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# A Comprehensive Fuzzy Decision-Making Model for Prioritizing Barriers to Circular Supply Chains in the Textile Industry: A Hybrid IVT2IF-TOPSIS Approach

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**ABSTRACT**

This study constructs a decision-making model to identify the key obstacles preventing the adoption of Circular Supply Chain Management (CSCM) in Bangladesh's textile sector and rank them. Based on the systematic literature review and technical assessments, six synthesized barriers were evaluated using a hybrid Interval-Valued Type-2 Intuitionistic Fuzzy TOPSIS (IVT2IF-TOPSIS) model, which provides a rigorous treatment of uncertainty in expert estimates. As can be seen, financial constraints and the problem of economic viability are the most significant obstacles, and other factors to be considered are limited knowledge, awareness, and preparation to be motivated. The technological and infrastructural differences and the lack of organizational capability become the secondary barriers, and regulatory and stakeholder-based limitations have relatively less acuity. This Prioritized CSCM barriers guide the industry toward faster circularity.

## INTRODUCTION

A linear chain of supply is based on the traditional design of Take-Make-Dispose and involves the concentration on a one-way flow of material. It is primarily focused on mass production, though it focuses on the short term. profit and volume (N. Singh, 2024). This practice has prevailed in the international sector system for decades, particularly in such industries as textiles and consumer goods (Rogan *et al.*, 2022). Due to the growing environmental awareness and regulatory pressures, industries are gradually shifting from linear models to more sustainable supply chain structures (Hossain, 2024). Sustainable supply chain involves managing resources, information, and capital flows while considering economic, environmental, and social goals based on stakeholder requirements & customer feedback (Seuring & Müller, 2008). The core of sustainable supply chain practices includes waste reduction, use of renewable energy sources, and proper resource utilization (Shenoy & Vikram, 2023).

The worldwide textile marketplace is facing a major revolution in the sense that companies are moving towards sustainable production and distribution concepts. The traditional linear supply chains, which are marked by a take-make-dispose model, are no longer working out because of the increasing environmental stress, scarcity of resources, and regulatory needs. Circular Supply Chain Management (CSCM) has in turn, responded with a strategic framework that gives importance to closed-loop flows of materials, waste reduction, resources efficiency, and recovery of value throughout the supply chain (Khan & Ali, 2022) . In developing economies like Bangladesh, which is among the largest producers of textiles and apparel in the world, the shift towards CSCM is especially essential given the industry's heavy reliance on water, chemicals, energy, and non-renewable resources.

Although the issues of circular practices are gaining momentum, the implementation of CSCM in the textile sector is still slow and uneven. The existing literature suggests that organizations face many obstacles, among which are high financial expenses, technical constraints, inefficient infrastructure, poor implementation of policies, disintegration of the supply chain, and poor managerial understanding (Khandelwal & Barua, 2024). These obstacles tend to be interconnected and specific to the context, and thus, they are complicated to assess. The scenario is also complicated in Bangladesh, where the textile industry is a blend of large export-oriented companies and small local companies that work under different regulatory and technological settings. It is then necessary to understand the relative significance of these barriers, so as to develop effective circular transition strategies as well as support policy interventions.

A large pool of literature has been involved in the tools of studying CSCM barriers based on different multi-criteria decision-making (MCDM) approaches AHP, DEMATEL, ISM, ANP and classical fuzzy TOPSIS (Lahane & Kant, 2021). Although these studies offer great information, they mostly depend on Type-1 or intuitionistic fuzzy sets that are expert-based judgments that are single-valued. These methods do not adequately represent the greater ambiguity, indecisiveness, and mixed perceptions that emerge when professionals assess the

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new sustainability practices in unpredictable settings (Islam *et al*., 2025). There is also a dearth of empirical research on the CSCM barriers to the textile industry in Bangladesh, even though it is an important industry in the world and has a high impact on the environment. Therefore, the current content demonstrates that there is a methodological and contextual gap in the accurate modeling of CSCM barriers in the context of higher-order uncertainty.

The more advanced representation of uncertainty provided by Interval-Valued Type-2 Intuitionistic Fuzzy Sets (IVT2IF) is that the membership, non-membership, and degree of hesitation can have a value that is within ranges and include secondary grades. This allows the more realistic and detailed modelling of the perceptions of experts. The choice of integrating IVT2IF and TOPSIS is hence warranted since this approach allows merging the expressive uncertainty-handling property of type-2 intuitionistic fuzziness with the computational efficiency and comprehensibility of the TOPSIS ranking approach. Specifically, this mixed method is well-suited to assessing the barriers to sustainability in the textile supply chain that are complex and multidimensional where judgments are inaccurate or biased in some way.

Considering the background, this study will assess and rank the major obstacles that impede the adoption of CSCM within the textile sector in Bangladesh. The particular research objectives are:

RO 1: Determine the pivotal impediments to CSCM adoption using a comprehensive literature review and confirming it with experts.

