In this context, Hung et al. (2014) proposed a MIP model to deal with the cutting schedule problem. The model determines optimal cutting times of fabric lays to meet the needs of the sewing process, minimizing piece inventory. For Wang et al. (2016), scheduling a cutting operation is similar to a 2D bin packing problem. By minimizing the makespan, the cutting schedule provides the cutting table, the location on the cutting table, and the start time of the cutting operation for each fabric lay.

3.2.9. Assembly line balancing problems

Assembly line balancing is a critical operational decision in manufacturing systems where products flow through workstations until the final product is obtained. The assembly line balancing problem (ALBP) aims to maximize the efficiency of an assembly line by distributing workstations throughout the line. Pereira (2018) provided two MIP formulations to minimize the total cost of stations while Efe et al. (2018) aimed to reduce the number of workstations. Gürsoy (2012), Gürsoy and Gürsoy (2015) explored ALBP in a lean environment, aiming to minimize idle time per operator, using constructive heuristics and GA approaches. For multi-line apparel industries, Zhang and Chen (2019) and Zhang et al. (2019) used multi-objective optimization to reduce the transfer distance of semi-finished products and the area occupied by the sewing assembly line. Considering sustainable aspects, Zhang and Chen (2019) addressed the ALBP with a carbon emission evaluation to minimize the time loss rate and provide the smoothness index of the assembly line.

3.2.10. Product quality problems

Physical properties of textile products are crucial for their quality, and several multi-objective programming models have been proposed to assess textile quality. Ünal and Koç (2010) Ghosh et al. (2013), and Chakraborty and Diyaley (2018) developed models to improve yarn and fabric characteristics such as strength, unevenness, hairiness, imperfections, and breaking elongation, among others, at a minimum cost. Majumdar et al. (2017) proposed a model to optimize fabric air permeability and thermal conductivity. He et al. (2022) proposed a multi-objective optimization system for helping textile manufacturing firms optimize overall process performance and product quality. For certain textiles, such as jeans or denim garments, prewashed fabrics are highly valued by customers due to their appearance and softness. In this context, Ke et al. (2019) proposed a MINLP model to minimize costs and meet hydrogen peroxide concentration, temperature, and treatment time requirements in a bleach-washing process for denim garments.

3.2.11. Transportation problems

Distribution operations involve transporting materials from origin to destination. Distribution decisions are crucial as they impact costs, flexibility, and inventory management. For instance, El Hachemi et al. (2018) proposed a two-stage method to address the synchronized bin-forklift scheduling problem, which involves scheduling dye jets and planning forklift transportation. The objective is to dye and transport all jobs to the wringing section at the lowest cost while respecting the dye-jet capacity. Similarly, Smirnov et al. (1976) developed an LP model to optimize the distribution of rayon yarns and staple fibers by maximizing the daily output produced at each plant.

Hu et al. (2015) investigated the uncertain try-on service time for apparel distribution. Try-on service is a benefit some apparel companies offer customers when choosing home clothes, improving customer satisfaction. However, the uncertainty of try-on service time can make the apparel distribution process uncertain and incur higher logistics costs and times. In this sense, Hu et al. (2015) formulated this problem as a vehicle routing problem (VRP). The model was extended to support the solution strategies for uncertain try-on times. Another VRP for the textile industry can be found in Eliguzel et al. (2021), which investigated the problem of picking up employees at a textile company.

3.3. Remarks and future research

The reviewed literature highlights various mathematical programming models and techniques to address production and distribution problems in textile and apparel manufacturing. These models seek to improve the overall efficiency and sustainability of textile manufacturing in different contexts. Given the analysis, we can point out the following:

- *Model characteristics*: The analysis of the model characteristics reveals a clear dominance of linear programming in the reviewed papers, where MIP is the predominant approach as illustrated in Fig. 7. Nonlinear programming models are less frequently used in reviewed articles and were applied to address specific challenges in product quality. Models in less than 3% of the papers are grouped in the *Others* class. Detailed models are presented in Table A.2.
  As Fig. 8(a) indicates, most papers deal with multiple items. Fig. 8(b) shows that most studies consider a single planning period rather than multiple periods, indicating a preference for simpler models and immediate operational focus. The limited exploration of multi-period scenarios highlights an opportunity for future research to address dynamic, long-term planning. Fig. 8(c) suggests that most studies focus on complex machine environments, reflecting a preference for real-world production settings. More details can be found in Tables A.3, A.5, and A.7.
- *Setup*: Fig. 8(d) shows that 27% of the reviewed textile manufacturing papers consider setup times or costs in their formulations. Tables A.3, A.5 and A.7 summarize the characteristics of studies incorporating setup costs or times, mainly focusing on scheduling and lot-sizing problems. Most of these studies assume sequence-dependent setups, highlighting their importance. Despite the benefits of setup carryover for cost reduction (Gopalakrishnan et al., 1995), only Camargo et al. (2021, 2014) have incorporated it. This presents opportunities for further research on cost and setup improvements in textile production planning.

- *Objective function*: Fig. 9 shows that most models are single objective function models, with only a few studies considering multiple objectives. Cost-related factors such as inventory, backorder, and setup are the main focus in cost minimization studies, while profit maximization has been little explored. In scheduling studies, the main objectives are minimizing tardiness and makespan, and a small number of studies consider the number of setups or setup time minimization. Operational performance is addressed through objectives like maximizing machine utilization and minimizing waste. Furthermore, the quality improvement of textile items is addressed through factors such as strength and softness. Details are presented in Tables A.3, A.5, and A.7.
- *Uncertainties*: Fig. 10 shows that only 6% of the reviewed papers address parameter uncertainties, primarily focusing on uncertain demand. Common methods used to represent these uncertainties include randomly generated numbers and stochastic programming. One study applies robust optimization to manage uncertainties in daily production quantities. One work applies fuzzy numbers to represent uncertain parameters such as costs and worker productivity. For further details, see Tables A.3, A.5, and A.7. More research is needed to investigate a broader range of textile and apparel manufacturing uncertainties, such as supply disruptions, market fluctuations, and machine failures.
- *Solution approach*: Commercial solvers are employed to obtain exact solutions on 44% of the papers. Authors predominantly count on approximate methods, particularly heuristics and metaheuristics as the solution approach (Table A.2). Among the approximate methods, genetic algorithms are the most used solution method, followed by search algorithms and constructive heuristics.
- *Future research*: We have identified several future opportunities for research in textile and apparel manufacturing upon analyzing the results. There is room to explore multiple periods in the planning horizon and consider multiple machines in the decision-making process to enhance production planning and scheduling. Improving cost and setup considerations presents valuable research opportunities, especially by incorporating setup carryover constraints for cost reductions. Exploring multiple objective functions, such as profit maximization, and optimizing operational performance factors like machine utilization, setup minimization, and waste minimization can significantly improve textile manufacturing processes. Furthermore, addressing uncertainties beyond demand and utilizing robust optimization and other techniques for uncertainty handling in textile and apparel manufacturing require further attention. Our findings reveal that integrated problems appear at the production stage for different scheduling combinations (lot-sizing, batch processing, and cutting). No papers consider integrated production and distribution planning in textile and apparel manufacturing. As suggested by Chen (2010), joint production and distribution planning can lead to more accurate delivery dates, reduced waiting times, lower inventory levels, and overall cost reduction. Future studies should focus on developing applicable models and solution methods that consider the specific characteristics of the textile industry and tackle integrated production and distribution problems effectively. Finally, some papers highlight the relevance of sustainable factors such as carbon emission, water, and energy consumption to textile production planning. However, there is a need for more research to investigate the benefits gained by including sustainable factors in production planning for textile industries.

4. Mathematical programming and optimization for the textile and apparel supply chain

The textile chain is a long and complex process from obtaining raw materials to the final goods that can be simplified into fiber, yarn, fabric, and apparel manufacturing (He et al., 2022). Characterized by a short product life cycle, high volatility, low predictability, vast product variety (e.g., color, size, style), labor-intensive processes, significant pollution, and substantial waste generation, the textile supply chain presents unique challenges (Chen et al., 2024; Li et al., 2016; Lorente-Leyva et al., 2024; Wen et al., 2019; Xu et al., 2024). Furthermore, the textile sector is highly fragmented, predominantly composed of small and medium-sized enterprises with poorly integrated and defined management systems (Su & Gargeya, 2016). The lack of sufficient historical data exacerbates these challenges, rendering traditional supply chain management models inadequate for addressing the specific requirements of the textile industry (Ghasemy Yaghin et al., 2020).

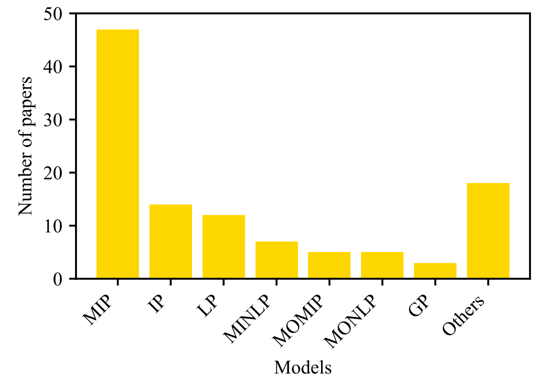


Fig. 7. Distribution of mathematical programming models in textile and apparel manufacturing.

In this section, we review works that explore multi-echelon supply chains, categorizing the planning decisions into three levels: strategic, tactical, and operational. Fig. 11 illustrates the relationships between stages in the textile supply chain, highlighting material and information flows. Companies make integrated decisions to manage material distribution within the chain, covering direct and reverse flows. The information flow involves uncertainties, often represented by fuzzy numbers, with few studies using random scenario generation. Additionally, the authors emphasize the importance of integrated decisions prioritizing waste reduction, such as reducing water and energy consumption and carbon emissions. Retail operations are not within the scope of this review.

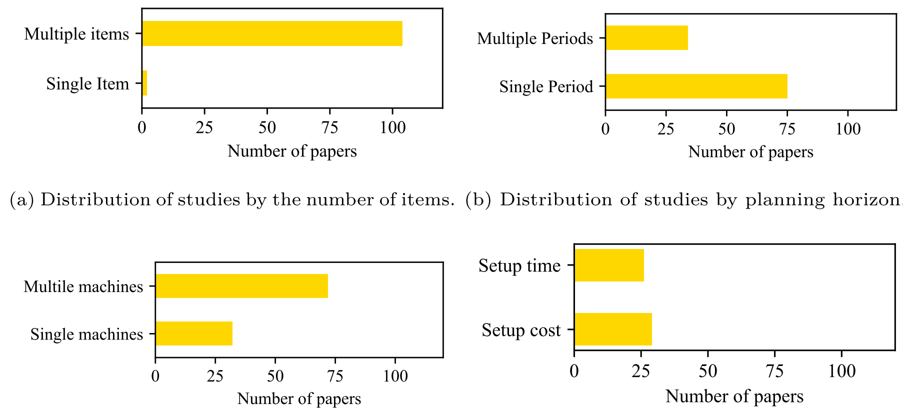
4.1. Strategic level decisions

Strategic planning is long-term planning (5–10 years), generally related to decisions such as plant or warehouse locations, capacity levels, technology and equipment acquisitions, activity outsourcing, transportation networks, suppliers, and order fulfillment approaches. At this level, we have works addressing supply chain network design (4.1.1), location–allocation problems (4.1.2), and closed-loop supply chain (4.1.3).

