Journal of Advances in Management Research, Available online 2 April 2024
DOI:10.1108/JAMR-05-2023-0112

Breaking Barriers: Paving the Path to Sustainable Fashion - Insights for a Greener Apparel & Textile Sector

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Abstract

Purpose:

Apparel and textile sector is one of the most polluting sectors. It is majorly responsible for air, water, soil pollution and other negative effect. To counter this implementing sustainability, play the major role. This study identified the various barriers that come across the path of implementing sustainability. Moreover, opinion from the experts is taken for distinguishing the critical barriers.

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The final published version (version of record) is available online at DOI:10.1108/JAMR-05-2023-0112. Please refer to any applicable publisher terms of use.

Methodology:

To perform this, ISM and fuzzy MICMAC decision making techniques are used. Result of these is again verified by using DEMATEL method. To understand the issues in detail, cause and effect diagraph is plotted.

Findings:

It was found out that disposal of clothing, lack of Adaptation of new technology, barriers that effect efficiency of this sector, barriers related to the fashion design comes out to be crucial barriers and act as driver for the remaining six barriers.

Originality:

The purpose of this research is to conduct an in-depth investigation of the barriers apparel and textile sectors. It is feasible that both the management team and the medical experts who provide direct patient care could benefit from this research.

Keywords: Sustainability, Textile & Apparel Industries, DEMETEL, ISM FMICMAC.

1. Introduction

The apparel and textile industry holds a central position in the global economy and is of particular significance to India. It not only contributes significantly to the country's GDP but also serves as a major source of employment for a large portion of the population. According to reliable data from the IBEF report in 2021, the Indian textiles and apparel industry played a vital role by contributing 2% to the nation's GDP, accounting for 12% of export earnings, and holding a 5% share in global trade for textiles and apparel during 2018-19. With approximately 45 million people employed in this sector, its importance cannot be understated. However, the remarkable growth and prosperity of the industry have come at a high environmental cost. It has been identified as the world's second most polluting industry, following the oil sector, demanding urgent attention to address sustainability issues. The adverse impact of this industry is not limited to a single aspect but affects all three dimensions of sustainability: environmental, social, and economic (Gupta et al., 2018). In particular, the sector significantly contributes to air, water, and soil pollution, exacerbating existing environmental challenges.

Textile production is a major contributor to the climate crisis, responsible for emitting 1.2 billion tonnes of greenhouse gases, as highlighted by Panday in 2018. A significant concern within textile production lies in the colouring operation, which unfortunately results in the pollution of water sources. The effluents produced during this process contain a wide range of chemicals, making them highly toxic. The conventional practice of discharging these untreated effluents into nearby water bodies leads to devastating consequences, causing severe harm to precious flora, fauna, and aquatic life, as pointed out by Henry et al. in 2019. One of the grave consequences of these effluents is the presence of heavy metals, which contributes to soil pollution, posing a serious threat to the ecological balance. The increasing popularity of fast fashion in developing countries has become a major sustainability challenge that requires urgent action. This trend encourages a throw-away culture among consumers, leading to a concerning rise in waste generation, as noted by Rathinamoorthy in 2018. Unfortunately, much of this waste ends up in incineration facilities or overcrowded landfills, exacerbating environmental problems. To ensure a better future for our planet and promote a healthy environment, it is crucial to address these pressing issues and find sustainable solutions.

Over the past decade, various studies have been conducted to examine the barriers that hinder the achievement of sustainability in the textile industry. Gardas et al. (2018) carried out a comprehensive investigation, identifying a wide range of barriers related to apparel and textile sustainability. They further classified these barriers based on different dimensions of sustainability and explored the intricate cause-and-effect relationships among them. Pedersen et al. (2018) focused specifically on the fashion industry, conducting a meticulous study to identify barriers. Their research involved collaboration with a diverse group of stakeholders, including industry experts, academic professionals, and non-governmental organizations (NGOs). Through this collective effort, they gained valuable insights into the barriers faced by the fashion industry in pursuing sustainability initiatives. On a related note, the work of Hur & Cassidy (2019) discussed on barriers specifically associated with the sustainable design of apparel. They categorized these barriers into two distinct domains: internal design barriers and external design barriers.

The collective efforts of these research endeavors have been instrumental in illuminating the multifaceted challenges that hinder sustainability within the textile and fashion sectors. As we embark on our own investigation, we aim to build upon these valuable insights and make substantial contributions to the comprehension and resolution of barriers that impede the achievement of sustainable practices in this industry. The primary focus of this study is to gain a comprehensive understanding of the barriers to sustainability within the context of the Indian apparel and textile industry. These barriers will be identified through a thorough review of existing literature, supplemented by expert opinions obtained through consultations. Subsequently, the Integrated Interpretive Structural Modeling (ISM) method will be employed to rank the identified barriers based on their criticality, categorizing them into five levels. Additionally, the Follow-up Management for Interpretive Structural Modeling and fuzzy MICMAC (FMICMAC) method will classify the barriers into four quadrants based on their driving and dependence power. Furthermore, we will employ the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique to explore the intricate cause-and-effect relationships among the identified barriers. By employing this comprehensive approach, our study aims to provide valuable insights and practical recommendations to foster sustainable practices within the Indian apparel and textile industry, thus contributing to the broader goal of advancing sustainability in the global fashion landscape.

This paper is organized in the following sequence: Section 1 includes an Introduction, Section 2 covers the literature review, Section 3 describes the research methodology, followed by the results of the study in Section 4. Section 5 discusses the Implications of the study, while Section 6 presents the conclusions and recommendations that emerged from the study.

2 Literature Review

In recent years, a growing body of literature has emerged addressing sustainability practices in the textile and apparel sector, many of which are indexed in prominent databases such as Web of Science and Scopus However, it is noteworthy to mention that complete access to these articles might be limited for policymakers and professional within the apparel sector. Given the cruciality of identifying pertinent literature in this competitive epoch, we undertook a systematic search using the following terms: "of Sustainability “AND " of Sustainable Development" OR "sustainable performance " OR "Circular Economy". For the scope of this study, we confined our selection of articles written in English that incorporated the search terms.

Integration of sustainability into the textile and apparel sector is not merely a merely a business imperative but is also vital for the national development and environmental protection. The sector holds immense potential, evident from the fact that India stands as the foremost producer of cotton and the largest producer of apparel. However, despit its production capabilities, India does not dominate as the chief exporter. Numerous factors constrain the sector’s growth, posing significant challenges. In light of this, the subsequence section aims to pinpoint these barriers. The identification process is done via an extensive literature survey, analysis of various reports (including those from Indian Brand Equity Foundation, of the Ministry of Textiles and report detailing Indian textile trade), and insights from industrial expert. This process is performed by deepening various parameters affecting the apparel & textile sector, including regulatory framework, environmental considerations, economic influences, societal aspects, and efficiency-related factors.