RO 2: Suggesting a suitable analytical framework to study and evaluate the barriers.

RO 3: Determine the inter-relations between the identified barriers via correlation analysis.

The contributions to this study are threefold. To start with, it presents one of the only empirical studies done on the barriers to CSCM in the textile industry in Bangladesh, which can inform other researchers and policymakers in the developing world. Second, it presents a sophisticated IVT2IF-TOPSIS decision-making system that better captures the expert uncertainty than the current fuzzy MCDM systems. Third, the research provides a prioritized list of CSCM barriers that can guide practitioners in planning specific intervention in order to speed up the process of circular transformation in the textile supply chain.

The research aims to provide a holistic insight into the multidimensional barriers to adopting CSCM. The research also seeks to provide evidence-based information that can be used by policymakers and practitioners in the textile industry to embrace sustainable and circular change in the sector.

## LITERATURE REVIEW

### CSCM Implementation in Bangladesh's Apparel Industry

Bangladesh is a key player in the global apparel and textile production, contributing significantly to the socio-economic growth (Khairul Akter *et al*., 2022). With more than $36 billion in apparel and textile exports in fiscal year 2023–2024, it has established itself as a crucial link in global supply chains. However, a concerning aspect is the challenge the country's apparel industry is facing regarding sustainable practices and resource management. Apart from the economic growth, the apparel supply chain also contributes to resource depletion, consumption of an extensive amount of energy, chemicals, and water throughout a product's life cycle, and a huge amount of waste generation (Hemal *et al*., 2024a). About 400,000 tons of pre-consumer textile waste are generated annually by the apparel industry, only 5% of which gets recycled locally. The remaining 95% is either landfilled or incinerated in furnaces, both of which are harmful to the ecosystem and humans.

Concerns about the ecological impact of textile production have been raised in our country, raising awareness among firms. Moreover, the pressure from stakeholders is also compelling the firms to prioritize economic, environmental, and social performance (Islam *et al*., 2024). Plenty of efforts have already been made to advance the country towards sustainable practices; however, there remain substantial obstacles, including the lack of formal markets for secondary raw materials, the inadequate recycling infrastructure, and the requirement for comprehensive policy support (Akash *et al*., 2025)

And the linear economy prevailing in the country can't contribute much to sustainability, as it generates waste and environmental impact (Pereira *et al*., 2020). The firms need the circular economy resulting from a circular supply chain to address the problems of unsustainable development.

Through the CSCM adoption, the environment is protected while the company maintains profitability (Dragomir & Dumitru, 2022). The apparel firms of the country can focus on developing new sustainable materials, designing products with longer lifecycles and durability, promoting the reusing and recycling of products, and improving manufacturing efficiency (Mazraani *et al*., 2025).

### Identified Barriers of CSCM

A systematic review was conducted to point out the key barriers impeding the implementation of Circular Supply Chain Management (CSCM). Some research protocols were employed to facilitate the review. We searched the databases like "Google Scholar" and "Scopus". Searching terms and keywords were CSCM, CE Integration, Barriers to implementation of CSCM, Bangladesh`s Textile Industry, etc.

Inclusion criteria:

a) Articles that are indexed in a reputable database

b) Articles published between 2020 and 2025

Exclusion criteria:

a) Articles that are not disseminated in English

b) Articles that are not relevant to all the ROs

Using the mentioned criteria, some key barriers were identified based on the literature review of 15 major studies published between 2020 and 2025 (Table 1). Our paper focuses on both the context of Bangladesh's apparel industry and other developing countries. While doing the comprehensive review, we focused on empirical and conceptual works that employed diverse methodologies such as fuzzy DEMATEL, ISM, FDM, surveys, and case studies.