4.1.1. Supply chain network design

Supply chain network design (SCND) decisions involve plant and distribution center locations, capacities, customer zones, supplier allocation, transportation modes, and other factors. An efficient SCND enables textile companies to meet customer orders while reducing travel times and global costs. Bouzembrak et al. (2013) analyzed SCND under uncertain demands and supplier levels, with costs modeled as fuzzy numbers.

Paydar et al. (2021) developed a bi-objective stochastic model for apparel SCND, optimizing total profit while minimizing downside risk. Ying-Hua (2010) used a co-evolutionary model and constraint-satisfaction mode to solve SCND (Berthier et al., 2020) addressed



(a) Distribution of studies by the number of items. (b) Distribution of studies by planning horizon.

(c) Distribution of studies by machine configuration. (d) Setup considerations in studies.

Fig. 8. Summary of model characteristics analyzed in the reviewed textile and apparel literature.

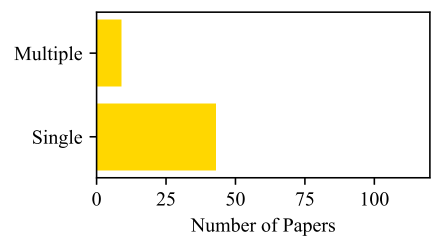


Fig. 9. Distribution of objective function types in models for textile and apparel manufacturing.

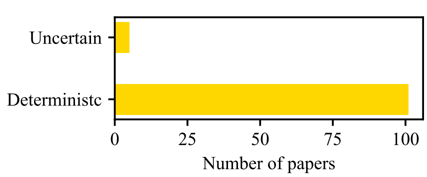


Fig. 10. Distribution of data type in textile and apparel manufacturing models.

SCND using a MIP model to determine optimal fabric production locations, minimizing costs across the whole chain. Additionally, Jafari et al. (2017), Kian et al. (2024), Mezatio et al. (2022, 2023a, 2023b), Moreno-Camacho et al. (2020), Shaw et al. (2013) and Shefa et al. (2024) considered sustainability aspects such as water recycling, carbon emissions, and green processes for SCND.

Sarma et al. (2021) investigated fashion retail supply chain strategies to deal with the COVID-19 pandemic. The proposed model presented the optimal retailing strategies for selling fashion goods over physical and online platforms, analyzing the effect of the pandemic on the supply chain.

4.1.2. Location–allocation problem

Li et al. (2017) focused on the location–allocation problem within a reverse network involving customer zones, collection points, and repair centers. The authors proposed a MIP model to minimize costs by assigning repair centers to collection points and allocating collection points to customer zones. Khannan et al. (2018) used linear programming to optimize the warehouse allocation considering cross-docking operations. Also, Zheng and Song (2019) proposed a stochastic model to optimize capacity allocation among clothing suppliers to maximize shared resource utilization.

4.1.3. Closed-loop supply chain and sustainable supply chain

Concern with environmental issues and developing a sustainable supply chain has grown in recent decades. Thus, the entire SC needs to be designed by incorporating sustainability concerns into several echelons of the SC. Some companies implement reuse or recycling policies. Others introduce environmental considerations, like carbon emissions, into planning. The forward chain combines processes from raw material producers and manufacturers to the final customers. A backward flow is needed for end-of-life management. The reverse flow starts with consumers, collecting discarded products that return to earlier production stages. Considering both flows in an SC will result in a new configuration known as a closed-loop supply chain (CLSC) (Govindan et al., 2015).

Masoudipour et al. (2017) developed a MINLP to deal with CLSC based on the quality of returned products. Their study explores the impact of CLSC on network decisions and profits. Oh and Jeong (2014) developed a multi-objective model to determine the trade-off between CLSC profit and carbon emissions. The model must decide the production, transportation, and inventory amounts for a CLSC network.

Jakhar (2015) proposed a set of sustainable SC performance measures for an apparel SC network. Using fuzzy logic, the author proposed a method to maximize sustainable purchasing, production, delivery, and logistics while minimizing costs and carbon emissions. Also, a MOMIP is presented by Jafari et al. (2017) to design a sustainable CLSC concentrating on water recycling and justice-oriented employment levels. Abbas et al. (2021) integrated cotton crop waste into the textile energy supply chain with an LP model, addressing sustainability and cost-effectiveness. The model converts waste into bioenergy, reducing fossil fuel dependency and emissions.

4.2. Tactical level decisions

Tactical planning is mid-term planning (12–18 months), ensuring that the firm meets the goals established at the strategic level. Commonly, tactical decisions include assigning production capacity to product families, supplier selection, capacity manufacturing planning, workforce requirements, distribution centers, shipment plans, inventory management, and transportation mode. At this level, we grouped works in supplier selection (4.2.1), aggregate production planning (4.2.2), and integrated production and distribution planning problems (4.2.3).

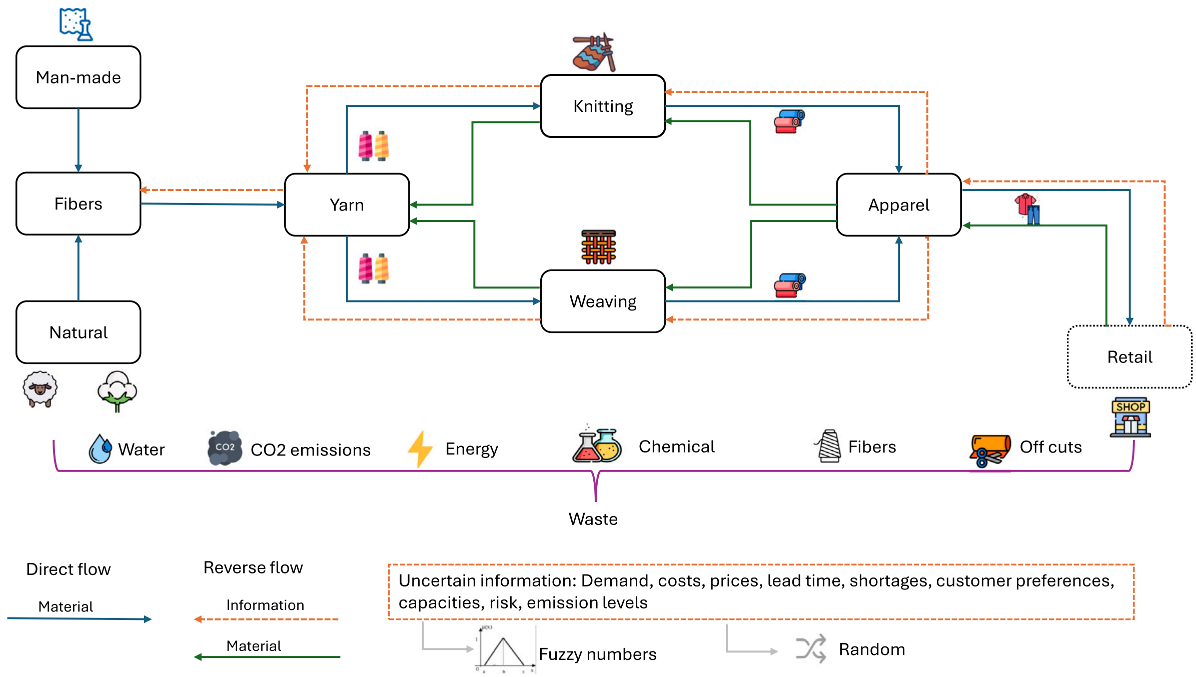


Fig. 11. Textile supply chain flow diagram.

4.2.1. Supplier selection

Supplier selection seeks to identify suppliers capable of meeting manufacturer needs with acceptable performance. Factors such as capacity, price, quality, and transportation further complicate decision-making, directly impacting customer satisfaction. Araz et al. (2007) proposed an integrated multi-criteria decision-making method using fuzzy goal programming to select suitable strategic suppliers and allocate order quantities.

Integrated decisions on supplier selection, order allocation, and transportation under uncertainty were studied in Ali and Zhang (2023), Ghasemy Yaghin and Darvishi (2019), Ghasemy Yaghin and Sarlak (2019) and Yaghin and Darvishi (2022). The authors proposed multi-objective linear programming, fuzzy goal programming, and fuzzy mixed integer nonlinear models. Ghasemy Yaghin and Sarlak (2019) considered corporate social responsibility and environmental variables, like air and water pollution and energy consumption. Hashim et al. (2017), Tayyab and Sarkar (2021), and Ali and Zhang (2023) also use fuzzy logic to tackle the sustainable supplier selection problem in a textile SC for purchasing raw materials. Sustainable supplier selection was also addressed by Mezatio et al. (2022). The MIP model proposed by the authors considers selecting suppliers, subcontractors, opening sites and warehouses, transportation modes, and raw material quantities based on carbon footprints.

Karami et al. (2020) developed a systematic approach incorporating environmental, social, and economic factors for supplier selection in the apparel industry. An LP approach was used to determine efficient suppliers in a three-stage framework. Similarly, Jatuphatwarodom et al. (2018) The EGP is explicitly used to focus on inventory optimization analysis.

4.2.2. Aggregate production planning

Aggregate Production Planning (APP) is a crucial medium-term production planning process that typically spans a planning horizon of 2 to 18 months. The primary objectives of APP involve determining optimal production, inventory, and employment levels. Several studies have explored the complexities of multiple suppliers, manufacturers, and customers within multi-site, multi-period, and multi-product APP models.

Leung et al. (2007, 2003, 2006) proposed different approaches for a multi-site APP for apparel SC. Data uncertainty (Table A.10) were considered in Leung et al. (2007, 2006). Likewise, Ghiani et al. (2003) presented a GP model with uncertain productivity for allocating production batches to subcontractors in a textile SC, using a fuzzy logic approach to handle data uncertainty. Moreover, a rolling-horizon APP method was proposed by Demirel et al. (2018), incorporating an alternative stabilizing approach into the conventional APP.

Darvishi et al. (2020), Ghasemy Yaghin et al. (2020) and Yaghin and Darvishi (2022) studied jointly inbound logistics and multi-site aggregate production planning (APP) decisions with uncertainties along the tactical planning horizon in a textile SC. The authors proposed nonlinear models with stochastic-fuzzy to integrate supplier selection and social responsibility related to the APP. Furthermore, considering the trade-off between carbon emissions, social performance, and supply chain total profit, Yaghin and Sarlak (2022) studied textile SC tactical planning under demand fuzziness.

Ghasemy Yaghin (2020) proposed a nonlinear model to combine marketing decisions into an APP. Marketing planning involves product selection, sales channels, and pricing, while production planning focuses on resource allocation to achieve these goals. Similarly, Guan et al. (2000) examined APP and proposed a fuzzy MIP formulation to determine production and capacity planning for a manufacturer operating within a supply chain that experiences seasonal demand.

4.2.3. Integrated production and distribution planning

To improve the performance of an SC, it is necessary to efficiently plan and manage production and distribution activities by coordinating information, services, and goods. Therefore, some papers seek SC coordination and overall cost-reduction approaches to the integrated production and distribution problem. Safra et al. (2019, 2021) proposed a planning approach involving tactical and operational decisions. The authors considered receiving preseason orders at the tactical level to determine production capacity and the need to hire outsourced labor. A weekly rolling horizon integrates the new replenishment orders received during the weeks.