2.1 AWS pollution

In the context of the textile and apparel industry**,** pollution impacting air, water, and soil (collectively referred to as AWS pollution) presents significant challenges. Concerning air pollution, the sector ranked among the top contributor of to the emission of harmful gases. Emission for this industry comprise pollutants like sulphur dioxide, Suspended Particulate Matter (SPM), and nitrogen oxides (Dutta et al.,2019). The manufacturing processes involved in apparel production - spinning, twisting, winding, warping, sizing, and weaving – introduce substantial amounts of dust into the atmosphere. Turning to water pollution, this sector encompasses operations like dyeing and finishing, which significantly contribute to the contamination of water bodies. The wet processing of textile often employs a multitude of chemicals, leading to heavily polluted effluents (Henry et al.,2019). These effluents when discharged into nearby water sources, introduce toxic harmful to aquatic life.

Addressing soil pollution, effluents enriched with harmful chemicals are often released into the ground, leading to severe soil degradation. The repercussions are manifold: the soil becomes unproductive, often reaching a state where it is rendered barren and unsuitable for cultivation or vegetation (Kirchain et al.,2015).

2.2 Wages-related issues

The textile and apparel sector in India is fraught with various wage-related barriers. A predominant issue is the inadequacy of wages; many workers are compensated so minimally that they struggle to meet their basic needs. The situation is exacerbated by wage disparities between gender, where both male and female workers are poorly compensated, but women are often paid even less (Asif 2017). Furthermore, the sector grapples with the insufficient enforcement of wage regulations. For instance, policies pertaining to the minimum wage, daily wage payments, and regular wage revisions are in place. However, the actual implementation of these regulations on the ground is sporadic at best. This lapse not only undermines workers' financial security but also indicates a broader systemic issue within the industry.

In a country like India, which boasts a rich tapestry of textile traditions and plays a pivotal role in the global apparel market, such wage concerns tarnish the industry's reputation. Proper implementation of regulations and the establishment of fair wage practices is not just a matter of ethics but also essential for the sustainable growth of the sector. Addressing these challenges can enhance workers' livelihoods, contribute to positive brand perceptions, and foster an environment conducive to long-term industry success.

2.3 Price hike-based barriers

This section examines the price hick-based barriers that significantly impact the cost of products. These barriers include several key facors primarily contributing to the escalation in product prices. Firstly, the increase in the price of raw materials plays a pivotal role, directly influencing the overall manufacturing cost of textile and apparels. Secondly, the rise in transportation costs, particularly driven by increased fuel price, possess a considerable challenge, as it adds to the expenses incurred during supply chain processes. Moreover, the escalating cost of logistics services further compounds the price hike-based barriers. Collectively, these factors have a direct bearing on the final product price and can significantly affect the market dynamics (Jestratijevic et al.,2020).

In the Indian context, addressing these price hike-based barriers becomes critical, as the textile and apparel sector plays a vital role in the country's economy. The industry not only contributes significantly to the nation's GDP and employment but also holds immense potential for export earnings. Consequently, the effective management of these barriers is essential to maintain competitiveness in the global market while ensuring affordability for domestic consumers. Sustainable strategies, such as optimizing supply chain logistics, exploring alternative raw materials, and embracing energy-efficient transportation methods, can play a pivotal role in mitigating the impact of these price hike-based barriers and foster a more robust and resilient India Textile and Apparel sector.

2.4 Barriers that affect the efficiency of this sector.

Barriers that affect the quality of the Textile and Apparel sector encompasses various factors influencing the quality of products, operation time, the overall productivity of crop growth (e.g. raw material like cotton) ultimately leading to lower efficiency. One critical issue is the inadequate infrastructure prevalent in most apparel and textile industries, where facilities and utilities often fall short, and power cuts or unreliable electricity supply pose significant challenges (Majumdar & Sinha, 2019). Additionally, the utilization of conventional machinery for essential operations such as ginning, spinning, and knitting contributes to the production of poor-quality products and consumes excessive time (Gardas et al., 2018). Another substantial obstacle lies in the prevalence of unskilled workers within the industry. Of the approximately 45 million workers employed in the Indian textile and apparel sector, including 3.5 million handloom workers, a significant portion lack formal professional training. Notably, around 60% of female workers in this sector were previously involved in domestic or agricultural roles, resulting in limited technical skills required for their jobs (Clarke-Sather & Cobb, 2019; Asif et al., 2017). Addressing these efficiency-related barriers becomes paramount in the textile and apparel industry, as enhancing infrastructure, upgrading machinery, and investing in skill development can significantly boost productivity, product quality, and overall competitiveness in the global market. Furthermore, providing opportunities for vocational training and empowering workers with technical expertise will not only elevate their livelihoods but also contribute to the sustainable growth of the sector.

2.5 **Government Policy and Regulation**

Government policy plays a substantial role in import and export decisions, foreign domestic investment (FDI), and the impact of demonetization on various sectors. In India, FDI policies are highly liberal, allowing 100% FDI in the textile sector through a automatic route, eliminating the need for prior approval by the Government of India or the Reserve Bank of India (RBI). Investors are required to notify the RBI's Regional office within 30 days of receving inword remittances. The FDI cell of the Government if India serves the purpose of monitoring and maintaining data on domestic textile production and foreign investment, providing assistance and advisory support to the organization (FDI cell GOI). However, demonetization has significantly impacted the entire Indian economy, especially the unorganized sector and Micro, Small, and Medium Enterprises (MSME). In the textile sector, which heavily relies on daily wage workers and cash transactions, demonetization resulted in cash crunch, hampering various activities such as payment of workers' wages and daily operational expenses. The adverse effects of demonetization included workforce layoff, the closure of small units, reduced manufacturing activities, increased production costs, and a rise in raw cotton prices in certain regions (Choudhury et al.,2021). Moreover, the COVID19 pandemic brought about extensive regulations and nationwide lockdowns, leading to halted production and distributed logistics globally. Consequently, there was a significant decline in the production of apparel from FY 2020 (34 US $) to FY 2021 (28 US $) and a reduction in export income (Report IBEF 2021). However the pandemic also led to increased demand for technical textiles, particularly Personal Protection Equipment (PPE) kits,which the government supported by providing additional funding and sponsoring appropriate machines. . Nevertheless, the increased use of non -biodegradable and is single-use PPE kits has given rise to a critical sustainability issue concerning proper waste disposal (Allison et al., 2020). Amidst these challenges, addressing and adapting to government policies, the impact of demonetization, and the implications of the COVID-19 pandemic becomes essential for sustaining and enhancing the resilience of the textile and apparel sector in India. It calls for a delicate balance between economic growth and environmental responsibility, necessitating innovative approaches and sustainable practices to navigate these dynamic and evolving circumstances.

2.6 Consumer-Related Barriers

The role of the consumer is pivotal in advancing sustainability in the textile and apparel sector, especially in a divers and dynamic market like India. By choosing sustainable apparel, concumers possess the power to influence industry practices and address many barriers. However, their lack of awareness and engagement with eco-conscious fashion poses significant sustainability challenges (Albloushy & Hiller 2019). Many consumers remain disengage from eco-conscious apparel choices, with their perceptions and behaviour showing limited change over time. This detachment can be attributed to multiple factors. First, sustainable apparel often carries a higher price tag compared to mainstream market alternatives, making it a less appealing choice for price-sentive consumers. Further, there is a perception that sustainable options lack the variety and style offered by regular market apparel (Carrigan & Attalla 2001; Barnes et al.,2006).

