

Design for Circularity in The Textile Sector: Key Influencers and Trends

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Abstract

Circular design in the textile industry aims to minimize waste by increasing resource efficiency and creating a sustainable production process by enabling products to be reused, repaired, and recycled. Therefore, circular design is crucial for ensuring the sustainability of the textile industry, as it helps reduce waste and use natural resources more efficiently. This study aims to define and elaborate on the main drivers and their linkages for the transition to circularity in the textile sector. Criteria will be identified from the literature, and the ISM method will be used to analyze the relationships among key factors for circularity in the textile sector. Based on the results, new circular business models and solutions for recycled/secondary raw materials should be developed to ensure and increase the vitality of this market. By providing valuable insights into sustainable practices, circular design principles, and strategies for reducing environmental impacts while promoting long-term economic viability, this study will be useful to policymakers and managers in the textile sector.

Keywords

Circular economy, sustainable product design factor, eco-friendly design, ISM

1. Introduction

Circular design of textiles means designing textiles so that they last longer, produce less waste throughout their lifecycle, are non-toxic, and can be recycled (Dissanayake, 2021). Circular textiles and fashion design promote the use of sustainable technologies and energy- and water-efficient finishing processes, which can contribute not only to better recyclability of the final product but also to a lower overall environmental impact of production (MacArthur, 2017).

Circular design in the textile sector plays an important role in reducing the sector's environmental impact (Rayhan et al., 2026). By prioritizing sustainable materials, waste reduction, and closed-loop production processes, it minimizes the consumption of natural resources, reduces carbon emissions, and prevents textile waste from going to landfills. In addition, recycling, reuse, and material reduction, along with the need for raw materials and energy-intensive production processes, contribute to a more environmentally friendly and resource-efficient textile industry (Pranta et al., 2025; Catarino et al., 2025).

Circular design is of great importance to Turkey for reducing the textile sector's environmental impact and achieving sustainable growth (Enginkaya et al., 2026). The textile sector is one of the largest industrial sectors in Turkey, and its heavy reliance on natural resources and production of waste places a heavy burden on the environment. Adopting circular design both minimizes the negative impact on the ecosystem by reducing pollution and provides economic benefits (Cancela et al., 2026). This approach can encourage local manufacturers to use resources more efficiently while contributing to Turkey's global sustainability goals.

The study's research questions are presented below.

- RQ1: What are the key success factors for the transition to circularity in the textile sector?
- RQ2: How can we investigate linkages of the key success factors for accelerating circularity in the textile sector?

This study aims to examine the key success factors driving accelerated circularity in the textile sector and investigate the linkages among these factors to achieve it. To achieve this aim, ten different key success factors are provided through a literature review. Then, Interpretive Structural Modeling (ISM) methodology is used to analyze the relationships between these success factors. Investigating these factors' interactions is important for accelerating circularity in the textile sector and for identifying key influencers and trends.

This paper is organized as follows: After the introduction, Section 2 discusses the literature review. Section 3 provides the research methodology; sections 4 and 5 present the results, discussion and conclusions, respectively.

2. Literature Review

Key success criteria for accelerating circularity in the textile sector are presented in Table 1.

Table 1. Key success criteria for accelerating circularity in the textile sector

#	Key success criteria	References
1	Design innovation and improving the disassembly and recyclability	Teixeira et al. (2023)
2	Using sustainable materials in the production	Akter et al. (2022)
3	Creating local production and green distribution models	Jensen & Whitfield (2022)
4	Encouraging on-demand custom	Lee (2021)
5	Development of the circular design strategies	Majumdar et al. (2022)
6	Innovative technologies for customer-driven design	Ramírez-Escamilla et al. (2024)
7	Providing better water management and water quality	Gomes et al. (2024)
8	Increased customer awareness	Ramírez-Escamilla et al. (2024)
9	Reducing the industry's environmental footprint	Li et al. (2024)
10	Traceability and transparency in the process	Garcia-Torres et al. (2024)

3. Methods

This paper used the ISM approach to investigate the relationships among the factors listed above. Warfield (1974) first introduced the Interpretive Structural Modeling (ISM) technique, employing fundamental concepts of graph theory. The application of ISM has been considered an effective technique for analyzing relationships among factors and for explaining their linkages. The ISM method is a technique for analyzing complex systems and understanding their relationships. The ISM method is a powerful tool, especially in areas such as system analysis and management, and these advantages can make decision-making processes more effective. ISM is an analytical tool that helps structure and analyze the interrelationships among a set of factors within a complex system. With its help, managers can learn the hierarchy and interrelation of variables, distinguish between drivers and dependent variables, and build a logical framework from a complex situation. By systematically applying expert knowledge, ISM improves communication among stakeholders, supports strategy planning, and provides a strong foundation for other analytical tools. This method guides managers and decision-makers in prioritizing and making strategic decisions. Identifying key factors in the system and understanding their effects enables more informed decision-making (Figure 1).