Felfel et al. (2015, 2016a, 2016b, 2018) studied an SC network composed of medium and small companies that comprise different textile stages. The authors proposed stochastic and multi-objective linear programming models for integrated production and distribution planning. Similarly, Ait-Alla et al. (2014) analyzed a production planning problem for a textile SC. Robust optimization represents the conditional value theory of uncertain data at risk by introducing and constraining a loss function. Wang et al. (2021) developed a stochastic multi-objective model to tackle sustainable production planning, considering workforce change and customer satisfaction.

4.3. *Operational level decisions*

Operational planning is related to short-term (daily or weekly) decisions regarding resource allocation and further steps on the shop floor to follow the tactical plans. Decisions on this level include problems such as scheduling machines, inventory balancing, customer order processing, warehouse operations scheduling, labor scheduling for manufacturing, vehicle routing, carrier selection for individual loads, and sales promotions. At this level, we grouped works in production planning (4.3.1) and distribution and transportation (4.3.2).

4.3.1. *Production planning*

De Toni and Meneghetti (2000) focused on the production planning process in a knitting SC aiming for synchronization across a large network. The network operates using seasonal campaigns within a make-to-order manufacturing system. The authors analyzed the impact of production planning on supply chain performance, particularly from a time-based perspective.

4.3.2. *Transportation*

The success of textile and apparel companies depends on supply chain management to ensure timely product flow at minimal cost (Safra et al., 2021). Distribution and transportation decisions are critical, encompassing determining shipment quantities to satisfy demand, scheduling daily inventory movement, and coordinating pickup and delivery activities.

Caro and Gallien (2010) addressed the distribution problem of allocating limited inventory across all stores in a large apparel supply chain. The authors developed a stochastic model to predict sales during replenishment, considering demand forecasts, initial inventory, and policy inventory. A MIP model calculated store shipments to maximize predicted sales while adhering to inventory constraints. The study evaluated operational performance metrics, including shipments, sales, and missed demand. In a different context, Mas'ud and Wahid (2022) analyzed a distribution problem in the processing of silk products, focusing on the challenges posed by digital disruption during the COVID-19 pandemic.

Companies often outsource logistics activities to third-party logistics providers (3PL). 3PLs specialize in warehousing, transport, freight consolidation, inventory management, and other logistics services. In this context, Kayvanfar et al. (2018) proposed an FMOGP for the distribution problem of a textile industrial cluster, using a 3PL for logistics services. The model had three objective functions: minimizing the total logistics costs, maximizing the demand satisfaction rate, and maximizing the quality of delivery. Also, Karabuk (2007) studied the transportation problem of a textile producer that operates many manufacturing facilities at all SC. Cotton and synthetic fibers yarns are shipped to weaving plants to produce fabrics. Fabrics are shipped from weaving to dyeing and finishing plants and sent to customers. The truck fleet is heterogeneous, allowing different loading shipments. The problem involves scheduling pickups and deliveries for daily inventory movements between plants.

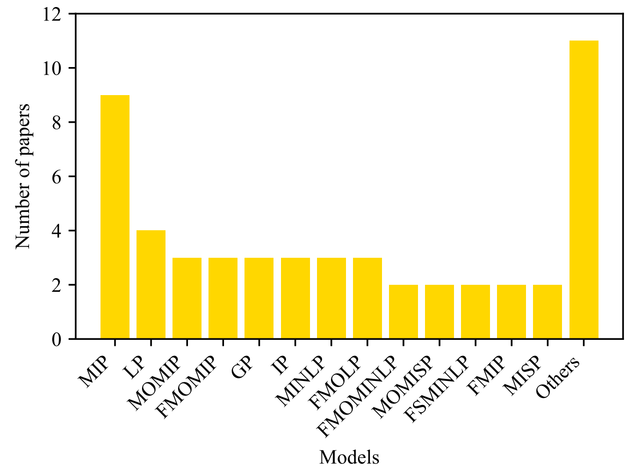
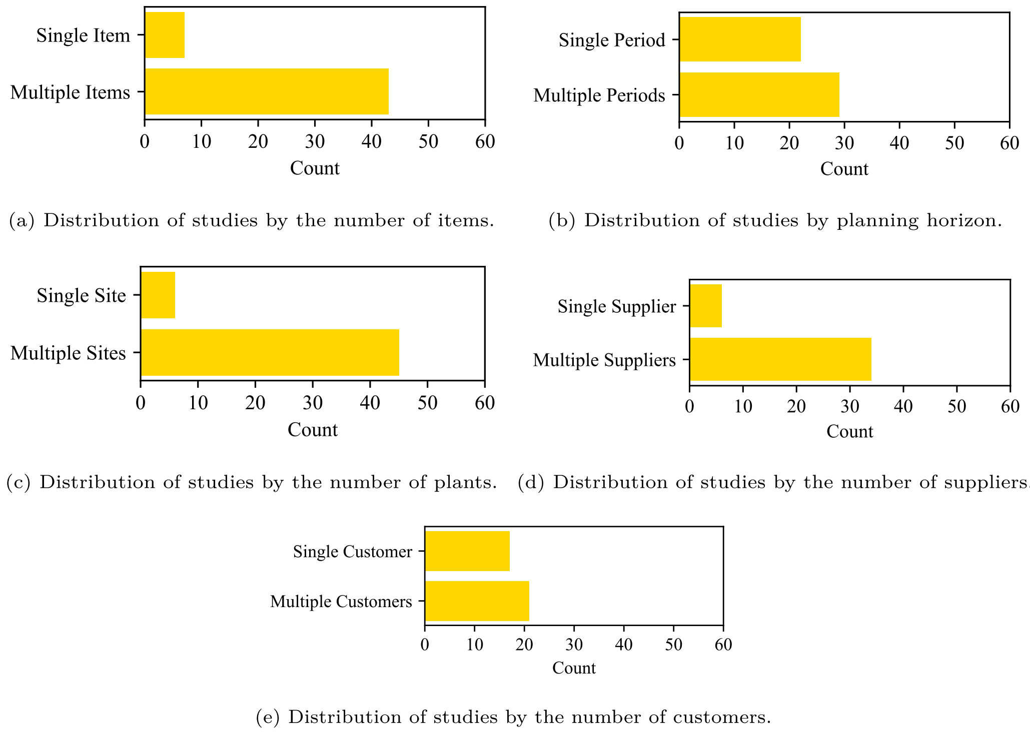


Fig. 12. Distribution of mathematical programming models in textile supply chain.

4.4. *Remarks and future research*

- *Model characteristics*: Fig. 12 shows the distribution of mathematical programming models in the textile supply chain. The analysis of the model attributes reveals that linear programming is predominant in supply chain papers, with MIP as the most popular approach. Nonlinear models appear in 17% of the articles. Models that appear only once are grouped under the *Others* category. Detailed models are presented in Table A.9
  Fig. 13 illustrates that most integrated supply chain studies focus on multiple items, multiple periods, multi-site production plants, and multiple suppliers. Yet, 42% of the studies still address single-period problems. Given the multi-echelon nature of these studies, our findings indicate a stronger research emphasis on the relationships between companies and suppliers (upstream supply chain) compared to the relationships between companies and customers (downstream supply chain). Future research could explore customer-centered studies to address gaps in downstream supply chain dynamics.
- *Objective function*: Fig. 14 shows that most models are single objective function models. Table A.11 indicates that minimizing costs – including inventory, transportation, labor, production, material, lost sales, and backorder costs – is the focus of most studies. It is worth mentioning that 36% of the studies use multi-objective models, targeting goals such as optimizing social value, minimizing water consumption and carbon emissions, maximizing capacity utilization, mitigating risk, reducing production time, improving product quality, and selecting green suppliers. These multifaceted objectives help capture the broader implications and sustainability considerations within the textile supply chain, highlighting a field for future research.
- *Uncertainties*: The presence of uncertain data in supply chain articles is higher compared to the articles discussed in Section 3. Fig. 15(a) reveals that half of the reviewed studies address uncertain environments. In these works, 55% formulated the uncertainty as Fuzzy numbers, as shown in Fig. 15(b). Table A.10 demonstrates several sources of uncertainty that are analyzed, including production times, capacity levels, sales prices, costs, lead times, customer preferences, and others, with demand being the primary source of uncertainty.
- *Solution approach*: In the field of the textile SC, 50% of the studies use only exact methods offered by commercial solvers, as shown in Table A.9. In 34% of the papers, approximate methods such as genetic and search algorithms are used to solve



(a) Distribution of studies by the number of items.

(b) Distribution of studies by planning horizon.

(c) Distribution of studies by the number of plants.

(d) Distribution of studies by the number of suppliers.

(e) Distribution of studies by the number of customers.

Fig. 13. Summary of model characteristics analyzed in the reviewed textile supply chain literature.

the proposed models. Both exact and approximate methods are applied in 11% of the studies. Some works employ mathematical programming as part of multi-criteria decision-making processes, including data envelopment analysis and analytical hierarchy process, particularly for supplier selection.

- *Future research*: Future research in textile supply chain management should go beyond the traditional focus on cost minimization and address the optimization of multiple objectives. There is a growing recognition of the significance of optimizing sustainability-related factors like social value, reducing water consumption and carbon emissions, maximizing capacity utilization, and mitigating risks. Exploring closed-loop supply chains and reverse flows can be particularly promising in building sustainable chains. A notable gap exists in understanding disruptions and resilience in the textile and apparel supply chain. While supplier selection has received considerable attention, there is a need to explore customer service levels and satisfaction, particularly considering the challenges of unpredictable demand patterns in the textile industry. Future studies can improve customer-centric strategies and enhance overall supply chain performance in the textile sector. Furthermore, while exact methods offered by commercial solvers are commonly used, there is space to explore alternative solution methods to tackle complex textile supply chain problems.

5. Final remarks, future research, and limitations

The textile sector is crucial, attracting significant academic interest across various aspects. In recent years, there has been a notable growth in research focused on this field. Given its specific characteristics, such as short product life cycles, high volatility, low predictability, and high demand accompanied by substantial energy and water consumption, as well as carbon emissions, the development of efficient management plans are essential to ensure competitiveness. To contribute to this field, we conducted a systematic review of mathematical programming

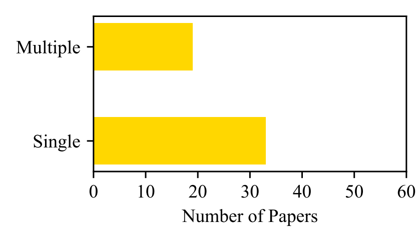
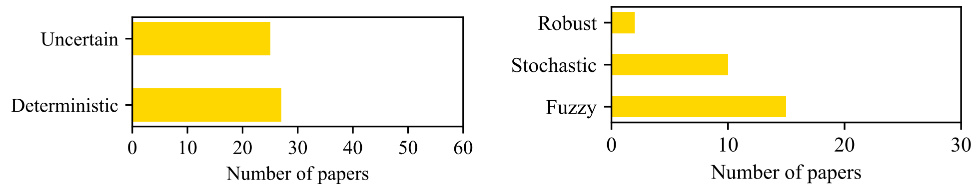


Fig. 14. Distribution of objective function types in textile supply chain models.

models used in the decision-making process for the textile supply chain, spanning different publication years. By categorizing the reviewed papers based on manufacturing stages and problem types, we identified key features, objective functions, and solution approaches employed in this domain.