Beyond these challenges, other factors further inhibt young Indian consumers from embracing sustainable apparel. Financial constraints, concerns about the performance and longevity of sustainable products, psychological barriers related to fashion and social-expression, and potential social risks tied to peer perceptions and social expectations all play a part (Kang & Kim, 2013Connell & Kozar, 2014). For the Indian textile and apparel industry to flourish sustainably, it is imperative to bridge these gaps. Tailoring awareness campaigns, enhancing product variety, and educating consumers about the long-term benefits, both environmentally and economically, of sustainable fashion could drive a significant shift in consumer behavior. Only by addressing these consumer-related barriers can the industry hope to achieve a harmonious blend of tradition, fashion, and sustainability.

2.7 Barriers Related to the Fashion design-

Design is the fundamental phase of the product. In the context of textile and apparel industry, fashion designers wield considerable influence, holding the potential to integrate sustaibability right from the onset of the design process (Hur & Cassidy,2019). However, designers face some challenges in this endeavor, which can be broadly categorized into:
Internal Challenges: At a personal level, designers confront uncertainties. There is often a lack of consensus about what exactly constitutes sustainable design. This ambiguity is compounded by a deficiency in the knowledge required to weave sustainability into fashion seamlessly. On another note, while designers might be eager to prioritize eco-friendly elements, the overarching organizational objectives might not always align. More often than not, decisions within the industry involve weighing one criterion against another. In such scenarios, designers frequently find themselves prioritizing commercial considerations—like aesthetic appeal, affordability, and current fashion trends—over sustainability. The commercial imperatives of the industry, which spotlight aesthetics, cost, and alignment with prevailing fashion trends, can sometimes overshadow the sustainability criterion.

External Challenges: Beyond the individual and organizational confines, designers must grapple with broader industry and societal challenges. To begin with, sustainability, by its very nature, is a complex domain with multifaceted issues, many of which extend beyond the control of single organizations. There is also a prevailing sentiment in the industry that the consumer appetite for sustainable fashion is not sufficiently robust. This perception can dampen enthusiasm for sustainable initiatives. Moreover, when sustainable fashion options are indeed available in the market, there exists a noticeable gap between consumers proclaimed eco-friendly attitudes and their actual purchasing behaviors. This inconsistency further complicates designers' tasks. Lastly, from a macro perspective, the broader textile and apparel industry sometimes appears to lack strong incentives or a compelling value proposition for businesses to ardently adopt and champion sustainable design strategies.

2.9 Fast Fashion-

In the Indian textile and apparel industry, the rise of fast fashion has fundamentally altered the dynamics of clothing consumption. Fast fashion offers clothing to consumers at significantly reduced prices, but this often comes at the cost of quality. Materials like polyester and nylon, which are commonly used in fast fashion, lack the longevity of natural fibers. As a result, it often becomes more economical to purchase new garments rather than repairing existing ones (Aakko & Sivonen,2013). Furthermore, fast fashion's allure doesn't just stop at affordability. By constantly offering the latest trends and designs at competitive prices, consumers are enticed to buy more garments than they actually need. This buying behavior leads to an excessive accumulation of waste as garments are quickly discarded. Several factors underpin the fast fashion model: high production speeds, rapid response times, shorter lead times, and the availability of inexpensive labor (Fletcher, 2010). Notable brands like ZARA and H&M are exemplars of this approach in the global fashion industry (Jung & Jin, 2014). The fast fashion phenomenon can be likened to a "planned obsolescence" strategy, where the durability of products is deliberately minimized to encourage frequent replacements. In the context of the Indian textile landscape, balancing this trend with sustainability and cultural preservation remains a formidable challenge.

2.10 Lack of Adaptation to New Technology-

In textile and apparel industry, the transformation from raw fiber to finished apparel involves a series of intricate operations. Key stages in this manufacturing process include ginning, spinning, weaving, knitting, and processing. A plethora of specialized machinery facilitates this transformation, ranging from knitting machines, crochet devices, and zipper production units to cloth cutting tools and trimmers. The growth of this sector has spurred increasing demand for such machinery. However, the industry's needs are not yet completely met, leading to unfulfilled orders and consequent delays in delivery periods (Raichurkar & Ramachandran, 2015). Further complicating matters, many production facilities continue to employ conventional machines alongside a mix of automated or computerized, and semi-automatic machinery. This hybrid setup poses its own challenges. Moreover, interruptions in power supply, which are not uncommon, further exacerbate the issue. Power outages invariably result in decreased production rates, directly impacting the overall productivity of the sector. The balance between modernization and reliable infrastructure remains a pressing concern for the Indian textile and apparel industry.

S.N.	Barriers	References
B1	AWS pollution	Moon & Chang (2015), Henry et al., (2019)
B2	Wages related issues	Asif (2017), Kane (2015), Annapooran (2017)
B3	Price hike-based barriers	(Choudhery et al.,2021), Adhikari & Weeratunge (2007), Gupta (2006)
B4	Barriers that effect efficiency of this sector	Gardas et al., 2018), Aboagyewaa et al., (2016)
B5	Government policy and Regulation	Umarji (2015), Allison et al., (2020), Aggarwal et al., (2022).
B6	Consumer Related Barrier	Pedersen & Andersen (2015), Albloushy & Hiller Connell (2019)
B7	Barriers Related to the fashion design	Mohajeri et al., (2016), Hur & Cassidy (2019).
B8	Disposal of clothing	Morgan& Birtwistle (2009), Vishwakarma et al., (2023)
B9	Fast Fashion	Jung & Jin, (2014), Fletcher (2010), Bhardwaj & Fairhurst (2010)
B10	Lack of Adaptation of New Technology	Asif (2017), Jaiswal et al., (2018), Gupta et al., (2022).

Table 1: Barriers of Barriers of Sustainability in Apparel & Textile Sector (Source: Author's own table)

So, lack of modern machinery and coupled with power cut hinders seamless garment production, posing significant barriers to the industry. All these above-discussed barriers are summarized in below in Table 1.

2. Methodologies

This section focuses on the analysis of the identified barriers using Multi-Criteria Decision Making (MCDM) techniques, specifically the Interpretive Structural Modeling (ISM) method, followed by the Fuzzy Matrice d'Impacts Croisés Multiplication Appliquée à un Classement (MICMAC) analysis. Additionally, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique is also employed. The section is further divided into three distinct subsections, each addressing a specific technique:

1. Implementation of the ISM Method: In this subsection, the first step is to map the barriers to identify their relationships and interdependencies. This mapping process leads to the formulation of the initial reachability matrix, which represents the direct relationships between the barriers. Next, the final reachability matrix is generated through a series of iterations, reflecting the transitive relationships between the barriers. Finally, the ISM model is presented, representing the hierarchical structure of the barriers based on their driving power and dependence.
2. Implementation of Fuzzy MICMAC Techniques: The second subsection involves the application of Fuzzy MICMAC analysis. Similar to the ISM method, barriers are mapped to understand their relationships. The initial fuzzy reachability matrix is constructed using fuzzy logic, considering uncertainties and vagueness in the data. Through subsequent iterations, the final fuzzy reachability matrix is obtained. Using this matrix, a driving-dependency diagram is plotted, visually illustrating the barriers' driving and dependence effects within the system.
3. Implementation of DEMATEL Techniques: The third subsection utilizes the DEMATEL technique. It begins with the creation of an initial direct-relation matrix, which shows the direct relationships between the barriers. The matrix is then normalized to account for the varying importance levels. The total influence matrix is derived from the normalized matrix, indicating the overall impact of each barrier on others. Finally, a cause-effect diagram is plotted to visualize the causal relationships among the barriers, helping to identify the most influential factors.