**Table 1:** List of Barriers after Literature Review

| No. | Author | Year | Method Used | Identified Barriers |
|---|---|---|---|---|
| 1 | (Huang *et al.*, 2021) | 2021 | Fuzzy Delphi Method (FDM) and TISM | -Lack of financial support and investment<br>-Poor technology<br>-Lack of awareness |
| 2 | (Karim *et al.*, 2021) | 2021 | DEMATEL | Lack of stakeholder involvement<br>-Insignificant financial gains<br>-Lack of supply chain integration |
| 3 | (Thoufiqul Islam & Abdul Jabber, 2022) | 2022 | Case Study | -Lack of knowledge<br>-High establishment cost,<br>-Inadequate monitoring |
| 4 | (Firdaus *et al.*, 2025) | 2025 | Literature review, conceptual framework | -Lack of knowledge<br>-Managerial capability<br>-Lack of motivation and awareness of circularity |
| 5 | (Schumacher & Forster, 2022) | 2022 | Qualitative analysis, surveys | -Organizational barriers<br>-Lack of Internal support, strategic planning, and employee training |
| 6 | (Ayati *et al.*, 2022) | 2022 | Conceptual frameworks, empirical research | -Supply chain complexity and collaboration challenges |
| 7 | (Farrukh & Sajjad, 2024) | 2024 | Literature review, case studies | -Lack of successful circular business models<br>-Low customer demand for recycled textile products |
| 8 | (Kazancoglu *et al.*, 2022) | 2022 | Fuzzy DEMATEL | -Lack of collecting, sorting, and recycling<br>-Reluctance for acceptance of the CE model |
| 9 | (Hemal *et al.*, 2024b) | 2024 | DEMATEL | -Financial constraints<br>-Lack of support and commitment from the top management. |
| 10 | (Tom Duhoux *et al.*, 2024) | 2024 | Regulatory analysis | -Inconsistent or absent extended producer responsibility (EPR) systems |
| 11 | (Luthra *et al.*, 2022) | 2022 | Multi-Method Approach | -Policy-making, regulatory frameworks, and institutional structures<br>-Environmental, cultural, and situational factors |
| 12 | (Saccani *et al.*, 2023) | 2023 | Multi-Method Approach | -Economic and Financial Viability Challenges<br>-Product Complexity and Design Issues<br>-Regulatory and Policy Gaps:<br>-Supply Chain Coordination and Collaboration Challenge |
| 13 | | 2020 | Conceptual Framework | -Lack of integration and collaboration<br>-Management and decision-making |
| 14 | (Chen *et al.*, 2021) | 2021 | DEMATEL | -Consumers' lack of knowledge and awareness about reuse/recycling<br>-Lack of successful business models and frameworks to implement CE<br>-Obstructive laws and regulations |
| 15 | (Vishwakarma *et al.*, 2022) | 2022 | A hybrid ISM-MICMAC and DEMATEL approach | -Lack of Reverse Logistics Practices<br>-Communication Gap Among Stakeholders |

This rigorous mapping ensures that the most influential and contextually relevant barriers are captured from both academic literature and stakeholder experiences.

**Consolidated Barriers to CSCM Implementation**

To make the analysis cleaner and reduce repetition, similar challenges were grouped into broader categories. This way, the main obstacles blocking the path for CSCM in Bangladesh's apparel industry became more organized and straightforward. After carefully reviewing different studies and clustering the overlapping points, six major barriers stood out. They were grouped by how often they showed up and how closely related they were (Table 2).

Topping the list were a lack of knowledge, awareness, and drive to act, along with financial struggles and doubts about economic viability. These two challenges appeared in five separate studies. This highlights how significantly they can hinder progress in adopting CSCM. Additionally, gaps in how stakeholders collaborate, communicate, and engage, along with policy, regulatory, and institutional barriers, also pose major obstacles.

Other important problems included limited technology, poor infrastructure, a shortage of management and organizational skills, and the complexity of integrating different parts of the supply chain. While things like the difficulty of redesigning products and cultural or situational factors did not get mentioned as much, they still add real complications to making CSCM happen.

**Table 2:** Consolidated Barrier

| No. | Consolidated Barrier | Frequency |
|---|---|---|
| B1 | Lack of knowledge, awareness, and motivation | 5 |
| B2 | Financial constraints and economic viability challenge | 5 |
| B3 | Lack of stakeholder involvement, collaboration, and communication | 4 |
| B4 | Technological limitations and infrastructure gaps | 3 |
| B5 | Policy, regulatory, and institutional barriers | 4 |
| B6 | Management and organizational capability gaps | 3 |

## MATERIALS AND METHODS

### Research Framework

This paper will use IVT2IF technique to assess and rank the obstacles to the implementation of Textile industry in Bangladesh CSCM. The strategy mixes intellectual experience and quantitative. analysis, rendering it appropriate in challenging decision situations in which opinion can be. uncertain or inconsistent. The impediments to the use of CSCM are not clearly defined. Instead, they are multi-dimensional and tend to be overlapping, including environmental, economic and other characteristics. organizational factors. In addition, professional judgments of these barriers are not necessarily accurate as they are subject to the deficiency of contextual knowledge, linguistic uncertainty, and stuttering. in judgment. Such judgments are often considered to be fixed numbers using traditional approaches, though this can be wrong. simplify the actual uncertainty of them. Whereas Interval-Valued Type-2 Intuitionistic Fuzzy Sets (IVT2IFSs) can be used to model membership and non-membership levels. intervals, which can give a more robust and the more flexible representation of the expert perceptions (Wan & Dong, 2020).

The general methodological process was characterized by three stages in a row:

### Barrier Identification

At first, we identified key barriers from 15 papers by an extensive systematic literature review. Then, we consolidated the six most frequent barriers and finalized them for further analysis.

### Expert Evaluation

In the next step, we surveyed some industry experts and academics (shown in Table 3) with experience in supply chain management, sustainability, and textile operations. This Survey was conducted to evaluate the relative importance of each barrier. They provided their assessments using linguistic terms. After that, the linguistic terms were converted into IVT2IF numbers so that the analysis can capture both the experts opinions as well as their hesitation in making precise judgments.

