COGNITIA
INTERNATIONAL ENGINEERING JOURNAL

e-ISSN : 3090-7403
p-ISSN : 3109-2225
DOI : 10.63288/ciej.v2i1.16

Research Article

Hybrid AHP TOPSIS Approach for Evaluating Green Supply Chain Management Barriers in the Poultry Processing Industry

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Received 1 April 2026, **Revised** 26 April 2026, **Accepted** 29 April 2026

Abstract: The implementation of Green Supply Chain Management (GSCM) has become increasingly important in the agro-industrial sector, particularly in the poultry processing industry, due to rising environmental concerns and growing demand for sustainable production practices. However, its adoption remains limited because of various operational, technological, and managerial barriers. This study aims to identify and evaluate the major barriers to GSCM implementation and determine the most appropriate strategic solutions using a hybrid multi-criteria decision-making approach. The methods applied combine the Analytical Hierarchy Process (AHP) to assess the priority weights of barriers and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank alternative strategies. Data were collected through literature review, expert validation, and questionnaires distributed to 37 respondents involved in poultry supply chain activities, with all instruments proven valid and reliable. The findings reveal five primary barriers, namely limited environmentally friendly technology, low management commitment, limited investment capacity, inadequate human resource training, and unclear regulatory support and incentives. The TOPSIS analysis indicates that training and awareness enhancement is the most effective strategy, achieving the highest closeness coefficient value of 0.812. The study concludes that strengthening internal organizational capabilities, particularly through training and awareness, along with improving external support mechanisms, is essential to facilitate effective and sustainable GSCM implementation in the agro-industrial sector.

Keywords: Green Supply Chain Management (GSCM), Agro-Industry, Poultry Supply Chain, AHP-TOPSIS, Sustainability Strategy.

1. Introduction

The poultry processing sector represents a vital component of the global food supply chain, playing a significant role in meeting the growing demand for animal protein. In recent years, increasing concerns regarding environmental sustainability have encouraged industries to adopt environmentally responsible operational practices [1]. One such approach is Green Supply Chain Management (GSCM), which integrates environmental considerations into supply chain activities, ranging from raw material procurement and production processes to product distribution [2]. Despite its potential to enhance environmental performance and operational efficiency [3], The implementation of GSCM within the poultry processing industry remains limited due to various operational and organizational constraints [4].

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Several challenges continue to hinder the effective adoption of GSCM practices [5]. These constraints often arise from technical limitations, financial pressures, and managerial complexities that restrict companies from integrating sustainability principles into their supply chain operations [6]. As a result, identifying and systematically evaluating the barriers that impede GSCM implementation becomes a critical step toward facilitating sustainable transformation within the industry [7].

One major obstacle frequently highlighted in sustainability initiatives is the limited awareness and understanding among stakeholders regarding the long-term benefits of environmentally responsible practices [8]. Many firms still prioritize short-term economic performance over environmental considerations, which can lead to resistance toward organizational change and innovation required for GSCM adoption [9]. In addition, inadequate technological infrastructure, insufficient expertise, and limited financial resources further constrain companies' ability to implement environmentally friendly supply chain strategies [10], [11]. Consequently, a comprehensive analytical approach is necessary to identify the most critical barriers and support the development of appropriate mitigation strategies [12].

To address these challenges, this study employs a hybrid multi-criteria decision-making framework integrating the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [13]. The AHP method is utilized to determine the relative importance and priority of factors influencing GSCM implementation, while TOPSIS is applied to evaluate and rank potential strategic alternatives based on their proximity to the ideal solution [14]. The integration of these two methods enables a structured and systematic evaluation process, allowing researchers to better capture the complexity of decision-making in sustainable supply chain management [13].

Furthermore, this research emphasizes the importance of contextual analysis by considering the specific characteristics of the poultry processing industry, particularly within developing economies [15]. Institutional factors such as government regulations, organizational culture, and local market dynamics may significantly influence the implementation of sustainable supply chain practices [16], [17]. Therefore, understanding these contextual conditions is essential in designing strategies that are both practical and effective.

Previous studies have examined the application of AHP and TOPSIS in evaluating GSCM implementation across various manufacturing sectors, including general manufacturing and the automotive industry [18]. While these studies provide valuable insights into sustainability adoption, limited research has specifically addressed the poultry processing sector. Accordingly, this study seeks to bridge this research gap by investigating the distinctive barriers encountered in this industry and evaluating them using a hybrid decision-making framework.