3.1 ISM Technique

In the ISM technique, initially, it might appear that certain barriers are dependent on single or multiple other barriers, while the remaining barriers are independent. For instance, environmental pollution barriers could be perceived as dependent on government environmental policy, clothing disposal practices, and consumer barriers related to the culture of apparel. On the other hand, fast fashion and the lack of adaptation to new technology may seem independent of each other. However, after consulting an expert in the sector and conducting an in-depth literature review, it has been revealed that every barrier has relationships with most of the other barriers. This study aims to explore and uncover these relationships.

In the ISM technique, different relationships between barriers are considered, and specific symbols are allotted to represent them. The possible combinations of these relationships between barriers and the corresponding symbols are given below:

V= barrier 'i' will help variable 'j'.

A= barrier 'j' will help variable 'i'.

X= barrier 'i' and 'j' will help each other.

O= barrier 'i' and 'j' are unrelated

Sequence is allotted to each barrier and mapping is done below

B1: AWS pollution

B2: Wages related issues

B3: Price hike based barriers

B4: Barriers that effect efficiency of this sector

B5: Government policy and Regulation

B6: Consumer Related Barrier

B7: Barriers Related to the fashion design

B8: Disposal of clothing

B9: Fast Fashion

B10: Lack of Adaptation of New Technology

3.1.1 Formation of Structural self-interaction matrix

The ISM method is suitable for addressing this formulated problem as it leverages the expertise of knowledgeable individuals. Consequently, this study has sought the opinions of five experts as shown in Appendix-1, each possessing deep knowledge and experience in this sector. These characteristics facilitate the exploration and examination of relationships among the barriers, specifically, the interdependence of one barrier on another. To represent this dependence, the directional symbols 'i' and 'j' are utilized and plotted accordingly.

Table 2: Structural self-interaction matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	X	O	O	O	A	A	A	A	A	O
B2		X	O	O	A	X	O	O	O	O
B3			X	V	A	V	O	O	V	V
B4				X	A	O	O	O	O	V
B5					X	O	O	A	O	V
B6						X	O	V	V	A
B7							X	V	V	A
B8								X	A	A
B9									X	A
B10										X

Based on the contextual relationships, a Structural Self-Interaction Matrix (SSIM) of order 10*10 is developed for the identified variables. The filled values are displayed in the table above, with the experts' opinions being utilized to complete this table. Direct linkages between barriers are established to assign the symbols in Table 2.

3.1.2 Description of SSIM

Upon initial observation, it becomes apparent that the symbol 'O' has occurred frequently in comparison to other symbols. This occurrence suggests that each barrier has been individually studied in the past, but a comprehensive analysis of all the barriers together has not been conducted. As a result, the relationships between certain barriers within the same sector have not been established.

However, it is noteworthy that the experts have indicated relationships among some barriers using symbols such as 'V', 'A', and 'X'.

3.1.3 Formation of Initial Reachability Matrix (IRM)

After constructing the SSIM matrix, the subsequent step involves creating the Initial Reachability Matrix (IRM), which includes the driving and dependence power of barriers. This matrix is filled by assigning values based on the symbols used in the SSIM matrix. As a result, only the upper diagonal matrix is filled.

To fill the lower diagonal matrix, the fundamental steps of the ISM method are followed, considering the direction of relationships, whether they are forward or reversed. This process enables completion of the entire matrix. The below, Table 3, illustrates the initial reachability matrix:

Table 3: Initial Reachability Matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	0	0	0	0	0	0	0	0	0
B2	0	1	0	0	0	1	1	0	0	0
B3	0	0	1	1	0	1	1	0	1	1
B4	0	0	0	1	0	0	1	0	0	1
B5	1	0	1	1	1	0	0	0	0	1
B6	1	1	0	0	0	1	1	1	1	0
B7	1	1	0	0	0	0	1	1	1	0
B8	1	0	1	0	1	0	0	1	0	0
B9	1	0	0	0	0	0	0	1	1	0
B10	0	0	0	0	0	1	1	1	1	1

3.1.4 Formation of Final Reachability Matrix (FRM)

The iteration of the FRM matrix based on the dependence relationships is a crucial and necessary step to achieve the final reachability matrix and, consequently, transmissivity. The resulting Table 4 below represents the FRM:

Table 4: Final Reachability Matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Driving
B1	1	0	0	0	0	0	0	0	0	0	1
B2	1*	1	0	0	0	1	1	1*	1*	0	6
B3	1*	1*	1	1	0	1	1	1*	1	1	9
B4	1*	1*	0	1	0	1*	1	1*	1*	1	8
B5	1	1*	1	1	1	1*	1*	1*	1*	1	10
B6	1	1	1*	0	1*	1	1	1	1	1*	9
B7	1	1	1*	0	1*	1*	1	1	1	1*	9
B8	1	1*	1	1*	1	1*	1*	1	1*	1*	10
B9	1	1*	1*	1*	1*	1*	1*	1	1	1*	10
B10	1*	1*	1*	1*	1*	1	1	1	1	1	10
Dependence	10	9	7	6	6	9	9	9	9	8	82

3.1.5 Classification of levels of the barriers

Based on the scores of dependencies and the driving power of barriers, levels of each have been classified. This process comprises identifying the reachability set and antecedent sets as shown in Table 5. The reachability set consists of the barrier itself and the other barriers that it may impact, whereas the antecedent set consists of the barrier itself and the other barriers that may impact it. From these two intersection sets, levels have been derived.

Table 5: Classification of barriers into different levels (Source: Authors own table)

	Reachability set	Antecedent set	Intersection Set	Level
B1	1	1,2,3,4,5,6,7,8,9,10	1	1
B2	1,2,6,7,8,9	2,3,4,5,6,7,8,9,10	2,6,7,8,9	2
B3	1,2,3,4,6,7,8,9,10	3,5,6,7,8,9,10	3,6,7,8,9,10	5
B4	1,2,4,6,7,8,9,10	3,4,5,8,9,10	4,8,9,10	3
B5	1,2,3,4,5,6,7,8,9,10	5,6,7,8,9,10	5,6,7,8,9,10	5
B6	1,2,3,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	2,3,5,6,7,8,9,10	5
B7	1,2,3,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	2,3,5,6,7,8,9,10	3
B8	1,2,3,4,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	4
B9	1,2,3,4,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	2,3,4,5,6,7,8,9,10	4
B10	1,2,3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	5

The fixation of the level is done via exact matching of the intersection set with the reachability set, and then eliminating those values. This process is repeated continuously until all the levels are decided.

3.1.6 Framing of ISM-based model.

Based on the information gathered from Table 1, Table 2, and Table 3, a structural model has been developed and is shown below in Figure 1. This model has been framed after eliminating transitivity by following the steps of ISM methodology.