### Quantitative Prioritization

Lastly, the fuzzy data were aggregated and the extended TOPSIS method was used to analyze the data. The Closeness coefficient (CC) of each barrier was calculated and it is an indicative of its proximity to the positive ideal solution (PIS) and also calculating the distance to the negative ideal solution (NIS). The resulting CC values were used to give a quantitative basis of ranking the barriers and hence identifying the ones. having the strongest effect on the implementation of CSCM to the textile industry in Bangladesh

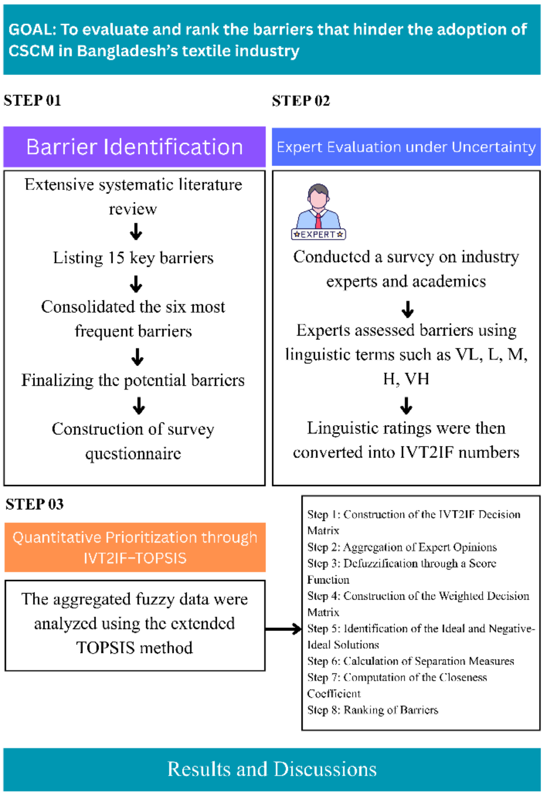


**Figure 1:** Research Framework

### Data Collection through Expert Evaluation

Primary data were collected through a structured expert survey to reconcile the findings from the literature review. A purposive sampling approach was used to ensure that participants possessed practical and theoretical knowledge relevant to the study (Kannan *et al.*, 2014). To keep a balance and link between industry application to academic knowledge the expert panel consists of both ranges. In total, 8 experts took part in the evaluation process. Their profiles included Supply chain manager, Textile industry professionals, Policy/Regulatory professional, and Academic/Researcher. Each expert was provided with a short explanation of the study's objectives and the definitions of the six consolidated CSCM barriers derived from the literature review. The general profile of the eight participating experts is provided in the table. Participants were asked to assess the relative importance of each barrier using a five-point linguistic scale: Very Low, Low, Moderate, High, and Very High (The survey questionnaires are available in the appendix). This linguistic scale was selected since it gives the experts an opportunity to further their opinion rather than necessarily giving them numerical values to be applied. This kind of qualitative judgment becomes useful in situations of sustainability problems where perceptions are usually held based on experience in context (Govindan & Hasanagic, 2018).

Nonetheless, linguistic expressions have certain degree of vagueness and reluctance, because the professionals might not fully believe in attributing a certain degree of significance. Their thinking may be sometimes contrasted at two levels of linguistic, and the decision made between one and the other may be a stain to the integrity of the study. To compensate this, the responses in the linguistic collected were transformed into IVT2IF numbers. This change allows every judgment to represent, not merely the level of membership (the extent to which a barrier is regarded as important) but also the level of non-membership (the extent to which it is not). The gap between the two degrees shows the error allowance, which is the uncertainty of the expert views.

**Table 3:** Demographic and Professional Profile of Experts

| Experts No. | Background | Institution Category | Experience (In Years) |
|---|---|---|---|
| E1 | B.Sc. in Textile Engineering | Textile industry professional | 8 |
| E2 | M.Sc. in Industrial and Production Engineering | Supply chain manager | 6 |
| E3 | B.Sc. in Textile Engineering | Textile industry professional | 7 |
| E4 | M.Sc. in Textile Engineering | Supply chain manager | 8 |
| E5 | M.Sc. in Textile Engineering | Policy/Regulatory professional | 15 |
| E6 | Ph.D. in Logistics Management | Academic/Researcher | 6 |
| E7 | M.Sc. in Supply Chain Management | Academic/Researcher | 10 |
| E8 | Ph.D. in Textile Engineering | Academic/Researcher | 6 |

### Interval-Valued Type-2 Intuitionistic Fuzzy Set

In order to deal with the corresponding ambiguity and reluctance of expert estimates, the Interval-Valued Type-2 Intuitionistic Fuzzy Set (IVT2IFS) framework is used in this study.

