**Analysis Of Barriers In Green Supply Chain Management (Gscm) Implementation Using Interpretive** **Structural Modeling (Ism) And Fuzzy Topsis**

Septian Nando Herliansyah1,a), Thomy Eko Saputro2,b), Ikhlasul Amallynda3,c)

1,2,3Department of Industrial Engineering, University of Muhammadiyah Malang, Malang, Indonesia

a) [nando9a31@webmail.umm.ac.id](mailto:nando9a31@webmail.umm.ac.id)

b)Corresponding author: [thomysaputro@umm.ac.id](mailto:thomysaputro@umm.ac.id)

c) ikhlasulamallynda@umm.ac.id

**Abstract.** Green Supply Chain Management (GSCM) is a strategic approach that aims to reduce environmental impacts in a company's supply chain process. However, its implementation often encounters various barriers that affect the overall effectiveness of the implementation. This study aims to identify the main barriers to GSCM implementation and prioritize their systematic handling. The interpretive structural modeling (ISM) method is used to map the relationship structure between barriers, while Fuzzy TOPSIS is applied to determine the priority order based on the level of urgency and influence. A case study of the paper-based packaging printing industry sector is used to illustrate how this approach can help companies recognize and overcome crucial barriers that arise during GSCM implementation. The results show that limited funds, the high cost of environmentally friendly materials and technologies, and lack of commitment from suppliers are the most significant barriers to the company. This approach provides strategic directions that can be utilized to strengthen the integration of environmental principles in the company's supply chain.

**Keywords :** Green Supply Chain Management, barriers, ISM, Fuzzy-TOPSIS, environmental principles

# **INTRODUCTION**

Increasing global awareness of environmental issues is driving companies to adopt more environmentally friendly practices in all aspects of their operations. One of the fastest growing approaches in this regard is Green Supply Chain Management (GSCM), which integrates environmental considerations into the supply chain management process. GSCM covers management from raw material selection, production processes, distribution, to the final stages of the product cycle such as recycling and waste disposal [1]. This approach not only enhances efficiency but also responds to stringent environmental regulations and evolving consumer preferences that increasingly prioritize sustainability [2].

However, the realization of GSCM at the industry level still faces various challenges, especially for small and medium-sized enterprises. Many of them experience constraints in terms of funding, technological limitations, and dependence on suppliers who are not yet committed to sustainability [3]. These issues often lead to a gap between pro-environmental company policies and operational practices that do not fully support these goals [4]. As a result, the potential benefits of GSCM cannot be maximized optimally.

Problems in the field show that the implementation of GSCM is often limited to certain aspects. For example, the use of biodegradable materials or VOC-based inks is only carried out on a small proportion of products due to high costs or limited demand from consumers [5]. In addition, limited funds also make it difficult for companies to implement production systems that support the principles of reuse and recycle. This results in increased production waste and decreased customer satisfaction, which in turn can weaken the company's position in the market competition[6].

Previous research confirms the importance of GSCM [7] implementation and the barriers faced by the industry [5] including blockchain adoption and green logistics [8]. The success of GSCM is influenced by environmental integration, internal commitment, technological readiness, and supplier involvement [9]. However, most studies are still descriptive and have not discussed in depth the analysis between barriers and the priority of handling them.

To fill this gap, this study aims to identify and analyze the main barriers to the implementation of GSCM and determine the priority of addressing them. An interpretive structural modeling (ISM) approach is used to understand the hierarchical structure of interrelationships between barriers [5]. Once the relationships between barriers are mapped, the Fuzzy TOPSIS method is applied to assess and determine alternative solutions based on their proximity to the ideal condition [10]. The combination of these two methods is expected to provide clear direction for companies in formulating effective and systematic strategies to overcome existing barriers [11].

# **METHODS**

This study adopts an integrated approach using interpretive structural modeling (ISM) and fuzzy TOPSIS to analyze barriers in implementing Green Supply Chain Management (GSCM). ISM is first applied to identify and structure the relationships among the barriers and to determine which factors have the strongest influence. The results from ISM are then analyzed further using Fuzzy TOPSIS to calculate the weight and rank of each barrier based on expert judgment under uncertainty. This combination enables a structured and prioritized understanding of the most critical barriers to GSCM implementation [12].