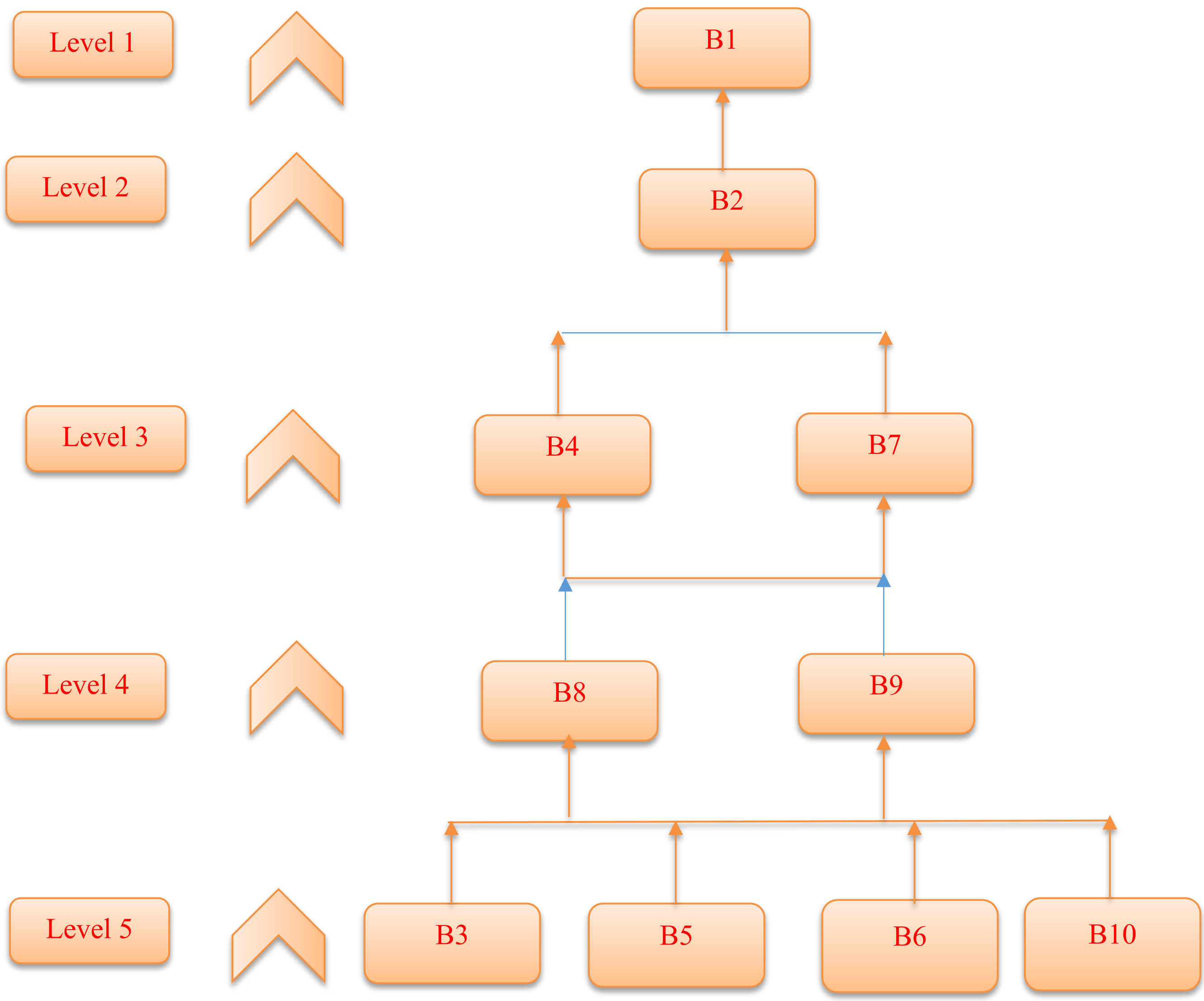

Figure 1: ISM model (Source: Authors own figure)

3.1.7 Findings from the ISM-based Framework

The ISM-based framework is structured with five levels, categorized into three sectors: 'most crucial', 'reasonably crucial', and 'least crucial'.

The 'most crucial' category comprises six barriers belonging to levels 4 and 5. These barriers are Economic Barriers, Government Policy and Regulation, Consumer-Related Barriers, Lack of Adaptation of New Technology, and Fast Fashion. They are labeled as the most crucial barriers because all the other barriers depend on them, and gaining control over these will have a positive impact on the other barriers.

The 'reasonably crucial' barriers are at levels 2 and 3. These barriers affect the efficiency of the sector and include barriers related to fashion design and social barriers. They are influenced by the most crucial barriers and, in turn, act as drivers for the least crucial barriers, situated in the middle part of the hierarchy.

At level 1, there is a single barrier, namely the environmental barrier. It falls under the 'least crucial' category because it is a driven type of barrier and does not exert control over any other barriers.

3.2 Fuzzy-MICMAC Analysis

In the ISM method, 0 and 1 are typically used to indicate the presence or absence of an association between two barriers. However, to explore the associations in more depth, the Fuzzy-MICMAC analysis is employed. This analysis allows for a finer categorization of the association strength, such as very strong, strong, low, etc., using fuzzy theory to handle uncertainty and weaknesses in the decision-making process (Zadeh, 1965).

To convert linguistic judgments into fuzzy numbers, expert opinions are taken into consideration. The scale for the possibility of a relationship is designed with specific measures, such as 'no = 0,' 'negligible = 0.1,' 'medium = 0.5,' 'high = 0.7,' 'very high = 0.9,' and 'full = 1.' The values obtained from the experts' opinions are then applied to the binary direct reachability matrix (BDRM) to derive a fuzzy direct reachability matrix (FDRM), as shown in Table 6.

Table 6: Fuzzy direct reachability matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0	0.3	0.1	0.3	0.3	0.1	0.1	0.7	0.3	0.1
B2	0.5	0	0.3	0.1	0.3	0.3	0.3	0.1	0.7	0.3
B3	0.7	0.3	0	0.9	0.7	0.7	0.3	0.5	0.3	0.7
B4	0.5	0.5	0.3	0	0.5	0.1	0	0.5	0.9	0.1
B5	0.9	0.7	0.5	0.5	0	0.3	0.9	0.7	0.5	0.3
B6	0.9	0.7	0.5	0.3	0.3	0	0.3	0.9	0.7	0.9
B7	0.1	0.7	0.5	0.7	0.1	0.3	0	0.7	0	0.1
B8	0.9	0.5	0.1	0.5	0.3	0.5	0.3	0	0.7	0.3
B9	0.7	0.3	0.1	0.3	0.1	0.5	0.7	0.9	0	0.3
B10	0.7	0.3	0.5	0.9	0.3	0.3	0.7	0.7	0.9	0

In FMICMAC analysis, the fuzzy matrix multiplication rule is followed instead of using Boolean matrix multiplication. Fuzzy matrix multiplication is generally considered a simplification of Boolean matrix multiplication (Sarkar and Panchal, 2015) (Patidar et al., 2017). According to the fuzzy multiplication rule, the product of two fuzzy matrices is also a fuzzy matrix (Khan & Haleem, 2012).