IVT2IFS is a generalization of (Atanassov, 1999) an intuitionistic fuzzy set, but where the degrees of membership and non-membership are represented as intervals to reflect more advanced levels of uncertainty in human thought (Öztayşi *et al.*, 2022) (Atanassov, 1999). Formally, an IVT2IFS can be expressed as:

$$\hat{A} = \{\langle x, [\mu L(x), \mu U(x)], [\nu L(x), \nu U(x)] \rangle \mid x \in X\} \quad (1)$$

subject to the condition,

$$0 \leq \mu U(x) + \nu U(x) \leq 1 \quad (2)$$

and the hesitation interval, $\pi(x) = 1 - \mu U(x) - \nu U(x)$

$$\pi(x) = 1 - \mu U(x) - \nu U(x) \quad (3)$$

In the present research, all the specialists have rated all barriers on a linguistic scale according to three parameters which include: Severity, Likelihood and Difficulty. Every linguistic label was also assigned to each interval-valued membership and non-membership pair indicated in Table 4.

**Table 4:** Linguistic scale for Interval-Valued Intuitionistic Fuzzy Sets (IVIFS)

| Linguistic label | Membership interval [μL, μU] | Non-membership interval [νL, νU] |
|---|---|---|
| Very High | [0.80, 0.90] | [0.05, 0.15] |
| High | [0.65, 0.80] | [0.15, 0.25] |
| Moderate | [0.45, 0.60] | [0.25, 0.40] |
| Low | [0.25, 0.40] | [0.40, 0.55] |
| Very Low | [0.10, 0.25] | [0.55, 0.70] |

For each barrier (i) and criterion (j), fuzzy evaluations from k = 8 experts were aggregated by arithmetic mean:

$\bar{A}_{ij} = 1/K \sum^{k}_{(e=1)} \hat{A}_{ij}^{(e)}$ (4)

This generated a composite IVT2IF decision table retaining inter-expert variability and minimizing subjective bias.

### TOPSIS Method and Its Integration with the IVT2IF Framework

TOPSIS Approach and the combination with the IVT2IF Structure. The combined IVT2IF assessments of the last stage represent the views of experts in a. comprehensive form. In order to make these fuzzy evaluations more readable and to identify the ranking of the barriers, a systematic procedure of ranking was needed. For this purpose, the current paper combines the IVT2IF model with the Technique of Order of Preference by. Like Ideal Solution (TOPSIS). This mixed approach transforms interval based fuzzy. tests of quantifiable closeness numbers relative to optimum and anti-optimal reference points, enable an objective and data-oriented comparison of the obstacles. Hwang and Yoon (1981) introduced the TOPSIS technique, which is one of the most popular MCDM. technique which orders alternatives in terms of their proximity to an ideal solution. The underlying concept presupposes that the best option is one that is closest to the geometric distance to the. Positive Ideal Solution (PIS) and the distance of the farthest form of Negative Ideal Solution (NIS) (Hwang & Yoon, 1981).

The degree of closeness coefficient (CCs) of each alternative is computed in the classical model as:

$CC_i = D_i^- / (D_i^+ + D_i^-)$ (5)

Where-

$D_i^+$ is the Euclidean distance from the PIS, and

$D_i^-$ is the Euclidean distance from the NIS.

The greater the values of CC the closer to the ideal are the alternatives that are more desirable.

### Integration of IVT2IF with TOPSIS

This is a hybrid method that consists of the ability of IVT2IFS to quantify uncertainty in the role of expert judgements and the ranking ability of TOPSIS, which allows organizing and transparent decision-making. The calculation process that was used in this research had the following eight steps:

**Step 1: Construction of the IVT2IF Decision Matrix**

Eight domain experts evaluated six key barriers ($B_1$–$B_6$) across three criteria: Severity, Likelihood, and Difficulty, using linguistic terms ranging from Very Low to Very High. Each linguistic term was mapped to its corresponding IVT2IF number, defined by interval-valued membership and non-membership degrees (see Table). This process produced a fuzzy decision matrix, where each element $\hat{A}_{ij} = \langle [\mu L, \mu U], [\nu L, \nu U] \rangle$ represents the collective uncertainty of the experts' judgments.

**Step 2: Aggregation of Expert Opinions**

Since each of the opinions might differ, all of the expert ratings of every barrier-criterion combination were summarized in terms of the arithmetic mean of the lower and upper limit of both membership and non-membership functions:

$\hat{\bar{A}}_{ij} = (1/k)\, \Sigma_e\, \hat{A}_{ij}^{(e)}$, where k = 8 experts.

This created an aggregated IVT2IF matrix that indicates an equitable group decision whilst preserving the data concerning uncertainty (S. Singh *et al.*, 2016).