Scheduling: Our findings emphasize the significance of scheduling problems in textile manufacturing. It is important to avoid mixing certain items and colors to maintain product quality. In this sense, each machine can process only one job at a time, and each job can be processed on only one machine. Several works have proposed different scheduling approaches on various machines, considering sequence-dependent setup costs or times. However, there is still room for further research on scheduling problems, especially when considering integrated problems encompassing multiple textile manufacturing aspects. Also, more practical concerns should be considered, including machine maintenance, machine eligibility, failure, product life-cycle, defective items, and re-dyeing.

Economic, environmental, and social aspects: While some models primarily focus on environmental aspects such as carbon emission reduction and energy and water consumption as indicators of sustainable production, it is crucial to recognize that sustainability encompasses the triple-bottom line: economic, environmental, and social dimensions (Ghasemy Yaghin & Sarlak, 2019; Jafari et al., 2017). Hence,



(a) Distribution of studies by data type

(b) Distribution of studies by type of uncertainty.

Fig. 15. Distribution of studies by data type in textile supply chain models.

it is vital to consider the economic and environmental impacts, including cost reduction through efficient resource utilization, integration of reverse flows, including carbon trade, minimizing waste, and reusing resources and products. Equally important is incorporating social responsibility factors, such as fair labor practices and community engagement, to ensure a comprehensive approach to sustainable production (Jafari et al., 2017; Sánchez-Herrera et al., 2019). It is important to note that while sustainable aspects have been incorporated into supply chain models, this topic remains underexplored in individual manufacturing stages.

Uncertainties: Several papers highlight the challenges faced in textile production planning, primarily due to various sources of uncertainty (e.g., Felfel et al., 2018; Karabuk, 2008; Rabbani et al., 2016). However, we observed that most of these studies still focus on deterministic parameters, especially for the individual manufacturing stages. Although demand is recognized as the primary source of uncertainty, further research is needed to explore demand modeling, considering factors such as sales channels, customer segmentation, and supplier prices. One aspect that has received limited attention is using safety stock to mitigate the impact of demand variability (Ghasemy Yaghin et al., 2020). Additionally, to closely resemble real-world scenarios, it is crucial to incorporate uncertain data into the models for production costs, purchasing costs, capacity levels, disruption, labor productivity, and sales prices. These factors play a key role in capturing the complexity and dynamics of textile production planning.

Operational performance metrics: Operational performance metrics are essential in the textile and apparel supply chain, providing valuable insights into the efficiency and effectiveness of operational activities. Our research highlights the significance of performance measures such as makespan, total processing times, tardiness, and earliness in addressing scheduling problems. Caro and Gallien (2010) have included metrics like shipments, returns, sales, and lost sales to quantify operational performance in the apparel supply chain. Additionally, Zhang et al. (2017) evaluated time machine utilization, and Tayyab et al. (2020) suggested including service-level constraints to improve production planning. These metrics enable organizations to track and measure key performance indicators (KPIs) related to production, inventory management, order fulfillment, and logistics. Companies can identify bottlenecks, optimize processes, and enhance operational performance by monitoring cycle time, throughput, on-time delivery, order accuracy, and inventory turnover. Further studies should include constraints and objective functions to evaluate operational performance metrics.

Solution approach: Several papers primarily concentrate on cost minimization using single objective functions. However, it is essential to recognize the significance of incorporating multiple objective functions to achieve a more holistic approach. By incorporating different goals like quality, customer satisfaction, sustainability, and production efficiency, textile companies can align their decision-making processes more effectively with the diverse requirements of the industry and stakeholders. In terms of solving these problems, developing exact or approximate solution algorithms, instead of solely relying on commercial solvers, can ensure successful resolutions for large instances in the textile supply chain.

Future research: Future textile and apparel manufacturing research should address several opportunities to advance the field. At the individual manufacturing stage level, there is room to explore multi-period planning horizons, multiple machine setups, and practical considerations that should be incorporated into the models. Addressing uncertainties beyond demand is crucial for tackling complex textile manufacturing problems. Sustainable environmental and social factors should be further examined in individual and integrated contexts to create comprehensive and impactful models. Investigating customer satisfaction and service levels alongside production planning problems can improve supply chain performance. Moreover, integrating production and distribution planning remains a significant research gap, with potential benefits such as reduced lead times, lower inventory levels, and overall cost efficiency. Finally, there is a need to develop innovative solution methods, beyond reliance on commercial solvers, to effectively address large-scale and complex problems in the textile supply chain.

Limitations: The current study had certain limitations regarding the method used. Firstly, while we used multiple databases for our search process, certain databases, such as Emerald, JSTOR, and ACM Digital Library, were not included. Secondly, our study focused exclusively on research articles published in English, missing valuable literature published in other languages. Additionally, we specifically concentrated on mathematical programming models, thus excluding other operational research techniques like simulations and game theory from the scope of this review. Furthermore, our study primarily centered around manufacturing stages and did not delve into retailer operations such as pricing, selling strategies, or customer behavior. We compensated for these limitations by presenting key problems and listing research gaps in the textile supply chain. We hope this work will inspire further research on mathematical programming in the textile industry.

CRediT authorship contribution statement

Giovanna Abreu Alves: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Roberto Tavares:** Supervision. **Pedro Amorim:** Writing – review & editing, Supervision. **Victor Claudio Bento Camargo:** Writing – review & editing, Validation, Supervision, Methodology.

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Appendix

See Tables A.1–A.11.

Table A.1
List of references and corresponding textile and apparel manufacturing stages.

Reference	Manufacturing stage	Reference	Manufacturing stage
Duran et al. (2024)	Yarn	Hu et al. (2015)	Apparel
Demir (2024)	Yarn	Khalili-Damghani et al. (2015)	Fiber
Wang and Zhang (2023)	Fabric	Zhang et al. (2014)	Yarn
Salem et al. (2023)	Fabric; Apparel	Camargo et al. (2014)	Yarn
Demir (2023)	Fabric	Eroglu and Ozmutlu (2014)	Fabric
Berthier et al. (2022)	Fabric	Hung et al. (2014)	Apparel
Wang et al. (2022)	Apparel	Salassi et al. (2013)	Fiber
Srinath et al. (2022)	Fabric	Ghosh et al. (2013)	Yarn
Demir (2022)	Yarn	Huang and Yu (2013)	Apparel
Demir and Inan (2022)	Yarn	Gürsoy (2012)	Apparel
Kousar et al. (2022)	Yarn; Fabric	Pimentel et al. (2011)	Fabric
Wei et al. (2022)	Yarn	Sumihartati et al. (2011)	Fabric
He et al. (2022)	Fabric	Azadeh et al. (2010)	Fabric
Malik et al. (2022)	Apparel	Ünal and Koç (2010)	Fabric; Apparel
Camargo et al. (2021)	Yarn	Hadi-Vencheh and Aghajani (2010)	Yarn
Eliguzel et al. (2021)	Apparel	Hsu et al. (2009)	Yarn; Fabric
Li, Wang, et al. (2021)	Fabric	Peric et al. (2009)	Fabric
Mourtos et al. (2021)	Fabric	Beraldi et al. (2008)	Yarn
Sumathy and Amirthalingam (2021)	Apparel	Jungwattanakit et al. (2008)	Yarn
Croft et al. (2021)	Fabric; Apparel	Karabuk (2008)	Yarn
Zhou et al. (2020)	Fabric	Bhattacharyya et al. (2008)	Yarn
Biadgligne et al. (2020)	Yarn	Pimentel et al. (2008)	Fabric
Ghosh et al. (2020)	Apparel	de Armas et al. (2008)	Apparel
Tayyab et al. (2020)	Fabric	Ballestero (2006)	Fiber
Tsao et al. (2020)	Apparel	Beraldi et al. (2006)	Yarn
Ünal and Yüksel (2020)	Apparel	Silva and Magalhaes (2006)	Yarn
Xu et al. (2020)	Apparel	Guo et al. (2006)	Apparel
Hu et al. (2020)	Fabric	Min and Cheng (2006)	Fabric
Hong et al. (2019)	Fiber	Cooper and Saydam (2003)	Fabric
Sánchez-Herrera et al. (2019)	Fabric; Apparel	Wu and Chang (2003a)	Fabric
Zhang and Chen (2019)	Apparel	Wu and Chang (2003b)	Fabric
Zhang et al. (2019)	Apparel	Saydam and Cooper (2002)	Fabric
Tsai and Jhong (2019)	Apparel	Qiu et al. (2002)	Yarn
Ke et al. (2019)	Fabric	Wong et al. (2001)	Fabric
Shang et al. (2019)	Fabric; Apparel	Maldonado et al. (2000)	Fabric
Efe et al. (2018)	Yarn; Fabric; Apparel	Wong et al. (2000)	Fabric; Apparel
Chakraborty and Diyaley (2018)	Yarn	Ozdamar (2000)	Fabric; Apparel
El Hachemi et al. (2018)	Fabric	Dumoulin and Vercellis (2000)	Fabric
Tsai (2018)	Yarn; Fabric	Heckmann and Lengauer (1998)	Apparel
Pereira (2018)	Apparel	Degraeve and Vandebroek (1998)	Apparel
Wuttke and Heese (2018)	Fabric	Puigjaner et al. (1996)	Fabric
Du et al. (2018)	Fiber	Serafini (1996)	Fabric
Campo et al. (2018)	Fabric	Tomastik et al. (1996)	Apparel
Elmehanny et al. (2018)	Apparel	Morales et al. (1996)	Fabric
Wineman and Crawford (2017)	Fiber	Duffy et al. (1994)	Fiber
Zhang et al. (2017)	Fabric	Akinc (1993)	Fabric
Zaharie et al. (2017)	Apparel	Gunasekaran et al. (1993)	Yarn
Majumdar et al. (2017)	Fabric	Richter (1992)	Fabric
Celikbilek et al. (2016)	Apparel	Serafini and Speranza (1992)	Fabric
Rabbani et al. (2016)	Yarn	Mogahzy (1992)	Yarn
Wang et al. (2016)	Apparel	Guinet (1991)	Fabric
Lin et al. (2016)	Fabric	Farley (1990)	Fabric
Gürsoy and Gürsoy (2015)	Apparel	Stern and Avivi (1990)	Fabric; Apparel
Gonçalves (2015)	Fabric	Frendewey and Sumichrast (1988)	Yarn
Silva et al. (2015)	Fabric; Apparel	Bhatnagar (1981)	Fabric
		Smirnov et al. (1976)	Yarn

Table A.2
Problems characteristics related to textile and apparel manufacturing.