## **Interpretive Structural Modeling (ISM)**

ISM is used to understand the complex structure of interrelated elements, so that the main bottlenecks that have the most influence on the GSCM system as a whole can be identified. The stages of ISM according to [5] is described as follows.

**Step 1**. The initial stage involved identifying elements that were relevant to the problem.

**Step 2**. The Structural Self-Interaction Matrix (SSIM) outlines the relationships between elements based on expert perceptions, using symbols: V (i affects j), A (j affects i), X (i and j influence each other), and O (no relationship).

**Step 3**. Normalization of matrix G = if the 0 ≤ gij ≤ 1 is obtained using equation (1)

*G* = *X , i, j* = 1,....., *n* (1)

**Step 4**. Calculating the Total Relation Matrix is calculated using the equation (2)

*T* = + + ...... (2)

**Step 5**. The Final Reachability Matrix (FRM) is formed by converting the SSIM into a binary matrix (IRM) using specific rules based on the symbols "*V*", "*A*", "*X*", and "*O*". This matrix is then used to calculate each factor’s driving power and dependence.

**Step 6**. Develop a cartesian diagram MICMAC (Matrix of Influence, Cross Multiplication Applied to a Classification) is used to categorize factors contributing to the cost of construction projects into four groups: independent, dependent, interrelated, and autonomous.

## **Shannon Entropy**

In this research, the weight of the criteria is determined based on three main criteria, namely Severity (S), Occurrence (O), and Detection (D). Using the Shannon Entropy method, the weight of each indicator is calculated objectively based on the diversity of values given to each alternative [13].

**Step 1**. Determine the comparison matrix between obstacle indicators and criteria using the TFN scale shown in **TABLE 1**.

**TABLE 1** Linguistic variables and the respective triangular fuzzy number (TFN) [14]

|  |  |  |
| --- | --- | --- |
| **Scale** | ***Linguistic variables*** | ***Triangular Fuzzy Number*** |
| 1 | Very Low (VL) | (0, 0.1,0.3) |
| 2 | Low (L) | (0.1,0.3,0.5) |
| 3 | Medium (M) | (0.3,0.5,0.7) |
| 4 | High (H) | (0.5,0.7,0.9) |
| 5 | Very High (VH) | (0.7,0.9,1) |

**Step 2**. Normalize the decision matrix using the following equation

*Pij =*  (3)

**Step 3**. After the matrix is normalized, the entropy value for each criterion is calculated using the following equation.

(4)

**Step 4**. After calculating entropy, the next step is to calculate the degree of dispersion or the level of informative variation of each criterion, with the formula (5)

(5)

**Step 5**. The last step determines the weight of the criteria (

(6)

## **Fuzzy TOPSIS (Fuzzy Technique for Order Preference by Similarity to Ideal Solution)**

Fuzzy TOPSIS is a technique of showing the best alternative by evaluating alternative solutions based on their closeness to the ideal solution which is used to calculate the weight of obstacles in the implementation of GSCM and ranking is carried out the procedure of fuzzy TOPSIS is given in detail in the following [14].

**Step 1**. Calculate the normalized matrix (R) by using the equations (7) & (8)

+ (7)

+ ) (8)

**Step 2**. Multiplying the normalized value by the weight of the criteria using equation (9)

*vij = wj x rj* (9)

**Step 3**. Determine the positive ideal solution matrix (A+) using equation (10), and the negative ideal matrix (A-) using equation (11)

= ( (10)

= ( (11)

**Step 4**. Calculating mathematical alternatives for positive ideal solutions can be seen in and for negative ideal solutions can be seen in equation (12)

(12)

**Step 5**. Determining the preference value (Ci) is the closeness of an alternative to the ideal solution, which can be found using equation (13)

*Ci* = (13)

# **RESULT AND DISCUSSION**

## **Case Study**

This study presents a case analysis of the barriers to implementing Green Supply Chain Management (GSCM) in a packaging company. Initially, the barriers are examined using the Interpretive Structural Modeling (ISM) method. Subsequently, a further analysis is conducted to determine the weight of each barrier based on Severity (S), Occurrence (O), and Detection (D) criteria, allowing for the identification and ranking of the most critical barriers to GSCM implementation. The respective indicators of barriers are shown in **TABLE 2**.