Ultimately, successful GSCM implementation requires coordinated efforts among multiple stakeholders, including government authorities, suppliers, industry actors, and consumers [19], [20]. Collaboration among these stakeholders can facilitate the development of policies, technological support, and market incentives that promote sustainable supply chain practices. By systematically identifying and prioritizing key barriers, this study aims to provide both theoretical contributions and practical recommendations that can assist industry practitioners in developing more effective sustainability strategies.

2. Research and Methodology

2.1 Materials

This study applies a hybrid multi-criteria decision-making approach by integrating AHP and TOPSIS to analyze barriers to the implementation of Green Supply Chain Management (GSCM) in the poultry processing industry. Data were collected using structured questionnaires distributed via

Google Forms (Google LLC, Mountain View, CA, USA) to 37 selected respondents, including managers, supervisors, and supply chain staff. The purposive sampling method ensured that relevant expertise was represented. The collected data were processed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) to construct pairwise comparison matrices and decision matrices for further analysis.

2.2 Experiments

The experimental procedure consists of applying AHP and TOPSIS in sequential stages. In AHP, the relative weight of each criterion is obtained from pairwise comparisons using:

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}} \tag{1}$$

Consistency is verified using the Consistency Ratio (CR). The resulting weights are then applied in TOPSIS, where the normalized decision matrix is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2}$$

These steps ensure systematic evaluation and ranking of alternative strategies..

2.3 Product characterization

The results are characterized based on prioritized barriers and ranked strategies obtained from AHP–TOPSIS analysis. In TOPSIS, the relative closeness to the ideal solution is calculated using:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{3}$$

where D_i^+ and D_i^- represent distances to the positive and negative ideal solutions. Higher values indicate better alternatives. Sensitivity analysis was also conducted to test ranking stability under varying weights. This characterization ensures that the results are robust and provide reliable recommendations for improving sustainable supply chain performance.

3. Results and Discussion

3.1. Determination of Respondent Count

Respondents were selected using purposive sampling to ensure they possess relevant knowledge and experience in supply chain activities within the poultry processing industry. This approach is appropriate for studies applying the Analytical Hierarchy Process and Technique for Order Preference by Similarity to Ideal Solution, which require expert judgment. A total of 37 respondents, including managers, supervisors, and operational staff involved in procurement, production, and logistics, participated in this study (Table 1).

Table 1. Respondent Demographic Characteristics

Criteria	Category	Number of Respondents	Percentage
Position	Manager	9	24.3%
	Supervisor	13	35.1%
	Operational Staff	15	40.6%
Work Experience	1–5 years	8	21.6%
	6–10 years	16	43.2%
	>10 years	13	35.2%
Involvement in Supply Chain Activities	Procurement	10	27.0%
	Production	14	37.8%
	Logistics & Distribution	13	35.2%

Based on Table 1, the distribution of respondents shows that operational staff represent the largest proportion (40.6%), followed by supervisors (35.1%) and managers (24.3%). This composition indicates that the data collected reflect both managerial perspectives and operational insights, which is essential for understanding the practical challenges of GSCM implementation. In terms of professional experience, most respondents (43.2%) have 6–10 years of work experience, while 35.2% have more than 10 years of experience, indicating that the majority of participants possess substantial industry knowledge. Furthermore, respondents are involved in various supply chain functions, including production (37.8%), logistics and distribution (35.2%), and procurement (27.0%). The diversity of roles ensures that the evaluation of GSCM barriers incorporates comprehensive perspectives from different stages of the poultry processing supply chain.

3.2. Identification of GSCM Barriers

Barriers to GSCM implementation in the poultry processing industry were identified through literature review and respondent validation. The barriers were grouped into four categories: organizational, financial, technological, and regulatory. These categories represent key challenges such as limited management commitment, high investment costs, inadequate green technology, and weak environmental regulations affecting sustainable supply chain practices.

These barriers are particularly relevant to the poultry processing industry, which often operates with tight production schedules, cost efficiency pressures, and limited technological infrastructure. As a result, companies may face difficulties in adopting environmentally friendly supply chain practices without adequate managerial support, financial resources, and regulatory incentives. The identified barriers and their corresponding criteria used in this study are presented in Table 2.