Reference	Problem	Model	Solution approach		
			Exact	Approximate	Method/Tool
Duran et al. (2024)	Batch-processing machine Scheduling	MOMIP	✓	✓	CPLEX; Adaptive Large Neighborhood Search
Demir (2024)	Batch-processing machine Scheduling	MOMIP	✓	✓	Gurobi; Iterated Greedy Algorithm
Wang and Zhang (2023)	Batch-processing machine Scheduling	MIP		✓	Tabu Search
Salem et al. (2023)	Cutting	MIP/MOMIP	✓		Gurobi
Demir (2023)	Batch-processing machine Scheduling	MOMIP	✓	✓	Gurbo; Genetic Algorithm
Berthier et al. (2022)	Scheduling	MIP	✓	✓	CPLEX; Genetic Algorithm
Wang et al. (2022)	Batch-processing machine Scheduling	MIP	✓	✓	CPLEX; Iterative heuristic; Variable neighborhood search procedure
Srinath et al. (2022)	Scheduling	MIP/MOMIP		✓	Constructive heuristics
Demir (2022)	Batch-processing machine Scheduling	MOMIP	✓	✓	Gurobi; Iterative greedy search algorithm; D-LexMOMIP; Constructive heuristic
Demir and Inan (2022)	Batch-processing machine Scheduling	IP		✓	Iterative greedy search algorithm
Kousar et al. (2022)	Resource planning	FLP	✓		Commercial solver
Wei et al. (2022)	Scheduling	MOMIP	✓		SCIP solver
He et al. (2022)	Product quality	MONLP		✓	Deep Q-networks
Malik et al. (2022)	Lot-sizing	GP	✓		LINGO
Camargo et al. (2021)	Lot-sizing and scheduling	MIP/MINLP	✓		CPLEX
Eliguzel et al. (2021)	Transportation	MIP	✓		Gurobi
Li, Wang, et al. (2021)	Batch-processing machine Scheduling	IP		✓	Hybrid differential evolution with chaos theory; Local search algorithms
Mourtos et al. (2021)	Scheduling	MIP		✓	Assignment heuristics
Sumathy and Amirthalingam (2021)	Scheduling	LP	✓		Commercial Solver
Croft et al. (2021)	Scheduling	MIP/NLP	✓	✓	Bridging Algorithm; GAMS; CPLEX; BARON
Zhou et al. (2020)	Scheduling	MOLP		✓	Genetic Algorithm; Variable neighborhood search
Biadgligne et al. (2020)	Blending	IP	✓		Excel Solver
Ghosh et al. (2020)	Lot-sizing	LP	✓		Excel Solver
Tayyab et al. (2020)	Lot-sizing	MINLP		✓	Genetic Algorithm
Tsao et al. (2020)	Cutting	MIP		✓	Constructive heuristics; Genetic Algorithm; Simulated annealing; Tabu search
Ünal and Yüksel (2020)	Cutting	MINLP	✓		LINGO
Xu et al. (2020)	Cutting	IP		✓	Genetic Algorithm
Hu et al. (2020)	Cutting	MIP		✓	Greedy adaptive search algorithm
Hong et al. (2019)	Cotton production	LP	✓		Commercial solver
Sánchez-Herrera et al. (2019)	Scheduling	MIP		✓	Sequence heuristic; Iterated local search; Greedy randomized adaptive search
Zhang and Chen (2019)	Assembly line balance	MONLP		✓	Genetic Algorithm
Zhang et al. (2019)	Assembly line balance	MOLP		✓	Genetic Algorithm
Tsai and Jhong (2019)	Lot-sizing	MIP	✓		LINGO
Ke et al. (2019)	Product quality	MINLP		✓	Monte Carlo Simulation
Shang et al. (2019)	Cutting	MIP		✓	Iterated greedy algorithm
Efe et al. (2018)	Assembly line balance	IP	✓		GAMS
Chakraborty and Diyaley (2018)	Product quality	MONLP		✓	Artificial bee colony algorithm; Ant colony optimization; Particle swarm optimization algorithm; Genetic Algorithm
El Hachemi et al. (2018)	Scheduling	MIP	✓		CPLEX; Branch-and-price
Tsai (2018)	Lot-sizing	MIP	✓		LINGO
Pereira (2018)	Assembly line balance	IP	✓	✓	CPLEX; Constructive heuristic; Estimation of Distribution Algorithm
Wuttke and Heese (2018)	Cutting	MIP	✓	✓	CPLEX; Sequential heuristic with feedback loop; Gilmore and Gomory approach
Du et al. (2018)	Scheduling	MORP		✓	Multiobjective evolutionary algorithm
Campo et al. (2018)	Lot-sizing	LP	✓		GAMS
Elmehanny et al. (2018)	Lot-sizing	MIP	✓		CPLEX
Wineman and Crawford (2017)	Cotton production	LP	✓		Simplex
Zhang et al. (2017)	Batch-processing machine Scheduling	MIP/MOLP	✓	✓	CPLEX; Artificial bee colony algorithm
Zaharie et al. (2017)	Scheduling	IP	✓		Commercial Solver
Majumdar et al. (2017)	Product quality	MONLP		✓	Genetic Algorithm
Celikbilek et al. (2016)	Scheduling	MIP/MOLP		✓	Genetic Algorithm
Rabbani et al. (2016)	Cotton production	MIP	✓		GAMS
Wang et al. (2016)	Cutting schedule	MIP	✓		Gurobi
Lin et al. (2016)	Cutting	QP		✓	Global optimization algorithm
Gürsoy and Gürsoy (2015)	Assembly line balance	IP		✓	Genetic Algorithm
Gonçalves (2015)	Cutting	IP		✓	Biased random-key Genetic Algorithm
Silva et al. (2015)	Cutting	MIP	✓		CPLEX; Column generation
Hu et al. (2015)	Transportation	MIP/MISP	✓		Evolutionary algorithm

(continued on next page)

Table A.2 (*continued*).

Reference	Problem	Model	Solution approach		
			Exact	Approximate	Method/Tool
Khalili-Damghani et al. (2015)	Cotton production	LP	✓		Commercial Solver
Zhang et al. (2014)	Blending	MINLP		✓	Lagrange multiplier; Genetic Algorithm
Camargo et al. (2014)	Lot-sizing and scheduling	MIP	✓	✓	CPLEX; Branch-and-bound incorporate into fix-and-optimize improvement method
Eroglu and Ozmutlu (2014)	Scheduling	MIP	✓	✓	CPLEX; Genetic Algorithm
Hung et al. (2014)	Cutting schedule	MIP	✓	✓	Gurobi; Constructive heuristic
Salassi et al. (2013)	Cotton production	LP	✓		Commercial Solver
Ghosh et al. (2013)	Product quality	MONLP		✓	Genetic Algorithm
Huang and Yu (2013)	Scheduling	MIP		✓	Ant colony optimization
Gürsoy (2012)	Assembly line balance	IP		✓	Constructive heuristic
Pimentel et al. (2011)	Lot-sizing and scheduling	MIP	✓	✓	CPLEX; Network flow heuristic
Sumihartati et al. (2011)	Scheduling	MIP	✓	✓	CPLEX; Neighborhood search algorithm
Azadeh et al. (2010)	Scheduling	GP	✓	✓	LINGO; Computer simulation; Design of experiment
Ünal and Koç (2010)	Product quality	NLP/MONLP	✓		LINGO
Hadi-Vencheh and Aghajani (2010)	Lot-sizing	GP	✓		LINDO
Hsu et al. (2009)	Scheduling	MIP		✓	Genetic Algorithm
Peric et al. (2009)	Cutting	MIP/GP		✓	Weight Coefficients Method; Satisfactory goals method
Beraldi et al. (2008)	Lot-sizing and scheduling	MIP	✓	✓	CPLEX; Rolling-horizon and fix-and-relax heuristics
Jungwattanakit et al. (2008)	Scheduling	MIP		✓	Constructive heuristic; Genetic Algorithm
Karabuk (2008)	Lot-sizing and scheduling	MISP	✓	✓	CPLEX; Two stage preprocessing; LP relaxation
Bhattacharyya et al. (2008)	Blending	LP	✓		Simplex
Pimentel et al. (2008)	Lot-sizing and scheduling	MIP	✓	✓	CPLEX; Network flow heuristic
de Armas et al. (2008)	Cutting	MIP	✓		Viswanathan–Bagchi algorithm
Ballestero (2006)	Blending	SLP	✓		LINGO
Beraldi et al. (2006)	Lot-sizing and scheduling	MISP	✓	✓	CPLEX; Fix-and-relax heuristic
Silva and Magalhaes (2006)	Lot-sizing and scheduling	MIP		✓	Constructive heuristics
Guo et al. (2006)	Scheduling	MIP		✓	Genetic Algorithm
Min and Cheng (2006)	Scheduling	MIP		✓	Genetic Algorithm
Cooper and Saydam (2003)	Scheduling	LP/MIP	✓	✓	LINDO; Fabric roll sequencing heuristic
Wu and Chang (2003a)	Lot-sizing	MINLP		✓	Genetic Algorithm
Wu and Chang (2003b)	Lot-sizing	MINLP		✓	Genetic Algorithm
Saydam and Cooper (2002)	Scheduling	LP		✓	3-phase general solution approach
Qiu et al. (2002)	Scheduling	MIP		✓	Constraint management heuristic
Wong et al. (2001)	Resource planning	MINLP	✓		Queuing theory models
Maldonado et al. (2000)	Scheduling	MIP		✓	Asymmetric traveling salesman problem heuristic
Wong et al. (2000)	Scheduling	MIP		✓	Genetic Algorithm
Ozdamar (2000)	Cutting	MIP		✓	Simulated annealing
Dumoulin and Vercellis (2000)	Lot-sizing and scheduling	MIP		✓	Lagrangean relaxation
Heckmann and Lengauer (1998)	Cutting	MIP	✓	✓	Greedy strategies; Simulated annealing; Branch-and-bound
Degraeve and Vandebroek (1998)	Cutting	MIP		✓	Enumerative search procedure
Puigjaner et al. (1996)	Batch-processing machine Scheduling	MIP		✓	Constructive heuristics
Serafini (1996)	Scheduling	MIP		✓	Max flow algorithm
Tomastik et al. (1996)	Scheduling	IP		✓	Lagrangian relaxation
Morales et al. (1996)	Scheduling	IP	✓		Branch-and-bound
Duffy et al. (1994)	Cotton production	MIP	✓		Commercial solver
Akinc (1993)	Lot-sizing and scheduling	MIP		✓	Fix-and-optimize
Gunasekaran et al. (1993)	Lot-sizing and scheduling	MIP		✓	Direct pattern search method
Richter (1992)	Cutting	MIP	✓		Dynamic programming
Serafini and Speranza (1992)	Scheduling	MIP		✓	Sweeping algorithm; LP-based heuristic
Mogahzy (1992)	Blending	LP	✓		Simplex
Guinet (1991)	Scheduling	MIP		✓	Hungarian method; Assignment with a re-employment algorithm; Transportation algorithm; Sequential assignment algorithm
Farley (1990)	Cutting	MIP	✓		Three-stage Gilmore–Gomory algorithm
Stern and Avivi (1990)	Scheduling	IP		✓	Early due date sequence; Greedy heuristic
Frendewey and Sumichrast (1988)	Lot-sizing and scheduling	IP		✓	LP relaxation
Bhatnagar (1981)	Lot-sizing	LP	✓		CPLEX
Smirnov et al. (1976)	Transportation	LP	✓		Commercial solver

Table A.3
Major features of the models on yarn manufacturing reviewed papers.