**TABLE 2** Barriers of GSCM

|  |  |  |  |
| --- | --- | --- | --- |
| **Code** | **Barriers** | **Code** | **Barriers** |
| A1 | Difficulty in maintaining environmentally certified suppliers | A11 | Lack of environmental knowledge |
| A2 | Complexity in measuring and monitoring suppliers' environmental practices | A12 | Absence of specific environmental targets |
| A3 | Lack of government support for adopting environmentally friendly policies | A13 | Difficulty in obtaining information on potential environmental improvements |
| A4 | Lack of technical expertise | A14 | High investment and low return on investment |
| A5 | Design complexity for reuse/recycling of used products | A15 | High cost of environmentally friendly packaging |
| A6 | Design complexity for reducing resource/energy consumption | A16 | Financial constraints |
| A7 | Current practices lack flexibility to transition to new systems | A17 | Lack of customer awareness and pressure regarding GSCM |
| A8 | Lack of new technologies, materials, and processes | A18 | Limited participation in environmental programs/meetings |
| A9 | Lack of awareness regarding reverse logistics adoption | A19 | Lack of top management involvement in GSCM adoption |
| A10 | Low environmental literacy among supply chain members | A20 | Lack of support and guidance from authorities |

## **Analysis barriers method ISM**

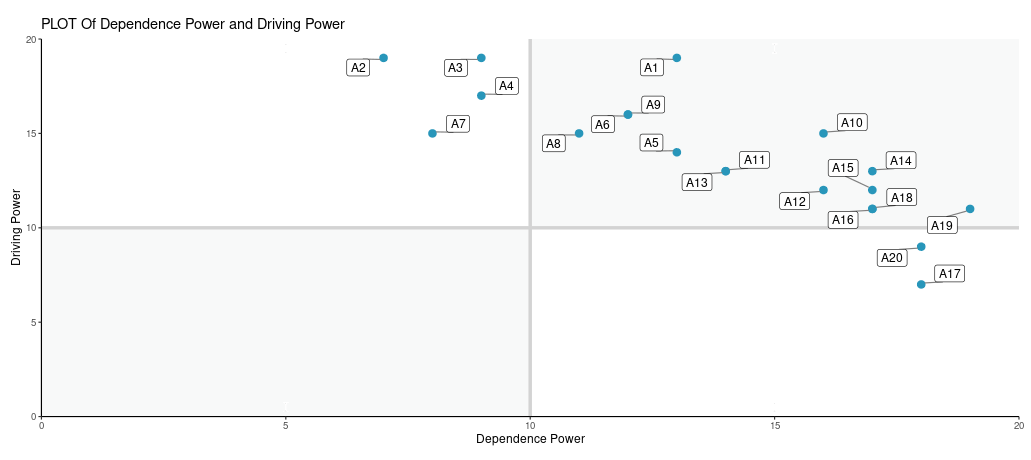
The ISM method is employed to identify the most influential obstacles in the implementation of GSCM, with results derived from the Structural Self-Interaction Matrix (SSIM). **TABLE 3** presents the SSIM, which outlines the relationships between elements based on expert judgment.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Barriers** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **A11** | **A12** | **A13** | **A14** | **A15** | **A16** | **A17** | **A18** | **A19** | **A20** |
| A1 |  | V | A | A | A | V | A | X | V | A | X | V | A | A | V | A | V | O | X | A |
| A2 |  |  | V | O | V | V | V | A | V | V | V | A | X | V | V | V | O | A | A | V |
| A3 |  |  |  | V | V | X | V | V | A | O | A | V | V | V | V | O | X | A | A | V |
| A4 |  |  |  |  | O | V | V | A | X | A | V | V | O | V | X | A | O | X | O | X |
| A5 |  |  |  |  |  | A | O | A | X | X | O | X | V | A | O | X | V | A | O | X |
| A6 |  |  |  |  |  |  | A | X | V | V | V | X | V | A | A | O | X | A | V | V |
| A7 |  |  |  |  |  |  |  | V | A | V | O | V | V | A | V | V | A | V | V | O |
| A8 |  |  |  |  |  |  |  |  | O | A | O | V | A | V | X | O | V | A | O | V |
| A9 |  |  |  |  |  |  |  |  |  | V | X | X | O | A | A | V | X | V | V | O |
| A10 |  |  |  |  |  |  |  |  |  |  | X | X | V | X | V | A | O | A | X | A |
| A11 |  |  |  |  |  |  |  |  |  |  |  | A | X | V | X | O | O | A | V | V |
| A12 |  |  |  |  |  |  |  |  |  |  |  |  | A | O | A | X | V | X | V | X |
| A13 |  |  |  |  |  |  |  |  |  |  |  |  |  | V | V | A | V | V | X | V |
| A14 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X | X | O | V | A | A |
| A15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | V | X | O | A | A |
| A16 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | V | O | X | V |
| A17 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | O | X | O |
| A18 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | A | X |
| A19 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | A |
| A20 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**TABLE 3** Matrixvariabel SSIM