**Step 3: Defuzzification through a Score Function**

In order to allow quantitative processing in the TOPSIS, the aggregated IVT2IF numbers were transformed to crisp scores by applying score function-

$S(\hat{\bar{A}}_{ij}) = [(\mu L + \mu U)/2] - [(\nu L + \nu U)/2]$ (6)

Such transformation results in one representative value of each fuzzy assessment, and it maintains the relative distance between barriers and criteria.

**Step 4: Construction of the Weighted Decision Matrix**

The weight w assigned to the criterion j was the perceived significance of that particular criterion. A weighted score of each pair of barriers-criterion was then computed as:

$V_{ij} = w_j \times S(\hat{\bar{A}}_{ij})$ (7)

The resulting weighted matrix integrates both the expert evaluations and the importance of each criterion.

**Step 5: The Ideal and Negative-Ideal Solution Identification**

The Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) were calculated as follows concerning every criterion:

$V_j^+ = \max(V_{ij})$ and $V_j^- = \min(V_{ij})$.

The PIS represents the most favorable performance value across all barriers, while the NIS represents the least favorable one.

**Step 6: Calculation of Separation Measures**

The Euclidean distance of each barrier from both reference points was calculated as:

$D_i^+ = \sqrt{\Sigma_j (V_{ij} - V_j^+)^2}$ (8)

$D_i^- = \sqrt{\Sigma_j (V_{ij} - V_j^-)^2}$ (9)

These distances express how close or far each barrier is from the ideal and anti-ideal conditions.

**Step 7: Computation of the Closeness Coefficient**
The relative performance of each barrier was expressed through the closeness coefficient (CC):
$CC_i = D_i^- / (D_i^+ + D_i^-)$
A higher CC value indicates a barrier that is closer to the ideal condition—meaning it exerts a stronger impact on CSCM implementation.

**Step 8: Ranking of Barriers**
Lastly, the barriers were prioritised concerning their respective CC values. The ranking offered a quantifiable, fact-based prioritization that determines the most significant impact of barriers on CSCM adoption on the whole. The entire middle and final calculations that go with these eight steps are recorded in the Supplementary

**Appendix**
In the classical version of TOPSIS, a normalization process is conducted in order to convert heterogeneous criteria into similar dimensions. Normalization was not a concern in this research, since all the expert ratings were achieved on uniform linguistic scale, which was translated into interval valued fuzzy numbers falling in [0, 1]. The following score function also yields clear values in this range and therefore all criteria are innately comparable. This model is consistent with recent fuzzy TOPSIS extensions, which do not explicitly normalize in the cases where all criteria are based upon homogeneous linguistic ratings.

## RESULTS AND DISCUSSION

### Results

**Overview of Expert Evaluations**
There were eight experts (E1-E8) who provided linguistic ratings as per the provided questionnaires. The ratings ranged from Very High (VH) to Very Low (VL). This was carried out for all six barriers (B1 to B6). Each barrier was assessed under three criteria shown in Table 5.

**Table 5:** Criteria Table

| Criteria | Characteristics | Details |
|---|---|---|
| C1 | Severity of impact | It shows strongly the barrier hinders the transition |
| C2 | Likelihood/Frequency | It shows how often the barrier is encountered |
| C3 | Difficulty to mitigate | It shows how challenging the barrier is to address |

The linguistic judgments were mapped to interval-valued intuitionistic fuzzy sets and aggregated across experts, yielding an IVT2IFS profile for each barrier-criterion pair (Step 4). These IVT2IFS triples were then transformed into crisp scores Sij, representing the net "barrier intensity" of barrier i under criterion j. At this stage, B2 consistently exhibited the highest aggregated scores across all three criteria, followed by B1, with B4 and B6. Whereas B5 and B3 ranked lower.
For example, the aggregated crisp scores Sij (mean of membership minus mean of non-membership) were:
B2: (C1 = 0.638, C2 = 0.609, C3 = 0.556)
B1: (C1 = 0.638, C2 = 0.447, C3 = 0.500)
B4: (C1 = 0.528, C2 = 0.459, C3 = 0.363)
To keep in mind, here, higher values indicate a more problematic barrier profile.

**Criteria Weights**
The criteria weights were derived directly from the aggregated IVT2IFS of the criteria themselves (Step 5). For each criterion, the interval-valued membership and non-membership degrees were averaged across experts to obtain $\bar{\mu}$ and $\bar{\nu}$. A scalar importance score was then computed as:
Scores= $\bar{\mu}-\bar{\nu}$
and normalized to obtain the final weights wj.
The resulting weights are:

**Table 6:** Criteria weights

| Criteria | $\bar{\mu}$ | $\bar{\nu}$ | Score_s | w_norm |
|---|---|---|---|---|
| C1 | 0.656 | 0.238 | 0.419 | 0.827 |
| C2 | 0.450 | 0.384 | 0.066 | 0.130 |
| C3 | 0.425 | 0.403 | 0.022 | 0.043 |

These values indicate how the experts prioritized the severity of the barrier's impact (C1) over other criteria. Likelihood (C2) and difficulty to mitigate (C3) are comparably less impactful, but experts have put likelihood ahead of the others. In other words, experts evaluated the ranking by how damaging the barrier is, how often it is encountered, and how challenging the barrier is to address, respectively.