Reference	Item		Period		Machine		Setup		Parameters		Uncertain	Function
	M	S	M	S	M	S	C	T	D	U	data	
Duran et al. (2024)	✓		✓		✓			✓	✓			
Demir (2024)	✓			✓	✓				✓			
Demir (2022)	✓			✓	✓				✓			
Demir and Inan (2022)	✓			✓	✓			✓	✓			
Wei et al. (2022)	✓			✓	✓				✓			
Camargo et al. (2021)	✓		✓		✓		✓	✓	✓			
Biadgligne et al. (2020)	✓			✓		✓			✓			
Chakraborty and Diyaley (2018)	✓				✓				✓			
Efe et al. (2018)	✓			✓					✓			
Rabbani et al. (2016)	✓		✓		✓			✓	✓			
Camargo et al. (2014)	✓		✓		✓		✓	✓	✓			
Zhang et al. (2014)	✓			✓		✓			✓			
Ghosh et al. (2013)	✓			✓					✓			
Hadi-Vencheh and Aghajani (2010)	✓			✓	✓				✓			
Hsu et al. (2009)	✓			✓	✓			✓	✓			
Beraldi et al. (2008)	✓		✓		✓		✓		✓			
Jungwattanakit et al. (2008)	✓		✓		✓			✓	✓			
Karabuk (2008)	✓		✓		✓		✓			✓	Demand	Scenario based
Bhattacharyya et al. (2008)	✓			✓		✓			✓			
Beraldi et al. (2006)	✓		✓		✓		✓			✓	Demand, processing times	Scenario based
Silva and Magalhaes (2006)	✓		✓		✓		✓		✓			
Qiu et al. (2002)	✓		✓		✓							
Gunasekaran et al. (1993)	✓			✓	✓		✓	✓	✓			
Mogahzy (1992)	✓			✓		✓			✓			
Frendewey and Sumichrast (1988)	✓		✓		✓		✓		✓			
Smirnov et al. (1976)	✓		✓		✓				✓			

Caption: M: Multiple S: Single, C: Costs, T: Times, D: Deterministic, U: Uncertain

Table A.4
Objective functions and other considerations on the yarn manufacturing reviewed papers.

Reference	Objective function			Real Data	Others
	Min costs	Max profits	Others		
Duran et al. (2024)			max processed jobs and min capacity usage	✓	Sustainability factors like water and chemical usage
Demir (2024)	✓		min over-capacity usage	✓	Optimization of boiler loading for yarn-dyeing
Demir (2022)	✓		min over-capacity usage	✓	Minimizing the number of batches for ground and pile-type yarn groups
Demir and Inan (2022)			min tardiness and number of boiler washing	✓	Special family group
Camargo et al. (2021)	✓			✓	Allow the decision maker to assign different priorities. Make-to-stock and for make-to-order decisions
Wei et al. (2022)			max production volume and min idle spindles	✓	Optimizing equipment allocation and for make-to-order decisions
Biadgligne et al. (2020)	✓			✓	Measurement of the diameter or linear density of an individual fiber
Chakraborty and Diyaley (2018)			min unevenness, hairiness, and imperfections, max yarn strength		Weight values are assigned to prioritize yarn characteristics
Efe et al. (2018)			min workstations		Age and gender-based workload constraint
Rabbani et al. (2016)		✓		✓	Make-to-order and water consumption constraints
Camargo et al. (2014)	✓			✓	Setup carry-over and micro-periods overlapping constraints
Zhang et al. (2014)			min distance between sample classes	✓	Image processing techniques for blending fibers
Ghosh et al. (2013)			max yarn strength, min cotton fiber quality	✓	Artificial neural network and regression equation to create objective functions
Hadi-Vencheh and Aghajani (2010)		✓	max demand fulfillment, max capacity utilization, and max material efficiency	✓	Workforce availability
Hsu et al. (2009)			min tardiness	✓	Job assignment and predecessor-successor constraints
Beraldi et al. (2008)	✓				Sequence-dependent setup costs, machine assignments and production rates constraints
Jungwattanakit et al. (2008)			min makespan		Constraints for partial schedule on each machine at each stage
Karabuk (2008)	✓			✓	Availability and changes in the number of machines and blends
Bhattacharyya et al. (2008)	✓			✓	Interfiber cohesion
Beraldi et al. (2006)	✓				Non-anticipative constraints
Silva and Magalhaes (2006)	✓			✓	Spinnerets have a limited lifetime
Qiu et al. (2002)		✓		✓	Constraint management
Gunasekaran et al. (1993)	✓			✓	Probability that are determined number of batches at each stage
Mogahzy (1992)	✓				Fiber quality index constraints
Frendewey and Sumichrast (1988)	✓				Overtime production
Smirnov et al. (1976)			max total output	✓	Multi-stage process

Table A.5
Major features of the models on fabric manufacturing reviewed papers.

Reference	Item		Period		Machine		Setup		Parameters		Uncertain	Function
	M	S	M	S	M	S	C	T	D	U	data	
Wang and Zhang (2023)	✓			✓	✓			✓	✓			
Demir (2023)	✓			✓	✓		✓		✓			
Salem et al. (2023)	✓			✓		✓			✓			
Berthier et al. (2022)	✓		✓		✓			✓	✓			
Li et al. (2022)	✓			✓	✓				✓			
Srinath et al. (2022)	✓			✓	✓			✓	✓			
He et al. (2022)	✓									✓	Variables on the process performance	Random forest
Kousar et al. (2022)	✓			✓		✓				✓	Demand, supply parameters,and energy cos	Spherical fuzzy number
Li, Wang, et al. (2021)	✓			✓	✓			✓	✓			
Mourtos et al. (2021)	✓			✓	✓			✓	✓			
Croft et al. (2021)	✓		✓		✓				✓			
Zhou et al. (2020)	✓			✓	✓		✓		✓			
Tayyab et al. (2020)	✓			✓		✓	✓			✓	Random defective rate	
Hu et al. (2020)	✓			✓		✓			✓			
Ke et al. (2019)	✓			✓		✓			✓			
El Hachemi et al. (2018)	✓			✓	✓		✓	✓	✓			
Tsai (2018)	✓			✓	✓		✓					
Wuttke and Heese (2018)	✓			✓	✓			✓	✓			
Campo et al. (2018)	✓		✓		✓				✓			
Zhang et al. (2017)	✓			✓	✓				✓			
Majumdar et al. (2017)	✓			✓		✓			✓			
Lin et al. (2016)	✓			✓		✓			✓			
Gonçalves (2015)	✓			✓		✓			✓			
Silva et al. (2015)	✓			✓	✓				✓			
Eroglu and Ozmutlu (2014)	✓			✓	✓			✓	✓			
Pimentel et al. (2011)	✓		✓		✓				✓			
Sumihartati et al. (2011)	✓			✓		✓		✓	✓			
Azadeh et al. (2010)	✓			✓	✓				✓			
Peric et al. (2009)	✓			✓		✓			✓			
Pimentel et al. (2008)	✓		✓		✓			✓	✓			
Min and Cheng (2006)	✓				✓	✓			✓			
Cooper and Saydam (2003)	✓			✓	✓				✓			
Wu and Chang (2003a)	✓		✓		✓				✓			
Wu and Chang (2003b)	✓			✓		✓			✓			
Saydam and Cooper (2002)	✓			✓	✓				✓			
Wong et al. (2001)	✓			✓					✓			
Maldonado et al. (2000)	✓			✓	✓		✓		✓			
Wong et al. (2000)	✓		✓	✓				✓	✓			
Ozdamar (2000)	✓			✓	✓				✓			
Dumoulin and Vercellis (2000)	✓		✓		✓		✓	✓	✓			
Puigjaner et al. (1996)	✓				✓	✓			✓			
Serafini (1996)	✓			✓	✓				✓			
Morales et al. (1996)	✓			✓		✓	✓		✓			
Akinc (1993)	✓			✓	✓		✓		✓			
Richter (1992)	✓			✓		✓			✓			
Serafini and Speranza (1992)	✓			✓	✓				✓			
Guinet (1991)	✓			✓	✓		✓	✓	✓			
Farley (1990)	✓			✓		✓			✓			
Stern and Avivi (1990)	✓			✓		✓			✓			
Bhatnagar (1981)	✓			✓	✓				✓			

Caption: M: Multiple S: Single, C: Costs, T: Times, D: Deterministic, U: Uncertain

Table A.6
Objective functions and other considerations on the fabric manufacturing reviewed papers.

Reference	Objective function			Real Data	Others
	Min costs	Max profits	Others		
Wang and Zhang (2023)			min makespan		Hybrid flowshop scheduling with batch processing for textile packing
Demir (2023)	✓		min total tardiness, min number of washes		Sequence-dependent setups
Salem et al. (2023)			min of the total fabric area, min total number of cuts		Precedence between cutting pattern and strips
Berthier et al. (2022)			min makespan		Sequence-dependent setup times and precedence constraints
Li et al. (2022)	✓		min lateness		Pollution costs
Srinath et al. (2022)			min makespan, min lateness, min total setup time, max scheduling preferences, min shade inconsistencies		Job-machine eligibility and shade consistency and transitions
He et al. (2022)	✓		max quality, max productivity		Multi-agent aspects
Kousar et al. (2022)	✓			✓	Availability of total working time and production rate
Li, Wang, et al. (2021)			min tardiness	✓	Sequence-dependent setup times
Mourtos et al. (2021)			min makespan	✓	Job splitting and sequence-dependent setup times
Croft et al. (2021)			min makespan, min net freshwater consumption	✓	Water Network Constraints
Zhou et al. (2020)	✓			✓	Sequence-dependent setup times
Tayyab et al. (2020)	✓			✓	Sequence-dependent setup costs and defective proportion
Hu et al. (2020)			min length	✓	Optimal sheet utilization without part overlap
Ke et al. (2019)	✓				Concentration of the hydrogen peroxide, temperature and treatment time
El Hachemi et al. (2018)	✓		min total cleaning time, min waiting time	✓	Maximum waiting time
Tsai (2018)		✓		✓	Batch-level activity constraints and carbon tax function
Wuttke and Heese (2018)			min total time	✓	Sequence-dependent setup times and permissible tolerances
Campo et al. (2018)	✓			✓	Employee training requirements
Zhang et al. (2017)	✓		max machine utilization		Incapable machines for jobs
Majumdar et al. (2017)			max air permeability, max thermal conductivity		Loop length, carriage speed, yarn input tension, and yarn count
Lin et al. (2016)			min material waste		Stock utility
Gonçalves (2015)			min total area of fabric		Customer-specified small fabric rectangle with specified width and length
Silva et al. (2015)			min waste		Minimum length for each cutting pattern
Eroglu and Ozmutlu (2014)			min makespan		Precedence between jobs on the same machine
Pimentel et al. (2011)			min tardiness		Deviations between product completion time and component completion time
Sumihartati et al. (2011)			min setup time		Sequence-dependent setup times
Azadeh et al. (2010)			min tardiness, min makespan		Required number of controller workers
Peric et al. (2009)			min waste, min production time		Selection of the criteria for optimization of fabric cutting
Pimentel et al. (2008)	✓				Deviations between product completion time and component completion time
Min and Cheng (2006)	✓			✓	Undetermined common due date
Cooper and Saydam (2003)			max machine utilization	✓	Fabric handling constraint
Wu and Chang (2003a)		✓		✓	Water balance constraint
Wu and Chang (2003b)		✓		✓	Grey input–output
Saydam and Cooper (2002)			max machine utilization, min delays	✓	Regulate the allowable differences in strand lengths
Maldonado et al. (2000)	✓				Sequence-dependent setup costs
Wong et al. (2000)			min makespan and idle time	✓	Feasible schedules between fabric lays
Ozdamar (2000)		✓		✓	Allocation of pieces to quality levels and rolls
Dumoulin and Vercellis (2000)	✓			✓	Resource absorption limitations
Puigjaner et al. (1996)	✓				Mixed intermediate storage
Serafini (1996)			min tardiness		Job preemption and job splitting
Morales et al. (1996)	✓				Photocolorimetric differences
Akinc (1993)		✓		✓	Shift hours are adjusted for efficiency, utilization, and schedule non-production activities
Richter (1992)		✓	min unusable rest		Profit parameters for units of single pieces
Serafini and Speranza (1992)			min tardiness		Job preemption and job splitting
Guinet (1991)	✓		min sum of job completion dates min processing time		Sequence-dependent setup times
Farley (1990)			min waste on each strip	✓	Total length of roll required to produce unit
Stern and Avivi (1990)		✓			Job preemption and job splitting
Bhatnagar (1981)	✓			✓	Machine shift count for pre weaving centers

Table A.7
Major features of the models on apparel manufacturing reviewed papers.