**V : Effect, A : Be affected, X : Interplay, O = None**

The MICMAC analysis reveals that no barriers fall into Quadrant I, while A17 and A20 are positioned in Quadrant II. The majority of barriers A1, A5, A6, A8–A16, A18, and A1 are located in Quadrant III, whereas A2, A3, A4, and A7 appear in Quadrant IV. Barriers in Quadrants III and IV are considered critical and should be prioritized due to their high levels of influence and interdependence. In contrast, barriers outside these quadrants are less critical and can be addressed progressively over time.



III

IV

II

I

**Figure 1.** Analysis of MIMCAC

## **Weights of Criteria Method Shannon Entropy**

Following the identification of obstacles using the ISM method, **TABLES** 4 and 5 present the results of further data processing using the Shannon Entropy method. This method is applied to calculate the weight values for the Severity (S), Occurrence (O), and Detection (D) criteria, which are subsequently used to compute the *Ci* values and rank the barriers using the fuzzy TOPSIS.

**TABLE 4** Shannon entropy comparison matrix results

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Barrier** | **Severity (S)** | **Occurrence (O)** | **Detection (D)** | **Barrier** | **Severity (S)** | **Occurrence (O)** | **Detection (D)** |
| A1 | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | A10 | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | (0.7, 0.9, 1) |
| A2 | (0.5, 0.7, 0.9) | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | A11 | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | (0.5, 0.7, 0.9) |
| A3 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | A12 | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) |
| A4 | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | A13 | (0.1, 0.3, 0.5) | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) |
| A5 | (0.1, 0.3, 0.5) | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | A14 | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) |
| A6 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | A15 | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) |
| A7 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | A16 | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) |
| A8 | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | A18 | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) |
| A9 | (0.1, 0.3, 0.5) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) | A19 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.1, 0.3, 0.5) |

**TABLE 5** Final result of criteria weight

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Severity (S)** | **Occurrence (O)** | **Detection (D)** |
| *hi* | 0.982 | 0.985 | 0.988 |
| *di* = 1–*hi* | 0.018 | 0.015 | 0.012 |
| *W* | 0.391 | 0.330 | 0.279 |

According to **TABLE 5,** The results indicate that the Severity (S) criterion carries the highest weight at 0.391, followed by the Occurrence (O) criterion at 0.330, and the Detection (D) criterion at 0.279.