**IVT2IF–TOPSIS Ranking of Barriers**
The findings of the IVT2IF-TOPSIS analysis are summarized in Table 7, which shows the calculated closeness coefficients (CC) and the respective rankings of the six main barriers.
The value of the CC reflects the approximate proximity of each of the barriers to the positive ideal solution (PIS) and the distance of that barrier to the negative ideal

solution (NIS). The higher the CC, the more influential a barrier is in the CSCM adoption, and the lower the usage, the less significant the impact.

Thus, financial constraints (B2) emerge as the most critical barrier in the IVT2IF context, followed closely by knowledge and awareness gaps (B1). Technological and organizational factors (B4, B6) form a second tier of concern, while policy/regulatory barriers (B5) and stakeholder-related issues (B3) are comparatively less critical within this particular decision setting.

**Table 7:** Ranking of Barriers

| Barrier code | Barrier description | $D^+$ | $D^-$ | CC | Rank |
|---|---|---|---|---|---|
| B2 | Financial constraints and economic viability concerns | 0.000 | 0.177 | 1.000 | 1 |
| B1 | Lack of knowledge, awareness, and motivation | 0.012 | 0.165 | 0.932 | 2 |
| B4 | Technological limitations and infrastructure gaps | 0.061 | 0.116 | 0.658 | 3 |
| B6 | Management and organizational capability gaps | 0.071 | 0.105 | 0.596 | 4 |
| B5 | Policy, regulatory, and institutional barriers | 0.170 | 0.008 | 0.044 | 5 |
| B3 | Lack of stakeholder involvement, collaboration, and communication | 0.177 | 0.000 | 0.000 | 6 |

## Discussion

### Dominance of Financial and Informational Barriers

The results of the IVT2IF-TOPSIS indicate a good hierarchy of the constraints: financial and economic viability issues (B2) are considered the most severe barrier, with the closeness coefficient, which is 1.0. This implies that the worst-case barrier profile, which is determined by the PIS, is nearly the same as barrier B2. This dominion coincides with the underlying IVT2IFS scores in this respect since it obtains top membership degrees to high barrier degrees with all three criteria, and especially in the severity and possibility criteria.

Intimately with B2 is the absence of knowledge, awareness, and motivation (B1), CC=0.932. The new difference between B2 and B1 indicates that the constraint system formed by financial and informational barriers is one that is highly integrated. In other cases, there is money, but it may take them too long to realize the transition pathway or too long to misjudge it, and vice versa, it is not possible to take any action without effective financial models, as motivation is very high.

This trend is supported by the criteria of weighting: the severity of impact (C1) is greatly weighted, which is approximately 0.83. This implies that those barriers that are deemed to have a high negative effect on the transition will be overemphasized in the final ranking. B1 and B2 score strongly on C1, hence their strong placement at the top of the ranking. The comparatively small weight on the difficulty of mitigation means that professionals cared more about the magnitude of harm resulting from a barrier than the level of hardship it could be to resolve.

### Role of Technological and Organizational Barriers

The following category of barriers includes technological barriers and infrastructure gaps with a closeness coefficient of approximately 0.66, and management and organizational capability gaps with a closeness coefficient of approximately 0.60. These values imply that B4 and B6 are both not negligible and dominant barriers. They simply highlight structural bottlenecks, which may support the effect of financial and informational constraints.

The sharp scores Sij give are also a bit more subtle since B4 and B6 have moderate-to-high severity in C1 and non-trivial severity in C2 and C3. This, in a practical sense, implies that financial resources and awareness may be increased, yet the successful implementation of the IVT2IF objectives may still be inhibited by the inadequate infrastructure, ineffective technologies, or the lack of organizational capacities. In terms of management, it is possible to consider B4 and B6 as enabling conditions. Before investments and information campaigns can be converted into actual results, they need to attain a certain level of adequacy.

### Lower-Ranked Barriers: Not Absent, But Relatively Less Critical

Policy, regulatory, and institutional barriers (B5) and the lack of stakeholder involvement, collaboration, and communication (B3) rank at the lower end of the ranking, with B3's closeness coefficient near zero. It is important to emphasize that this does not imply that these barriers are unimportant in an absolute sense. Rather, within this expert sample, set of barriers, and weighting structure:

1. B1 and B2 are relatively more restraining than B5 and B3.
2. If we consider severity and frequency, we can see that their IVT2IFS profiles are closer to the NIS.