Table 2. Identified GSCM Barriers and Criteria

Category	Barrier Code	Identified Barriers
Organizational Barriers	OB1	Lack of management commitment to environmental practices
	OB2	Limited employee awareness of environmental sustainability
Financial Barriers	FB1	High investment cost for green technology
	FB2	Limited financial resources for sustainability programs
Technological Barriers	TB1	Limited availability of green technology
	TB2	Lack of technical expertise in environmental management

Category	Barrier Code	Identified Barriers
Regulatory Barriers	RB1	Weak enforcement of environmental regulations
	RB2	Limited government support for green initiatives

Based on Table 2, several barriers play a significant role in influencing the implementation of GSCM in the poultry processing industry. Organizational barriers often arise due to insufficient commitment from top management and limited awareness among employees regarding environmental practices. Financial barriers are also critical because adopting environmentally friendly technologies generally requires substantial investment. In addition, technological barriers indicate that companies may lack access to advanced green technologies or the necessary expertise to implement them effectively. Regulatory barriers further contribute to the challenge, particularly when environmental regulations are not strictly enforced or when government incentives for sustainable practices are limited. These identified barriers serve as the basis for the next stage of analysis using AHP to determine their relative priority in the decision-making process.

3.3. AHP Analysis: Priority of GSCM Barriers

This section presents the analysis of the priority level of barriers to the implementation of GSCM using the Analytical Hierarchy Process method. AHP is applied to determine the relative importance of each identified barrier based on expert judgments collected from respondents. Through this approach, barriers can be systematically evaluated and ranked by their influence on the implementation of sustainable supply chain practices in the poultry processing industry.

3.3.1. Hierarchical Structure

The AHP analysis begins with developing a hierarchical structure that represents the study's decision framework. The hierarchy consists of three levels: the overall goal of determining priority barriers to GSCM implementation in the poultry processing industry, the criteria level, including organizational, financial, technological, and regulatory barriers, and the sub-criteria describing specific barrier types. This structure enables systematic pairwise comparisons to determine the relative priority of each factor, in Figure 1.

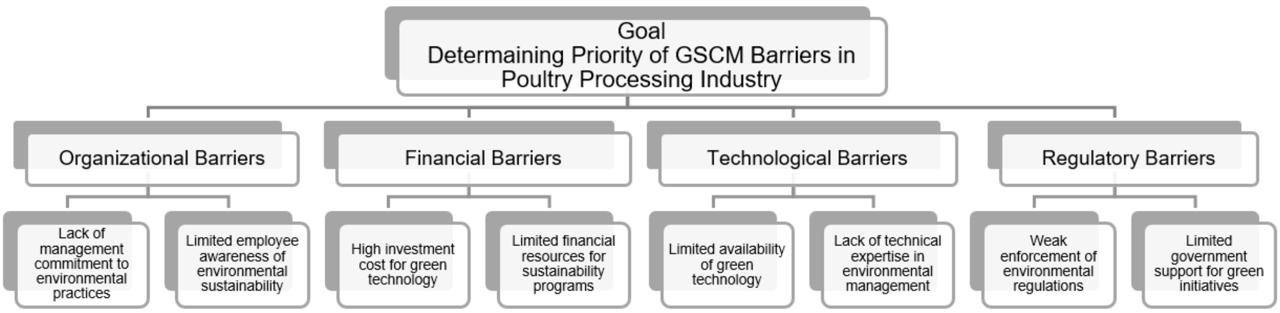

Figure 1. Hierarchical Structure for Evaluating GSCM Barriers

Figure 1: The hierarchical structure used to evaluate barriers to GSCM implementation using the AHP. The model consists of three levels: the goal, criteria, and sub-criteria. The criteria include four main barriers: organizational (OB), financial (FB), technological (TB), and regulatory (RB). Each criterion contains two sub-barriers (OB1–OB2, FB1–FB2, TB1–TB2, RB1–RB2), which are evaluated through pairwise comparisons to determine the priority barriers in the poultry processing industry.

3.3.2. Pairwise Comparison Results

In the Analytical Hierarchy Process analysis, a pairwise comparison matrix was constructed to evaluate the relative importance of barriers affecting Green Supply Chain Management implementation. The comparisons were based on judgments from 37 respondents using a standard comparison scale. Each barrier category: OB, FB, TB, and RB, was compared to determine its influence on sustainable supply chain adoption. The aggregated results form a matrix used to calculate priority weights, as presented in Table 3.

Table 3. Pairwise Comparison Matrix of GSCM Barrier Criteria

Criteria	OB	FB	TB	RB
Organizational Barriers (OB)	1.00	0.50	0.33	2.00
Financial Barriers (FB)	2.00	1.00	0.50	3.00
Technological Barriers (TB)	3.00	2.00	1.00	4.00
Regulatory Barriers (RB)	0.50	0.33	0.25	1.00

Table 3 presents the pairwise comparison matrix in the Analytical Hierarchy Process used to assess barriers affecting GSCM implementation. It compares four criteria: OB, FB, TB, and RB. Each value indicates relative importance; for example, TB–OB = 3 shows that technological barriers are moderately more influential than organizational barriers.