Fuzzy Multiplication Equation

$$AB = Max\{Min(a_{ij}, b_{ij})\}$$

Where,

$$A = (a_{ij})$$

$$B = (b_{ij})$$

The FDRM is taken as the preliminary matrix to start the procedure. The matrix is repeatedly multiplied until the hierarchies of the driver power and the dependence power stabilize, as shown in Table 7. The multiplication process follows the fuzzy matrix multiplication rule.

These values are plotted in the table below. The dependence and driving power of elements are found in the same way as earlier, i.e., obtained by summing up the columns and the rows of the final fuzzy reachability matrix, respectively. Table 7 presents the final fuzzy reachability matrix.

Table 7: Fuzzy stabilized matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Sum
B1	0.7	0.5	0.3	0.5	0.3	0.5	0.3	0.3	0.7	0.3	**4.4**
B2	0.7	0.3	0.3	0.3	0.3	0.5	0.7	0.7	0.3	0.3	**4.4**
B3	0.7	0.7	0.5	0.7	0.5	0.5	0.7	0.7	0.9	0.7	**6.6**
B4	0.7	0.5	0.5	0.5	0.3	0.5	0.7	0.9	0.5	0.3	**5.4**
B5	0.7	0.7	0.5	0.7	0.5	0.5	0.5	0.7	0.7	0.5	**6**
B6	0.9	0.5	0.5	0.9	0.5	0.5	0.7	0.7	0.9	0.5	**6.6**
B7	0.7	0.5	0.3	0.5	0.5	0.5	0.3	0.5	0.7	0.5	**5**
B8	0.7	0.5	0.5	0.3	0.5	0.5	0.7	0.7	0.5	0.5	**5.4**
B9	0.9	0.7	0.5	0.7	0.3	0.5	0.3	0.7	0.7	0.5	**5.8**
B10	0.7	0.7	0.5	0.7	0.5	0.5	0.7	0.9	0.9	0.5	**6.6**
Sum	**7.4**	**5.6**	**4.4**	**5.8**	**4.2**	**5**	**5.6**	**6.8**	**6.8**	**4.6**	

3.2.1 Findings from fuzzy MICMAC analysis

The purpose of fuzzy MICMAC analysis is to assess the driving power and dependence of the elements. Based on these assessments, the elements are categorized into four sections, visually represented in Figure 2 as quadrants I, II, III, and IV. These sections consist of autonomous, dependent, linkage, and independent elements.

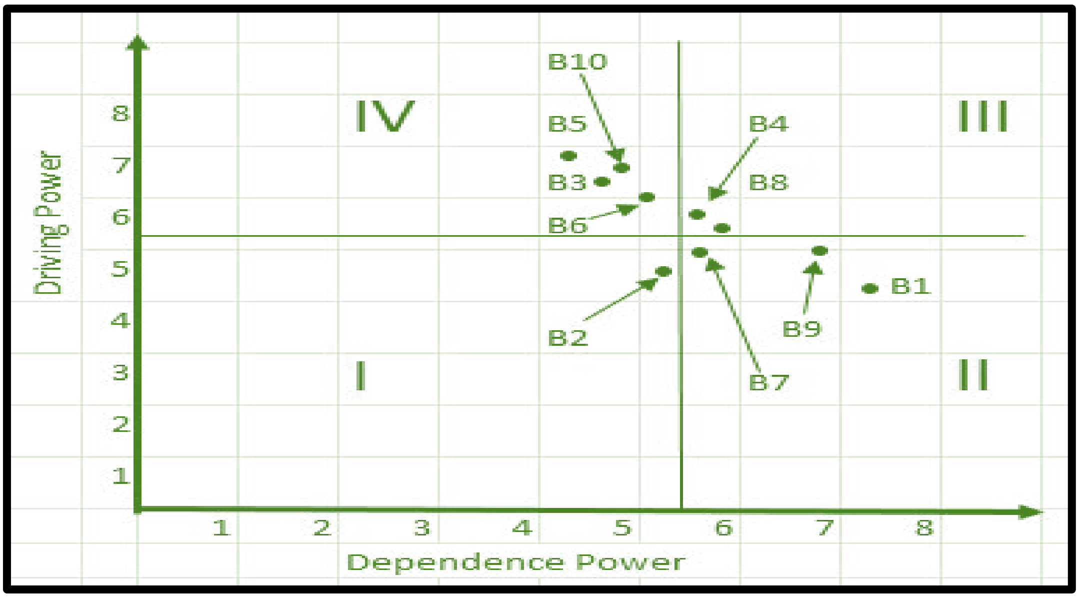

Figure 2: Driving-dependence power diagram (Source: Authors own figure)

- **Autonomous elements**

The factors belonging to the autonomous group are considered less critical because they possess lower driving power and dependency power. These elements are placed in the first quadrant, and the B2 barrier is an example of such an element.

- **Dependent elements**

Elements in the second quadrant exhibit high dependency power but have the least driving power. Dependent barriers are considered less crucial as they contribute relatively low driving power and do not support any other barriers. This quadrant includes barriers B1, B7, and B9, which aligns with the findings of the ISM method.

- **Linkage elements**

The third quadrant comprises elements with both high dependencies and driving power. These linkage elements possess substantial influential power and dependency. Within this quadrant, barriers B4 and B8 can be found. The alignment of these elements with the ISM method's results is evident, as they hold a central position within the framework.

- **Independent elements**

The fourth quadrant houses elements with low dependency power, hence referred to as independent elements. However, they boast high driving power, allowing them to influence other elements significantly. This quadrant encompasses three distinct types of barriers: B3, B5, B6, and B10. This concurs with the findings of the ISM method, as these barriers occupy the lower part of the framework.

3.3 DEMATEL Method:

The decision-making trial and evaluation laboratory (DEMATEL) is a multi-criteria decision-making (MCDM) tool used for selecting crucial variables from a list of variables relevant to an issue (Gardas et al., 2019). This method aims to identify cause-and-effect relationships among the identified barriers. Some of them are cause-related barriers, while the rest fall under the effect category. One of its useful aspects is that by controlling the cause-related barriers, all the relevant barriers can be effectively managed.

To execute the DEMATEL method, these are the step to follow.

Step 1: Initiation of direct-relation matrix

Step 2: Normalised direct-relation matrix

Step 3: Estimation of Total relation matrix

Step 4: Evaluate sum of rows and columns in T matrix

Step 5: Defining the threshold values

Step 6: Formation of cause-effect relationship digraph

3.3.1 Initiation of direct-relation matrix

The direct relation matrix is created based on the responses collected from the experts. The responses are provided in the form of a Likert scale ranging from 0 to 4, where each value corresponds to a specific meaning: 'No influence', 'Very Low influence', 'Low influence', 'High influence', and 'Very high influence', respectively.

A = Average initial direct-relation matrix (Table 9),

K = Numbers of experts, and

zkij= Initial direct-relation matrix corresponding to *kth*

Table 8 below mentions the value of each barrier over the other.