Reference	Item		Period		Machine		Setup		Parameters		Uncertain	Function
	M	S	M	S	M	S	Costs	Time	D	U	data	
Malik et al. (2022)	✓			✓	✓				✓			
Wang et al. (2022)	✓			✓	✓				✓			
Eliguzel et al. (2021)	✓				✓				✓			
Sumathy and Amirthalingam (2021)	✓			✓					✓			
Ghosh et al. (2020)		✓		✓	✓				✓			
Tsao et al. (2020)	✓			✓		✓	✓		✓			
Ünal and Yüksel (2020)	✓			✓		✓			✓			
Xu et al. (2020)	✓			✓		✓			✓			
Sánchez-Herrera et al. (2019)	✓			✓		✓			✓			
Zhang and Chen (2019)	✓			✓	✓				✓			
Zhang et al. (2019)	✓			✓	✓				✓			
Tsai and Jhong (2019)	✓			✓	✓				✓			
Shang et al. (2019)	✓			✓		✓			✓			
Pereira (2018)	✓			✓	✓		✓		✓			
Elmehanny et al. (2018)	✓		✓						✓			
Du et al. (2018)	✓			✓	✓					✓	Daily production quantity	
Zaharie et al. (2017)	✓		✓		✓				✓			
Celikbilek et al. (2016)	✓			✓		✓			✓			
Wang et al. (2016)	✓			✓	✓				✓			
Gürsoy and Gürsoy (2015)	✓			✓	✓				✓			
Hu et al. (2015)		✓		✓		✓				✓	Try on times	Randomly generated
Hung et al. (2014)	✓			✓		✓			✓			
Gürsoy (2012)	✓			✓	✓				✓			
Ünal and Koç (2010)	✓			✓		✓			✓			
de Armas et al. (2008)	✓			✓		✓			✓			
Guo et al. (2006)	✓			✓	✓				✓			
Ghiani et al. (2003)	✓		✓		✓		✓			✓	Worker productivity	Triangular fuzzy numbers
Heckmann and Lengauer (1998)	✓			✓		✓			✓			
Degraeve and Vandebroek (1998)	✓			✓		✓			✓			
Tomastik et al. (1996)	✓			✓	✓			✓	✓			

Caption: M: Multiple S: Single, D: Deterministic, U: Uncertain

Table A.8
Objective functions and other considerations on the apparel manufacturing reviewed papers.

Reference	Objective function				
	Min costs	Max profits	Others	Real Data	Others
Malik et al. (2022)			min the sum of undesired relative deviations, min the maximum relative deviation, min the range of unachieved goals	✓	Maximum limit of unsatisfied goals
Wang et al. (2022)			min total energy consumption		Lower and upper bounds on the makespan
Eliguzel et al. (2021)			min distance	✓	P-median and K-means models
Sumathy and Amirthalingam (2021)			min the number of staff	✓	One type of shift
Ghosh et al. (2020)		✓		✓	Manufacturing lead time constraints
Tsao et al. (2020)	✓				Layers in each section must fall within the specified range
Ünal and Yüksel (2020)			min total usage of fabric	✓	Maximum number of plies per spreading
Xu et al. (2020)	✓			✓	Mass customization
Sánchez-Herrera et al. (2019)			min tardiness	✓	Processing times are affected by the deteriorating effect
Zhang and Chen (2019)			min time loss rate, min smoothness index	✓	Material consumption, energy consumption, carbon emission and labor consumption.
Zhang et al. (2019)			min transfer distance of the semi-finished products, min the area occupied by the assembly line	✓	Three assembly line layotus
Tsai and Jhong (2019)		✓		✓	Batch-level activity constraints and carbon tax function
Shang et al. (2019)			min number of total used lays		Maximum allowed fabric length and layer number of the cutting bed
Pereira (2018)	✓			✓	Cycle time and precedence constraints
Elmehanny et al. (2018)		✓		✓	Make-to-order and mak-to-stock products
Du et al. (2018)			min tardiness, min total preproduction event clashes	✓	Preproduction events
Zaharie et al. (2017)	✓		min total earliness	✓	Order can be accepted, adjusted or rejected
Celikbilek et al. (2016)			min tardiness, min the number of tardy jobs	✓	Waiting times
Wang et al. (2016)			min makespan		Specific scenarios of fabric lay overlay
Gürsoy and Gürsoy (2015)			min idle time		Flexible operations
Hu et al. (2015)			min traveling time	✓	Try on services
Hung et al. (2014)			min cut piece WIP		Epoch break points
Gürsoy (2012)			min idle time		Flexible and non-flexible operations
Ünal and Koç (2010)	✓		min softness, max weft breaking strength, min hydrophility		Physical and performance properties
de Armas et al. (2008)		✓		✓	Reduce waste
Guo et al. (2006)	✓			✓	Operation precedence
Ghiani et al. (2003)			min the reduction of orders, min the average setups, max overall goods quality	✓	Throughput and quality of finished goods
Heckmann and Lengauer (1998)			min the length of the surface	✓	Computing cutting images and lower bounds on waste
Degraeve and Vandebroek (1998)	✓			✓	Maximum length and high of the stack
Tomastik et al. (1996)			min tardiness and earliness	✓	Flexible manufacturing system

Table A.9
Problem characteristics related to supply chain textile manufacturing.

Reference	Problem	Model	Solution approach		
			Exact	Approximate	Method/Tool
Kian et al. (2024)	Green Product Processes	MOMIP	✓	✓	GAMS; Genetic Algorithm
Shefa et al. (2024)	Location allocation	MIP	✓	✓	Commercial solver
Ali and Zhang (2023)	Supplier selection	FMOLP	✓		LINGO
Mezatio et al. (2023a)	Sustainable SC Network design	MINLP	✓		CPLEX
Mezatio et al. (2023b)	Sustainable SC Network design	MINLP	✓		CPLEX
Yaghin and Sarlak (2022)	Tactical production planning	FMOLP		✓	Credibility chance constraint programming
Yaghin and Darvishi (2022)	Integrated textile material and production management	FMOMINLP		✓	Three-stage hybrid algorithm
Mas'ud and Wahid (2022)	Resilient supply chain	LP	✓		LINGO
Mezatio et al. (2022)	Sustainable SC Network design and supplier selection	MIP	✓		CPLEX
Abbas et al. (2021)	Sustainable energy supply	LP	✓		AIMMS
Sarma et al. (2021)	Resilient retail supply chain	GP		✓	Theory of constraints and business secnario
Paydar et al. (2021)	SC Network design	MOSLP	✓		LINGO; Downside risk management
Safra et al. (2021)	Production and distribution planning	IP	✓		CPLEX
Tayyab and Sarkar (2021)	Supplier Selection	FMOMIP	✓		LINGO
Wang et al. (2021)	Production and distribution planning	MOMISP	✓		CPLEX
Ghasemy Yaghin et al. (2020)	Aggregate production and transportation planning	FSMINLP	✓		Generalized geometric programming; GAMS; IPOPT/MINOS solver
Darvishi et al. (2020)	Aggregate production and transportation planning	FSMINLP	✓		Linearization; Robust optimization; GAMS
Ghasemy Yaghin (2020)	Aggregate production planning	FMINLP	✓	✓	Scenario-based two-stage stochastic programming; Fuzzy credibility-based chance constraints; GAMS and BARON solver; Hybrid solution algorithm
Karami et al. (2020)	Supplier Selection	LP		✓	Integrated DEA-PCA-VIKOR approach
Berthier et al. (2020)	SC Network design	MIP	✓		CPLEX
Moreno-Camacho et al. (2020)	Sustainable SC Network design	MIP	✓		GAMS/CPLEX
Ghasemy Yaghin and Darvishi (2019)	Order allocation and procurement transport planning	FMOMIP	✓	✓	Fuzzy multi-choice goal programming; Isolating the non-convexities; GAMS and BARON solver; Hybrid solution algorithm
Safra et al. (2019)	Production and distribution planning	IP	✓		CPLEX
Ghasemy Yaghin and Sarlak (2019)	Supplier selection, order allocation, transportation planning	FMOMINLP	✓		CPLEX
Zheng and Song (2019)	Capacity allocation	MIP	✓		CPLEX
Khannan et al. (2018)	Warehouse allocation	LP	✓		LINGO
Kayvanfar et al. (2018)	Supply distribution	FMOGP	✓		CPLEX
Jatuphatwarodom et al. (2018)	Supplier selection and inventory optimization	MOGP	✓		LINGO
Felfel et al. (2018)	Production and distribution planning	MISP/ MOMISP	✓		Conditional-value-at-Risk; Downside risk management; Pareto optimal solutions; LINGO
Demirel et al. (2018)	Aggregate production planning	MIP	✓		CPLEX
Masoudipour et al. (2017)	Closed-loop supply chain	MOMINLP	✓		Linearization; CPLEX
Hashim et al. (2017)	Supplier Selection	FMOMIP		✓	Genetic algorithm
Jafari et al. (2017)	Sustainable SC Network design	MOMIP		✓	Pareto-based approach
Li et al. (2017)	Location allocation	MIP		✓	Bee colony algorithm
Felfel et al. (2016a)	Production and distribution planning	MOMIS	✓	✓	Epsilon-constraint method; Minimax method 3. LINGO
Felfel et al. (2016b)	Production and distribution planning	MOMISP	✓	✓	Pareto optimal robust solutions
Felfel et al. (2015)	Production and distribution planning	MISP		✓	LINGO
Jakhar (2015)	Performance evaluation and allocation decisions	FMOLP		✓	Fuzzy-AHP; LINDO
Saghaei et al. (2014)	Supplier selection	MINLP		✓	LINGO
Ait-Alla et al. (2014)	Production planning	MIRP		✓	Conditional-value-at-Risk; Frontline risk solver
Oh and Jeong (2014)	Closed-loop supply chain	MOMIP		✓	CPLEX
Bouzembrak et al. (2013)	SC Network design	FMIP		✓	Equivalent crisp model; CPLEX
Shaw et al. (2013)	Sustainable SC Network design	GP		✓	LINGO
Ying-Hua (2010)	SC Network design	MIP	✓	✓	LINGO; Genetic algorithm
Caro and Gallien (2010)	Distribution and inventory planning	MISP/MIP		✓	Approximation heuristic
Karabuk (2007)	Transportation planning	IP	✓		CPLEX; Column generation
Araz et al. (2007)	Supplier selection	FGP	✓		Integrated multicriteria decision-making method
Leung et al. (2007)	Aggregate production planning	RP		✓	LINDO
Leung et al. (2006)	Aggregate production planning	MISP		✓	LINDO
Leung et al. (2003)	Aggregate production planning	GP		✓	LINDO; Analytical hierarchy process
De Toni and Meneghetti (2000)	Production planning	MIP	✓	✓	CPLEX; Constructive heuristic
Guan et al. (2000)	Aggregate production planning	FMIP	✓		Equivalent crisp model; CPLEX

Table A.10
Major features of the models on the textile supply chain in reviewed papers.