## **Weights and Rank of Indicator Barriers Method Fuzzy TOPSIS**

Weighting and ranking of the largest to smallest indicators of GSCM barriers based on 3 criteria weights Severity (S), Occurrence (O), Detection (D) for decision makers based on using the Fuzzy TOPSIS method, the final results of Fuzzy TOPSIS are summarized in **TABLES 6 & 7.**

**TABEL 6** Matrix fuzzy TOPSIS

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Barrier** | **Severity (S)** | **Occurrence (O)** | **Detection (D)** | **Barrier** | **Severity (S)** | **Occurrence (O)** | **Detection (D)** |
| A1 | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | A10 | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | (0.7, 0.9, 1) |
| A2 | (0.5, 0.7, 0.9) | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | A11 | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | (0.5, 0.7, 0.9) |
| A3 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | A12 | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) |
| A4 | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | A13 | (0.1, 0.3, 0.5) | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) |
| A5 | (0.1, 0.3, 0.5) | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | A14 | (0.5, 0.7, 0.9) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) |
| A6 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | A15 | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) |
| A7 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.5, 0.7, 0.9) | A16 | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) | (0.3, 0.5, 0.7) |
| A8 | (0.7, 0.9, 1) | (0.3, 0.5, 0.7) | (0.1, 0.3, 0.5) | A18 | (0.3, 0.5, 0.7) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) |
| A9 | (0.1, 0.3, 0.5) | (0.7, 0.9, 1) | (0.5, 0.7, 0.9) | A19 | (0.3, 0.5, 0.7) | (0.5, 0.7, 0.9) | (0.1, 0.3, 0.5) |

**TABEL 7** Weight and rank of GSCM barriers indicators

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Barrier** | **D⁺** | **D⁻** | **Ci** | **Rank** | **Barrier** | **D⁺** | **D⁻** | **Ci** | **Rank** |
| A1 | 0.8415 | 10.075 | 0.5449 | 4 | A10 | 12.819 | 0.5664 | 0.3064 | 13 |
| A2 | 11.553 | 0.6986 | 0.3768 | 8 | A11 | 0.9090 | 0.9419 | 0.5089 | 5 |
| A3 | 15.075 | 0.3435 | 0.1855 | 18 | A12 | 13.947 | 0.4542 | 0.2457 | 17 |
| A4 | 12.673 | 0.5835 | 0.3153 | 12 | A13 | 12.612 | 0.5871 | 0.3176 | 10 |
| A5 | 13.740 | 0.4763 | 0.2574 | 15 | A14 | 13.627 | 0.4906 | 0.2647 | 14 |
| A6 | 11.346 | 0.7190 | 0.3879 | 7 | A15 | 12.681 | 0.5878 | 0.3167 | 11 |
| A7 | 13.801 | 0.4727 | 0.2551 | 16 | A16 | 0.6341 | 12.155 | 0.6572 | 3 |
| A8 | 0.4919 | 13.564 | 0.7339 | 2 | A18 | 12.292 | 0.6218 | 0.3359 | 9 |
| A9 | 10.956 | 0.7546 | 0.4078 | 6 | A19 | 0.3592 | 14.918 | 0.8060 | 1 |

The final result of obstacle A19 (Lack of top management involvement in adopting GSCM) has the largest weight of 0.806, in second place obstacle A8 (Lack of new technologies, materials, and processes) has a weight of 0.733, for third place A16 (Financial constraints) with a weight of 0.657, and finally obstacle A3 (Lack of government support for adopting environmentally friendly policies) the smallest weight of 0.185.

## **Implications of Barriers GSCM**

Based on the analysis using the Interpretive Structural Modeling (ISM) and Fuzzy TOPSIS methods, this study emphasizes that companies need to seriously prioritize addressing key barriers in the implementation of Green Supply Chain Management (GSCM). These barriers, such as lack of top management involvement (A19), limited access to new technologies and processes (A8), and financial constraints (A16), were shown to have a significant influence on the failure to implement sustainability in the supply chain. The results of this study provide a clear picture of the priority barriers that must be addressed immediately so that the implementation of GSCM can be carried out in a planned, systematic and sustainable manner [15]. By overcoming these barriers, companies will not only improve efficiency and compliance with environmental regulations, but also strengthen competitiveness and long-term reputation [16].