Table 8: Initial direct-relation matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0	1	1	3	3	1	1	3	3	2
B2	1	0	2	4	3	2	2	2	2	0
B3	1	2	0	3	4	4	2	3	2	3
B4	2	1	3	0	2	3	2	1	1	3
B5	3	4	3	4	0	4	1	1	3	4
B6	3	3	4	1	3	0	3	3	3	3
B7	1	1	2	1	3	2	0	1	2	2
B8	3	1	2	1	3	3	2	0	2	2
B9	2	1	1	1	1	2	3	2	0	1
B10	2	4	2	3	2	3	2	4	2	0

3.3.2 Normalised direct-relation matrix

In this step, the mean or average of the initial direct relation matrix, as recorded from the experts, is calculated. This calculation is shown in Table 9 and is based on the following formula.

$$D = \frac{1}{\sum_{j}^{n} \quad a_{ij}} A$$

Where,

D = Normalised direct-relation matrix (Table 10),,

A = Average initial-direct relation matrix,

a_{ij} = values in matrix A.

Table 9: Normalised direct-relation matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0.00	0.04	0.04	0.11	0.11	0.04	0.04	0.11	0.11	0.07
B2	0.04	0.00	0.07	0.15	0.11	0.07	0.07	0.07	0.07	0.00
B3	0.04	0.07	0.00	0.11	0.19	0.19	0.07	0.11	0.07	0.11
B4	0.07	0.04	0.11	0.00	0.07	0.11	0.07	0.04	0.04	0.11
B5	0.11	0.15	0.11	0.15	0.00	0.15	0.04	0.04	0.11	0.15
B6	0.11	0.11	0.15	0.04	0.11	0.00	0.11	0.11	0.11	0.11
B7	0.04	0.04	0.07	0.04	0.11	0.07	0.00	0.04	0.07	0.07
B8	0.11	0.04	0.07	0.04	0.11	0.11	0.07	0.00	0.07	0.07
B9	0.07	0.04	0.04	0.04	0.04	0.07	0.11	0.07	0.00	0.04
B10	0.07	0.15	0.07	0.11	0.07	0.11	0.07	0.15	0.07	0.00

3.3.3 Compute total-influence matrix

The computation of the total influence matrix is performed using the equation mentioned below, and the results are presented in Table 10. By using the formula

$$T = (t_{ij}) = D(1 - D)^{-1}$$

Where,

T = Total-influence matrix (Table 10),

t_{ij}= corresponding values in matrix T,

D = Normalised average initial-direct relation matrix, and

I = Identity matrix

This include the multiplication of matrix in which one of the matrix is in the inverse form.

Table 10: Total-Influence matrix (Source: Authors own table)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	**Sum**
B1	0.21	0.24	0.26	0.33	0.36	0.31	0.24	0.32	0.32	0.30	**2.88**
B2	0.24	0.21	0.30	0.37	0.37	0.35	0.27	0.28	0.29	0.24	**2.92**
B3	0.35	0.39	0.35	0.45	0.57	0.58	0.37	0.43	0.40	0.45	**4.32**
B4	0.28	0.26	0.34	0.25	0.36	0.39	0.28	0.27	0.27	0.35	**3.06**
B5	0.40	0.44	0.44	0.48	0.40	0.54	0.34	0.37	0.43	0.47	**4.32**
B6	0.39	0.40	0.45	0.37	0.49	0.39	0.39	0.42	0.42	0.42	**4.14**
B7	0.22	0.22	0.27	0.24	0.34	0.31	0.18	0.23	0.27	0.27	**2.55**
B8	0.33	0.26	0.31	0.29	0.39	0.40	0.29	0.24	0.31	0.32	**3.14**
B9	0.23	0.19	0.21	0.21	0.25	0.28	0.26	0.24	0.17	0.21	**2.24**
B10	0.34	0.40	0.37	0.40	0.42	0.46	0.33	0.42	0.36	0.29	**3.80**
Sum	**2.99**	**3.02**	**3.31**	**3.38**	**3.95**	**4.02**	**2.93**	**3.22**	**3.25**	**3.31**	

The last row and last column contain the sum of the respective column and row entries. These values are calculated because all the entries are used in the further process.

3.3.4 Prominent and influence of each barrier

Prominent concern and its influence is given

$$R = \sum_{1 \le j \le n} t_{ij}$$

$$C = \sum_{1 \le i \le n} t_{ij}$$

Were,

R =Row sum of matrix *T*,

C = Column sum of matrix *T*, and

t_{ij} = corresponding values in matrix *T*.

3.3.5 Cause-effect relationship digraph

From the T matrix, the cause-and-effect relationship is explored by analyzing the values of the sum of columns and rows. The sum of rows (Ri) and columns (Ci) are calculated, and the sum and difference values of these row sums and column sums are plotted in Table 11. Negative values of (Ri-Ci) indicate the effect relationship, and on the other hand, positive values represent the cause relationship.

Table 11: Prominence and Influence of Each Concern (Source: Authors own table)

S.N.	Ri	Ci	Ri+Ci	Ri-Ci	Relationship
1	2.88	2.99	5.87	-0.11	Effect
2	2.92	3.02	5.94	-0.10	Effect
3	4.32	3.31	7.63	1.01	Cause
4	3.06	3.38	6.44	-0.32	Effect
5	4.32	3.95	8.27	0.37	Cause
6	4.14	4.02	8.16	0.12	Cause
7	2.55	2.93	5.48	-0.38	Effect
8	3.14	3.22	6.36	-0.08	Effect
9	2.24	3.25	4.06	-1.01	Effect
10	3.80	3.31	4.80	0.49	Cause

3.3.6 Findings from DEMATEL

Based on the information provided in the Table 11, it is evident that there are 4 barriers categorized under the "cause" category, and 6 barriers fall into the "effect" category.

The four barriers classified under the "cause" category are as follows:

1. Barriers that affect the efficiency of this sector (B4)
2. Barriers Related to fashion design (B7)
3. Disposal of clothing (B8)
4. Lack of Adaptation of New Technology (B10)

The six barriers grouped under the "effect" category are as follows:

1. Environmental barriers (B1)
2. Social Barriers (B2)
3. Economic Barriers (B3)
4. Government policy and Regulation (B5)

5. Consumer Related Barriers (B6)
6. Fast Fashion (B9)

3.3.7 Development of the Cause-Effect Diagraph

The digraph is created by calculating the average values of the T-matrix, resulting in a value of 1.95 for this specific T-matrix. This value is referred to as the threshold value (α) for the T-matrix, as mentioned in Gardas et al. 2019a. To determine the direction of the arrow from each barrier, the threshold value is utilized. If the entries in the T-matrix surpass the threshold value, an arrow is plotted from the respective barrier to the corresponding other barriers. This process is illustrated in Figure 3, which represents the cause-effect diagram.