Reference	Site		Item		Period		Supplier		Customer		Distri-	Parameters		Uncertain	Function
	M	S	M	S	M	S	M	S	M	S	bution	D	U	data	
Kian et al. (2024)	✓		✓		✓		✓		✓		✓	✓			
Shefa et al. (2024)	✓		✓			✓	✓		✓		✓	✓			
Ali and Zhang (2023)	✓		✓			✓	✓			✓			✓	Transportation risks, supplier performance, exchange rates	Fuzzy (triangular fuzzy numbers)
Mezatio et al. (2023a)	✓		✓			✓	✓		✓		✓	✓			
Mezatio et al. (2023b)	✓		✓			✓	✓		✓		✓	✓			
Yaghin and Sarlak (2022)	✓		✓		✓		✓				✓		✓	purchasing prices, costs, carbon emission levels, demand, capacities, and labor levels	Fuzzy (trapezoidal possibility distribution)
Yaghin and Darvishi (2022)	✓		✓		✓		✓				✓		✓	purchasing prices, supplier scores, late deliveries, exchange rate, costs, and capacities	Fuzzy (triangular possibility distribution)
Mas'ud and Wahid (2022)	✓		✓			✓					✓	✓			
Mezatio et al. (2022)	✓		✓			✓	✓		✓		✓	✓			
Abbas et al. (2021)	✓		✓		✓		✓			✓	✓	✓			
Sarma et al. (2021)	✓		✓			✓						✓			
Paydar et al. (2021)	✓		✓		✓		✓				✓		✓	demand and price	Scenario based generation
Safra et al. (2021)	✓		✓		✓		✓				✓	✓			
Tayyab and Sarkar (2021)	✓		✓		✓		✓				✓		✓	Customer complaints	Fuzzy (triangular fuzzy numbers)
Wang et al. (2021)	✓		✓		✓		✓		✓		✓		✓	Demand	Scenario based generation
Ghasemy Yaghin et al. (2020)	✓		✓		✓		✓				✓		✓	selling prices,costs, production time and safety stock	Scenario based generation and Fuzzy trapezoidal possibility distribution
Darvishi et al. (2020)	✓		✓		✓		✓				✓		✓	Demand, Inventory cost, exchange rate, volume of fabric rolls, production capacity, inventory capacity, labor costs, and transportation variable cost	Fuzzy (symmetric triangular fuzzy numbers)
Ghasemy Yaghin (2020)	✓		✓		✓		✓								
Karami et al. (2020)		✓	✓			✓						✓			
Berthier et al. (2020)	✓		✓			✓	✓					✓			
Moreno-Camacho et al. (2020)	✓		✓			✓	✓		✓		✓	✓			
Ghasemy Yaghin and Darvishi (2019)		✓	✓			✓	✓				✓		✓	maximum transportation cost, purchasing price, percentage of late deliveries, suppliers capacity, total purchase of fabrics, percentage discounts, number of hole per fabric roll and preferential weight	Fuzzy (symmetric triangular fuzzy numbers)
Safra et al. (2019)	✓		✓		✓		✓				✓	✓			
Ghasemy Yaghin and Sarlak (2019)	✓		✓			✓	✓				✓		✓	transportation cost, purchasing cost, demand, transportation pollution, water pollution, energy consumption and lead time	Fuzzy (trapezoidal possibility distribution)
Zheng and Song (2019)	✓		✓		✓		✓		✓		✓	✓			
Khannan et al. (2018)	✓		✓			✓	✓		✓		✓	✓			
Kayvanfar et al. (2018)	✓		✓		✓		✓		✓		✓		✓	demand	Fuzzy (triangular fuzzy numbers)
Jatuphatwarodom et al. (2018)							✓								
Felfel et al. (2018)	✓		✓		✓		✓				✓		✓	demand and price	Scenario based generation
Demirel et al. (2018)		✓	✓		✓							✓			
Masoudipour et al. (2017)	✓			✓		✓	✓		✓			✓			
Hashim et al. (2017)		✓	✓		✓		✓							cost, demand, and quality	Fuzzy (triangular fuzzy numbers)
Jafari et al. (2017)	✓		✓			✓			✓		✓	✓			
Li et al. (2017)	✓				✓				✓			✓			
Felfel et al. (2016a)	✓		✓		✓				✓		✓	✓			
Felfel et al. (2016b)	✓		✓		✓				✓		✓	✓		demand	Scenario based generation
Felfel et al. (2015)	✓		✓		✓				✓		✓		✓	demand	Scenario based generation
Jakhar (2015)	✓			✓	✓		✓				✓		✓	parameters of the five objective functions	Fuzzy (triangular fuzzy numbers)
Saghaei et al. (2014)	✓		✓			✓		✓							
Ait-Alla et al. (2014)	✓		✓		✓						✓		✓	demand	Scenario based generation
Oh and Jeong (2014)	✓			✓	✓		✓		✓		✓	✓			
Bouzembrak et al. (2013)	✓			✓		✓	✓				✓		✓	demand, opening costs, transportation costs, treatment costs, and storage costs	Fuzzy (triangular fuzzy numbers)
Shaw et al. (2013)	✓			✓		✓	✓		✓		✓	✓			
Ying-Hua (2010)	✓		✓			✓	✓		✓		✓	✓			
Caro and Gallien (2010)	✓		✓			✓					✓		✓	Demand	Function of demand forecasts
Karabuk (2007)	✓			✓		✓			✓		✓	✓			
Araz et al. (2007)		✓	✓		✓		✓						✓	objective function	Fuzzy goals membership function
Leung et al. (2007)	✓		✓		✓								✓	Demand, labor hiring and lay-offs	
Leung et al. (2006)	✓		✓		✓								✓	Demand, production time and costs, inventory costs, shortage costs	
Leung et al. (2003)	✓		✓		✓										
Guan et al. (2000)		✓		✓	✓								✓	Capacity levels	
De Toni and Meneghetti (2000)	✓		✓			✓						✓		capacity plants	Fuzzy (Verdegay's non-symmetric approach)

Table A.11
Objective functions and other considerations on the textile supply chain in reviewed papers.

References	Objective function					Real	Other considerations
	Number		Min	Max	Others		
	S	M	costs	profits		Data	
Kian et al. (2024)		✓	✓		min production time, min environmental impact	✓	Green suppliers and purifiers stages
Shefa et al. (2024)	✓		✓			✓	Wastewater management
Ali and Zhang (2023)		✓	✓		min delivery late, min transportation risks, min defect rate	✓	Carbon emission, rejection rate, quality assurance
Mezatio et al. (2023a)	✓		✓				Several sources of energy, fuel consumption and travel speeds
Mezatio et al. (2023b)	✓		✓				Carbon emission, life cycle assessment
Yaghin and Sarlak (2022)		✓	✓	✓	max total social value of purchasing min late deliveries min carbon emission tax	✓	Carbon emission and social responsibility
Yaghin and Darvishi (2022)		✓	✓		max total value of purchasing, min late deliveries	✓	Supplier selection, order allocation, inbound transportation
Mas'ud and Wahid (2022)	✓		✓			✓	COVID-19 impact on supply chain,Digital disruption
Mezatio et al. (2022)	✓		✓				Carbon emission
Sarma et al. (2021)		✓			max performance from the stores	✓	COVID-19 impact on supply chain
Paydar et al. (2021)	✓	✓		✓	min risk of having a low net profit	✓	Downside risk (DRisk) to manage uncertainty
Abbas et al. (2021)	✓		✓			✓	Sustainable energy supply using cotton crop waste
Safra et al. (2021)	✓		✓			✓	Tactical and operational decisions
Ghasemy Yaghin et al. (2020)	✓			✓		✓	Procurement and social responsibility plannings
Darvishi et al. (2020)	✓		✓			✓	Suppliers election, order allocation, inbound transportation logistics with cross-docking
Ghasemy Yaghin (2020)	✓			✓		✓	Marketing/retailing planning
Karami et al. (2020)	✓				min sum of dual variables	✓	Quantitative and qualitative decision-making criteria
Berthier et al. (2020)	✓		✓			✓	
Moreno-Camacho et al. (2020)	✓		✓			✓	Carbon emission
Ghasemy Yaghin and Darvishi (2019)		✓	✓	✓	max total social value of purchasing min delivery lead time min air and water pollution min energy consumption	✓	Social responsibility
Safra et al. (2019)	✓		✓			✓	Tactical and operational decisions
Ghasemy Yaghin and Sarlak (2019)		✓	✓	✓	min late deliveries	✓	Social responsibility
Zheng and Song (2019)	✓				max utilization of shared resources	✓	Entropy maximization
Khannan et al. (2018)	✓		✓			✓	Cross-docking, reserve, and forward areas
Kayvanfar et al. (2018)		✓	✓		max rate of demand satisfaction max delivery quality	✓	Using Third-party logistics (3PL)
Jatuphatwarodom et al. (2018)	✓				min sum of deviations from the similarity goals and consistency goals	✓	Quantitative and qualitative decision-making criteria
Felfel et al. (2018)				✓		✓	Risk aversion
Demirel et al. (2018)	✓		✓			✓	Flexible Requirements Profile
Masoudipour et al. (2017)	✓			✓		✓	Quality of returns
Hashim et al. (2017)		✓	✓		max suppliers environment friendly product quality	✓	Green raw materials
Jafari et al. (2017)		✓	✓		min water consumption, max number of employment opportunities		Water consumption, Justice-oriented employment
Li et al. (2017)	✓		✓			✓	Reverse logistics network system
Felfel et al. (2016a)		✓	✓		max product quality	✓	Multi stage problem and product quality
Felfel et al. (2016b)		✓	✓		min lost demand level	✓	Multi stage problem and semi-finished products
Felfel et al. (2015)	✓			✓		✓	Semi-finished products
Jakhar (2015)		✓	✓		max total value of sustainable performances; min carbon emission	✓	Sustainable supply chain
Saghaei et al. (2014)	✓			✓		✓	Quality improvement of the supply chain
Ait-Alla et al. (2014)	✓			✓		✓	Conditional value at risk
Oh and Jeong (2014)	✓			✓		✓	Carbon emission
Bouzembrak et al. (2013)	✓		✓			✓	
Shaw et al. (2013)		✓	✓		min carbon emission max trade credit	✓	Carbon emission
Ying-Hua (2010)	✓		✓			✓	

(*continued on next page*)

Table A.11 (*continued*).

References	Objective function					Real	Other considerations
	Number		Min	Max	Others		
	S	M	costs	profits		Data	
Caro and Gallien (2010)	✓				max overall predicted sales	✓	
Karabuk (2007)	✓				Model LTL1: min the total of trailer imbalances Model LTL2 min distance Model TL min empty travel distance	✓	Full truckload (TL) and less than full truckload (LTL) shipments
Araz et al. (2007)		✓	✓		max ordered quantities to the highest performing suppliers; max number of accepted units max quantities ordered from each supplier		Evaluation criteria for the suppliers and the objectives of the company
Leung et al. (2007)	✓		✓			✓	Warehouse to storage products
Leung et al. (2006)	✓		✓			✓	Regular-time production, overtime production and subcontracting cost
Leung et al. (2003)		✓	✓	✓		✓	Hiring and layoff goal, hierarchy priority for objective functions
De Toni and Meneghetti (2000)	✓				max capacity loading of the knitting firms	✓	Time-based competition
Guan et al. (2000)	✓		✓			✓	Seasonal demand
Caption:	M: Multiple						

Data availability

Data will be made available on request.

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