The results of the MICMAC analysis provide valuable insights into the structural interrelationships among the barriers to implementing Green Supply Chain Management (GSCM) in the packaging sector. The absence of any barriers in Quadrant I (low driving power, low dependence) suggests that all identified barriers possess a certain degree of influence or are influenced by others in the system. This highlights the complex and interconnected nature of the challenges involved in GSCM implementation.

Barriers A17 and A20, which fall under Quadrant II (weak driving power, strong dependence), can be classified as dependent barriers. These obstacles are significantly influenced by other barriers and may not initiate major changes on their own. Therefore, addressing these barriers in isolation is unlikely to yield significant progress in GSCM adoption. Instead, they should be managed alongside more influential barriers to ensure a holistic solution.

The majority of the barriers, including A1, A5, A6, A8–A16, A18, and A19, reside in Quadrant III (strong driving power, weak dependence). These are known as independent or driving barriers, indicating that they exert significant influence on other obstacles but are themselves relatively unaffected by the rest. This suggests that strategic intervention at these points can trigger a cascading positive effect across the system. Prioritizing efforts to eliminate or reduce the impact of these barriers could significantly accelerate the adoption of GSCM practices. For instance, barriers related to lack of top management support or absence of environmental regulations may fall under this category and addressing them would unlock broader improvements.

Barriers A2, A3, A4, and A7 are positioned in Quadrant IV (strong driving power, strong dependence), also known as linkage barriers. These are unstable and sensitive elements that both influence and are influenced by many other barriers. Changes to these barriers can have widespread effects, but they also require careful handling due to their high interdependence. Interventions targeting these barriers should be approached with a systems-thinking perspective, ensuring alignment with broader organizational strategies to prevent negative feedback loops.

The practical implication of these findings is clear: organizations aiming to implement GSCM effectively must prioritize addressing the driving and linkage barriers in Quadrants III and IV. Doing so will not only remove direct obstacles but will also alleviate the dependent barriers in Quadrant II through a ripple effect. Conversely, barriers outside these critical quadrants can be improved incrementally as resources permit, without significantly disrupting the implementation process.

The MICMAC analysis provides a strategic roadmap for overcoming the most critical barriers to GSCM implementation. By targeting highly influential and interconnected barriers, firms in the packaging sector can enhance their readiness for sustainable practices, respond effectively to stakeholder pressures, and strengthen their overall competitive advantage in a sustainability-driven market landscape.

# **CONCLUSIONS**

This study identified 20 key barriers to the implementation of Green Supply Chain Management (GSCM) in companies, based on a comprehensive review of the literature and observations of actual field conditions. Using the Interpretive Structural Modeling (ISM) method and MICMAC analysis, it was found that the majority of barriers are located in Quadrants III and IV, indicating strong interdependencies and high influence factors that warrant priority attention. Barriers with low influence, specifically A17 and A20, were excluded from further analysis. The Shannon Entropy method was employed to determine the weights of evaluation criteria, resulting in weights of 0.391 for Severity (S), 0.330 for Occurrence (O), and 0.279 for Detection (D). Subsequently, the Fuzzy TOPSIS method was applied to rank the remaining barriers, identifying the five most critical as: lack of top management involvement (A19), limitations in new technologies and processes (A8), financial constraints (A16), dependence on non-environmentally friendly suppliers (A1), and low environmental knowledge (A11).

The practical implications of these findings highlight the need to prioritize strategic efforts in overcoming key barriers to GSCM, particularly through internal organizational improvements. Recommended solutions include strengthening top management involvement, adopting green technologies, securing sustainable financial resources, fostering collaboration with environmentally responsible suppliers, and providing continuous education and training for employees. Regular evaluation of barriers and the use of their weighted significance as a strategic reference are expected to facilitate more effective and sustainable implementation of GSCM.