Step 1: Development of a Structural Self-Interaction Matrix (SSIM).

Step 2: Development of the reachability matrix.
 Step 3: Presenting the development of level partitions.
 Step 4: Developing a Conical Matrix
 Step 5: Creating a digraph.
 Step 6: ISM Model Framework

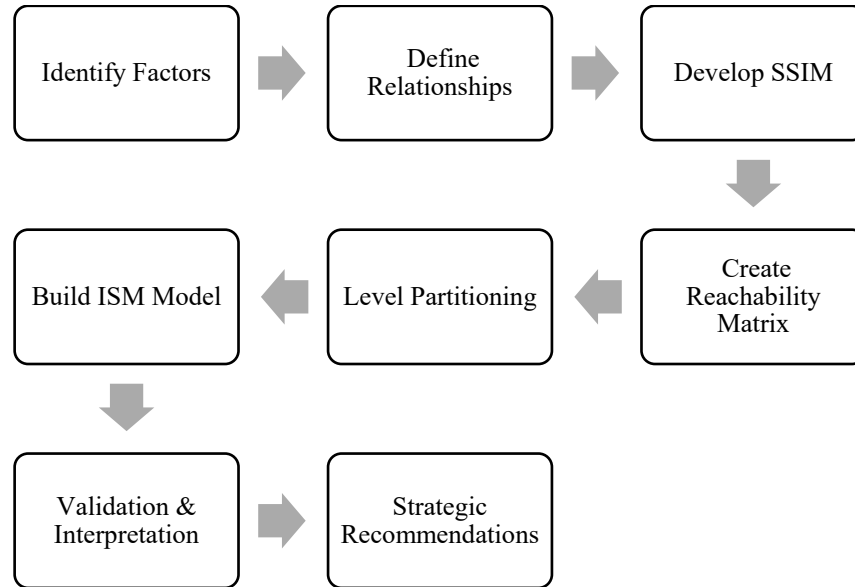


Figure 1. Flowchart of the Interpretive Structural Modeling (ISM) methodology

Thus, the ISM method has been adopted to analyze and structure the interrelationships among the identified factors in this research. ISM is a proven method that enables complex, vague systems to be converted into a hierarchy of such systems using experts' judgment. The first step in the ISM method involved identifying appropriate factors through a literature review and expert consultation. Thereafter, relationships among the factors in the context were established using the Structural Self-Interaction Matrix (SSIM). The SSIM was further transformed into a reachability matrix, and a transitivity check was done. Using the reachability matrix, level partitioning was performed to determine the hierarchy of the factors. Finally, a digraph for ISM was prepared.

4. Results and Discussion

The study's implementation and results are presented in this section.

Table 2. Expert Information from the Industry

Experts	Experience (year)
Textile Engineer	8
R&D Engineer	10
Sustainability Specialist	5
Environmental Engineer	8
Quality Control Engineer	9
Production Engineer	6
R&D Engineer	9

These evaluations were gathered from industry experts with several years of experience, whose expertise is reflected in Table 2. The opinions of these experts served as a basis for analyzing the relationships among these variables within the context of the ISM model. A structured self-interaction matrix is presented in Table 3.

Table 3. Structured Self-Interaction Matrix

i, j	V10	V9	V8	V7	V6	V5	V4	V3	V2
V1	V	0	A	A	A	A	V	A	V
V2	0	V	0	A	V	A	0	A	1
V3	V	V	A	V	A	A	0	1	
V4	A	A	0	A	A	A	1		
V5	V	A	A	0	0	1			
V6	A	A	V	A	1				
V7	V	0	A	1					
V8	0	A	1						
V9	A	1							
V10	1								

Table 4 designates the final reachability matrix.