The Pearson correlation matrix in Table 8 offers additional insights here. Stakeholder barriers (B3) are strongly and positively correlated with policy and regulatory barriers (B5), suggesting they tend to co-occur; contexts with weak stakeholder engagement are often also characterized by institutional or regulatory misalignment. Simultaneously, we can conclude that various barrier configurations exist throughout the organizational or contextual level based on the negative correlations B3 shows with some of the other barriers (e.g., B6)

In essence, both B3 and B5 might be the second-order amplifiers: they might not be viewed as the key bottlenecks in the scenario of the baseline, but they can greatly intensify the effect of the dominating barriers (such as financial constraints) in particular institutional settings.

**Inter-Barrier Relationships and Clustering**

The 6×6 Pearson correlation matrix derived from expert-level crisp scores reveals several noteworthy relationships:

1. B1 (knowledge/awareness) and B3 (stakeholder involvement) are moderately positively correlated (r=0.55), indicating that experts who perceive strong informational barriers also tend to perceive deficits in stakeholder engagement.
2. B3 (stakeholders) and B5 (policy/regulation) exhibit a strong positive association (r=0.78), pointing to a plausible "socio-institutional cluster" where weak collaboration and misaligned policies reinforce each other.
3. B2 (financial) and B6 (management capability) show a moderate positive correlation (r=0.49), which may reflect that organizations struggling with financial constraints also exhibit weaker managerial capacity to plan and execute the transition.

These patterns suggest that barriers should not be treated as independent. While TOPSIS provides a useful scalar ranking, the correlation structure indicates clusters of co-occurring obstacles: financial–organization, informational–stakeholder, and stakeholder–policy. Targeting one barrier in isolation may therefore yield limited impact if its correlated partners are left unaddressed.

**Table 8:** 6×6 Pearson correlation matrix

| | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|
| B1 | 1 | -0.1581 | 0.5531 | 0.1787 | 0.4245 | -0.1437 |
| B2 | -0.1581 | 1 | 0.2343 | -0.2644 | 0.231 | 0.4862 |
| B3 | 0.5531 | 0.2343 | 1 | 0.0878 | 0.7751 | -0.5456 |
| B4 | 0.1787 | -0.2644 | 0.0878 | 1 | -0.2525 | -0.3541 |
| B5 | 0.4245 | 0.231 | 0.7751 | -0.2525 | 1 | -0.3535 |
| B6 | -0.1437 | 0.4862 | -0.5456 | -0.3541 | -0.3535 | 1 |

*Note: Red = strong positive correlation; green = strong negative correlation*

**Implications and limitations**

Practically, the results of the IVT2IF-TOPSIS point to the importance of the priority interventions being aimed at the Reduction of financial and economic viability risks (B2), Strengthening of knowledge, awareness, and motivation (B1), and the enabling conditions (B4, B6) to guarantee that technological and infrastructural preparedness, managerial capabilities, and organizational capabilities are at an adequate level to take in and implement new investments.

Meanwhile, the analysis also has a number of limitations, including the results' conditionality on the selected criteria and weights. The penchant towards severity (C1) is one of the factors contributing to the dominance of B2 and B1. Other weighting mechanisms (e.g. by giving more weight to the difficulty of mitigation or the long-term lock-in effects) might rearrange the relative locations of the barriers. The expert sample size (n = 8), typical of expert-driven MCDA, might not be sufficiently representative to reflect the diversity of perspectives across stakeholder groups or regions.

Irrespective of these cautions, the IVT2IF-TOPSIS model provides a consistent, mathematically sound, and interpretable ranking of obstacles, with financial and informational limitations being the key central issues, and how the technological, organizational, policy, and stakeholder conditions interact with obstacles. Such a systematic understanding can be used to facilitate more specific strategic action at the system level to overcome impediments in the IVT2IF transition (Ali *et al.*, 2025).

**CONCLUSION**

The research on CSCM barriers in the Bangladesh textile industry considers the most important obstacles to the system adoption with a hybrid IVT2IF-TOPSIS framework. The proposed approach explicitly characterizes expert uncertainty and hesitation, providing a strong and clearer mechanism for assessing complex sustainability-related decision problems under the supply chain environment.

These findings suggest that the most critical barrier to implementation of CSCM is the financial constraints and economic feasibility issues, followed by the lack of knowledge, awareness, and motivation. The second layer of constraints, which affect the effectiveness of the circular transition efforts, involves technological and infrastructural constraints and gaps in management and organizational capacity. Although policy, regulatory, and stakeholder-related barriers rated lower, the correlation analysis indicated that they might support prevailing barriers in some institutional conditions.

In terms of supply chain management, the findings can be seen to highlight that interventions at the system level should be prioritized, which should concentrate on financial feasibility and capability building before going on to broader institutional alignment. The methodology of this paper shows that IVT2IF-TOPSIS is applicable to the barrier prioritization issues that are ambiguous and subjective. The outcomes are normalized by the criteria and weighting structure, as well as the expert sample size chosen. Future studies can build on this study by including causal modeling methods, increasing the representation of stakeholders, or applying the framework to comparative or multi-sector chain of supply.

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