# **REFERENCES**

[1] M. A. Ferreira, C. J. C. Jabbour, and A. B. L. de Sousa Jabbour, "Maturity levels of material cycles and waste management in a context of green supply chain management: An innovative framework and its application to Brazilian cases," *Journal of Material Cycles and Waste Management,* vol. 19, no. 1, pp. 516-525, 2017.

[2] W. Yu, R. Chavez, M. Feng, and F. Wiengarten, "Integrated green supply chain management and operational performance," *Supply Chain Management: An International Journal,* vol. 19, no. 5/6, pp. 683-696, 2014.

[3] V. Kumar, S. Sabri, J. A. Garza-Reyes, S. P. Nadeem, A. Kumari, and S. Akkaranggoon, "The challenges of GSCM implementation in the UK manufacturing SMEs," 2018: IEEE, pp. 1-8.

[4] Y. Inoue and P. Alfaro‐Barrantes, "Pro‐environmental behavior in the workplace: A review of empirical studies and directions for future research," *Business and Society Review,* vol. 120, no. 1, pp. 137-160, 2015.

[5] A. Jayant and M. Azhar, "Analysis of the barriers for implementing green supply chain management (GSCM) practices: an interpretive structural modeling (ISM) approach," *Procedia Engineering,* vol. 97, pp. 2157-2166, 2014.

[6] R. Chavez, W. Yu, M. Feng, and F. Wiengarten, "The effect of customer‐centric green supply chain management on operational performance and customer satisfaction," *Business Strategy and the Environment,* vol. 25, no. 3, pp. 205-220, 2016.

[7] N. M. Suki, N. M. Suki, A. Sharif, S. Afshan, and G. Rexhepi, "Importance of green innovation for business sustainability: identifying the key role of green intellectual capital and green SCM," *Business Strategy and the Environment,* vol. 32, no. 4, pp. 1542-1558, 2023.

[8] B. Q. Tan, F. Wang, J. Liu, K. Kang, and F. Costa, "A blockchain-based framework for green logistics in supply chains," *Sustainability,* vol. 12, no. 11, p. 4656, 2020.

[9] A. Susanty, D. P. Sari, D. I. Rinawati, and L. Setiawan, "The role of internal and external drivers for successful implementation of GSCM practices," *Journal of Manufacturing Technology Management,* vol. 30, no. 2, pp. 391-420, 2019.

[10] S. K. Patil and R. Kant, "A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers," *Expert systems with applications,* vol. 41, no. 2, pp. 679-693, 2014.

[11] M. Rossi, M. Germani, and A. Zamagni, "Review of ecodesign methods and tools. Barriers and strategies for an effective implementation in industrial companies," *Journal of Cleaner Production,* vol. 129, pp. 361-373, 2016.

[12] T. Rahman, S. M. Ali, M. A. Moktadir, and S. Kusi-Sarpong, "Evaluating barriers to implementing green supply chain management: An example from an emerging economy," *Production Planning & Control,* vol. 31, no. 8, pp. 673-698, 2020.

[13] S. A. Jozi, M. Shafiee, N. MoradiMajd, and S. Saffarian, "An integrated Shannon's Entropy–TOPSIS methodology for environmental risk assessment of Helleh protected area in Iran," *Environmental monitoring and assessment,* vol. 184, no. 11, pp. 6913-6922, 2012.

[14] M. Tavana, A. Shaabani, and N. Valaei, "An integrated fuzzy framework for analyzing barriers to the implementation of continuous improvement in manufacturing," *International Journal of Quality & Reliability Management,* vol. 38, no. 1, pp. 116-146, 2021.

[15] R. K. Malviya and R. Kant, "Prioritising the solutions to overcome the barriers of green supply chain management implementation: a hybrid fuzzy AHP-VIKOR framework approach," *Journal of Decision Systems,* vol. 27, no. 4, pp. 275-320, 2018.

[16] D. Ervin, J. Wu, M. Khanna, C. Jones, and T. Wirkkala, "Motivations and barriers to corporate environmental management," *Business Strategy and the Environment,* vol. 22, no. 6, pp. 390-409, 2013.