Table 4. Final Reachability Matrix

i, j	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	Driving Power
V1	1	1	0	1	0	1*	0	0	1*	1	6
V2	1*	1	1*	1*	1*	1	0	1*	1	0	8
V3	1	1	1	1*	1*	1*	1	1*	1	1	10
V4	0	0	0	1	0	0	0	0	0	0	1
V5	1	1	1	1	1	1*	1*	1*	1*	1	10
V6	1	1*	1	1	1*	1	1*	1	1*	0	9
V7	1	1	1*	1	1*	1	1	1*	1*	1	10
V8	1	1*	1	1*	1	1*	1	1	1*	1*	10
V9	1*	1*	1*	1	1	1	1*	1	1	1*	10
V10	1*	1*	1*	1	1*	1	1*	1*	1	1	10
Dependence	9	9	8	10	8	9	7	8	10	7	

Table 4 shows the reachability matrix after transitivity is added to the original reachability matrix. The driving power and dependence of the variables were computed from the sums of rows and columns, respectively. From the results, it can be seen that V3, V5, V7, V8, V9, and V10 have the highest driving power value of 10, indicating that these variables dominate the others in the system. Conversely, the variable that has the least driving power of 1 is V4. The driving power of V4 was the least (1), indicating that it has little impact on other variables and is rather influenced by interactions among other factors.

Driving Power	10							10,7	3,5,8		9
	9									6	
	8									2	
	7										
	6									1	
	5										
	4										
	3										
	2										
	1										4
		1	2	3	4	5	6	7	8	9	10
Dependence											

Figure 2. MICMAC Analysis

In the MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) method, variables are assessed along two basic dimensions: influence and dependence measures. Influence measures indicate how much one variable influence another, while dependence shows how much one variable is influenced by others (see Figure 2). The "Encouraging on-demand custom" factor is the dependent variable, while the other variables are considered linkage variables. The dependent variable is the variable in a system that is highly influenced by other variables but does not significantly affect them. It exhibits high dependence and low influence, and represents the system's outcomes.

5. Conclusion

This study aims to investigate the key success factors driving increased circularity in the textile sector and explore their linkages. ISM analysis showed that "Encouraging on-demand custom production" was the dependent variable characterized by high dependence and low driving power. Thus, according to the results, the introduction of on-demand custom production within the textile industry was not the driver of the circular economy but rather the result of its effective implementation, serving as another driver or a combination of multiple circular economy drivers.

From the perspective of the circular economy, this result indicates that on-demand custom production should be seen as the outcome of transformations within the textile industry rather than as their trigger. In light of rising consumer demand for customized products and increasing pressure on sustainability, on-demand production can help avoid overproduction and waste and enhance resource efficiency. Yet, implementing such an approach would require additional support from various technological, organizational, and marketing factors. It can be concluded that on-demand, customized production requires the use of innovative technologies to make the production process customer-centric, including advanced data analytics, AI-enabled demand forecasting, and digital design solutions. This dependency demonstrates that on-demand manufacturing can be achieved only through sustainable production systems that incorporate efficient resource use and waste reduction to minimize the industry's ecological impact. This finding also means that an integrated, open supply chain system is necessary to drive on-demand customization in the textile sector. Moreover, on-demand customization is closely linked to shifts in consumer preferences toward individualization and sustainable consumption. From a circular economy perspective, on-demand production is important for reducing overproduction and textile waste; however, its application depends on the development of other circular economy enablers.

Policymakers should develop different policies and strategies to minimize waste through incentives and tax reductions. It should be ensured that production processes aimed at minimizing waste are adopted, and that studies are conducted to enable design innovation tailored to each product type. New circular business models and solutions for recycled/secondary raw materials should be developed to ensure and increase the vitality of this market. The implementation of design-oriented training and awareness should be increased to equip customers with responsibility, through training and seminars across various sectors, to achieve circularity in design.

The limitations of the study can be summarized as follows. ISM is generally a static modeling approach. In the future, dynamic ISM models can be developed to include systems that change and evolve over time. Additionally, ISM is a modeling method often based on expert opinions. This may affect the model's accuracy and reliability because different experts may interpret the data differently. ISM may have difficulty identifying relationships between factors. In some cases, the relationships between factors can be quite complex and difficult to model accurately. The success

of ISM depends on selecting the right factors and data. Determining the right relationships can be time-consuming and difficult.

In the future, dynamic ISM models can be developed to analyze how the system evolves over time and the effects of different variables. For this purpose, the methodology can be expanded with various simulation models. Since ISM is based on expert opinions and subjective, integrating ISM with machine learning algorithms can increase the model's accuracy and allow meaningful conclusions to be drawn from larger data sets, thereby creating more objective and accurate models.

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Biography

Deniz Sezer is an Assistant Professor in the Department of Business Administration at Yaşar University. She obtained her bachelor's degree in Industrial Engineering from Eskişehir Osmangazi University in 2014. In addition, she completed a double major program in Business Administration at the same university. She obtained her Master's degree in Industrial Engineering from Dokuz Eylül University in 2019. Between October 2022 and June 2023, she worked as a visiting researcher at the University of Groningen. Her research interests include supply chain management, system dynamics, sustainability, circular economy, and renewable energy supply chains.