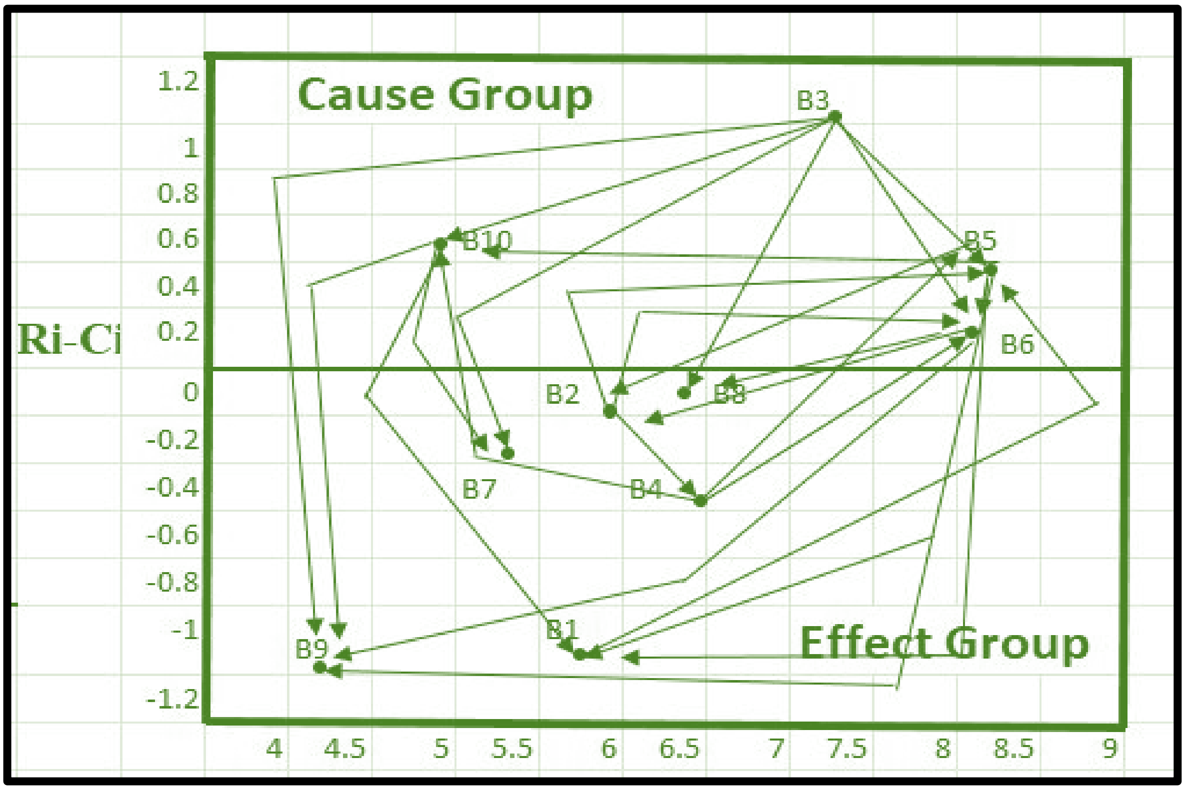

Figure 3: Cause-effect digraph (Source: Authors own figure)

4. Result and Discussion

This work focuses on identifying barriers to sustainability in the apparel and textile industry. Ten barriers were identified from the latest reports and current literature, and expert opinions were obtained using binary digits, fuzzy numbers (decimal values between 0 and 1), and Likert scale. The ISM technique, MICMAC analysis, and DEMATEL technique were employed to investigate the criticalness of these barriers. The ISM method classified the barriers into five different levels (level 1 to level 5), with level 5 being the most critical. These barriers were further categorized into two groups: Group 1 comprising level 1 and level 2 barriers, and Group 2 consisting of level 3, level 4, and level 5 barriers. Group 2 was found to be more influential than Group 1.

Using the DEMATEL technique, the barriers were also classified into two groups based on cause-and-effect relationships. Cause-based barriers were considered more critical than effect-based barriers. Notably, all the cause-based barriers belonged to Group 2 (level 5), further emphasizing their critical nature. These cause-based barriers have a substantial impact on sustainability and contribute to other barriers.

The investigation recommended that firms interested in adopting sustainable practices or already involved in sustainability initiatives should prioritize mitigating the most critical barriers. Price hike-based barriers (B3), Government policy and Regulation (B5), Consumer Related Barrier (B6), and Lack of Adaptation of New Technology (B10) were identified as the most critical barriers. Therefore, special attention should be given to addressing and eliminating these barriers when formulating policies and implementing sustainability practices within the firm.

5. Practical and research implication of the study

This research work makes a significant contribution to the literature on sustainability in the apparel and textile industries. Its primary focus is on identifying and understanding the barriers to sustainability and their interconnected relationships. Given the current scenario, these barriers are of great concern for the successful implementation of sustainability practices. The findings of this study can serve as a benchmark for firms interested in adopting sustainability practices. By understanding the barriers and their relationships, decision-makers and policymakers can formulate effective strategies and policies to promote sustainability in the industry. The cause-and-effect diagram developed in this research can be a valuable tool for controlling the critical barriers. Among the identified barriers, four are found to be particularly critical: Price hike-based barriers (B3), Government policy and Regulation (B5), Consumer Related Barrier (B6), and Lack of Adaptation of New Technology (B10). As these barriers are also cause-based, addressing them will have a positive impact on mitigating other related barriers as well. Special attention should be given to their mitigation. Regarding Consumer

Related Barriers, firms should focus on raising consumer awareness about the benefits of purchasing sustainable apparel and the negative consequences of supporting fast fashion. Educating consumers and encouraging sustainable purchasing decisions can play a crucial role in promoting sustainability in the apparel and textile industry.

6. Conclusion

This paper focuses on identifying barriers to sustainability in the apparel and textile industry. Through a thorough review of the latest reports and current literature, 10 barriers were identified. The primary objective of this research is to pinpoint the critical barriers that hinder sustainability initiatives. To assess the influencing power and criticalness of these barriers, expert opinions were sought to map the relationships between them. An integrated ISM-DEMATEL technique was employed for this purpose. As a result of this technique, four critical barriers were identified: Price hike-based barriers (B3), Government policy and Regulation (B5), Consumer Related Barriers (B6), and Lack of Adaptation to New Technology (B10). These four barriers have been recognized as significant hurdles that impede the successful implementation of sustainability practices in the apparel and textile industry. To move towards sustainability, it is essential to address and eliminate these critical barriers. This research does acknowledge certain constraints and limitations that may affect the outcomes. One of the constraints is the potential for bias in the expert's decisions, which may influence the results and interpretations. Additionally, there might be variations in opinions among the experts when scaling the barriers, leading to discrepancies in the data. Another limitation is the different forms of opinions provided by the experts (binary digits, fuzzy numbers, and Likert scale). This could introduce variability in the data, and integrating these diverse opinions into the analysis may present challenges. Furthermore, the scope of this research is limited to sustainable practices specifically in the apparel and textile sector.

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Appendix 1: Detailed Information About Experts (Source: Author's own contribution)

Experts Domain	S. No.	Year of Experience	Qualification	Designation	Organization Description
Industry	1	8	B.E., M.Tech	Senior Engineer	Apparel Firm in Indore (Madhya Pradesh)
	2	10	Diploma, B.E., M.Tech	Production Manager	Apparel Firm in Indore (Madhya Pradesh)
	3	11	B.E	Manager	Textile firm in Gandhinagar (Gujarat)
Academic	4	18	B.E., M.Tech. Ph.D	Professor	Institute of National Importance,Rajasthan
	5	9	B.E., M.Tech. Ph.D	Associate Professor	Institute of National Importance,Rajasthan

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2024-04-02
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Vishwakarma A, Mehrotra D, Agrahari R, et al., (2024) Breaking barriers: paving the path to sustainable fashion–insights for a greener apparel and textile sector. Journal of Advances in Management Research, Volume 21, Issue 3, July 2024, pp. 376-379
https://doi.org/10.1108/JAMR-05-2023-0112
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