3.3.3. Consistency Ratio Test

The Consistency Ratio (CR) test in the Analytical Hierarchy Process (AHP) is used to evaluate the reliability of pairwise comparison judgments. It is calculated using the Consistency Index (CI) and Random Index (RI).

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

The CI is obtained from the maximum eigenvalue, while RI depends on the number of criteria. In this study, the calculated CR value is 0.07, which is less than the acceptable threshold of 0.10. This indicates that the respondents' judgments are consistent and reliable, allowing the derived priority weights to be used in further TOPSIS analysis.

Table 4. Priority Weights and Consistency Test Results

Barrier	Weight	Rank
Financial Barrier (FB)	0.35	1
Technological Barrier (TB)	0.27	2
Organizational Barrier (OB)	0.22	3
Regulatory Barrier (RB)	0.16	4
λmax	4.21	-
CI	0.07	-
RI	0.90	-
CR	0.07	-

Table 4 presents the final priority weights of the identified barriers along with the consistency test results. Financial Barrier (0.35) is ranked as the most critical factor, followed by Technological Barrier (0.27), Organizational Barrier (0.22), and Regulatory Barrier (0.16). The calculated maximum eigenvalue (λmax = 4.21) is used to derive the Consistency Index (CI = 0.07), which is then divided by the Random Index (RI = 0.90) to obtain the Consistency Ratio (CR = 0.07). Since CR is below 0.10, the results confirm that the judgments are consistent and acceptable.

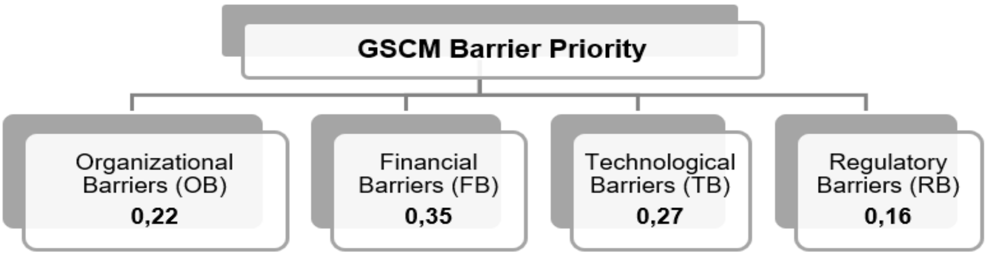

Figure 2. Priority Weights of GSCM Barriers Based on AHP

Figure 2. The AHP hierarchy diagram the priority structure of GSCM barriers based on calculated weights. The main goal is to determine the most critical barrier affecting GSCM implementation. Financial Barrier (0.35) holds the highest priority, indicating its dominant influence on decision-making. It is followed by Technological Barrier (0.27), Organizational Barrier (0.22), and Regulatory Barrier (0.16). This structure clearly shows the relative importance of each barrier and supports decision-makers in focusing on key issues. The hierarchy simplifies complex relationships into a clear and systematic framework for strategic planning.

These findings are supported by recent studies which emphasize that financial and technological barriers remain the most critical challenges in GSCM implementation. High investment costs, limited access to green technologies, and uncertainty in returns are frequently identified as dominant constraints [21]. Additionally, organizational capability and management commitment significantly influence the successful adoption of sustainable practices [22], [23]. Regulatory barriers tend to have a lower impact when policy enforcement is weak or inconsistent [24]. The application of AHP as a prioritization tool is also widely validated for its effectiveness in handling complex decision-making problems in sustainability contexts [25], [26].

3.4. TOPSIS Analysis: Evaluation of Alternative Solutions

This section presents the evaluation of alternative strategies for overcoming barriers to the implementation of GSCM using the Technique for Order Preference by Similarity to Ideal Solution method. The TOPSIS approach is applied after obtaining the priority weights of the criteria from the Analytical Hierarchy Process analysis. This method evaluates several strategic alternatives by measuring their relative distance from the positive ideal solution and the negative ideal solution. Through this process, the most appropriate strategies for addressing the identified GSCM barriers can be determined.

3.4.1. Decision Matrix

The first step in the TOPSIS analysis is the construction of the decision matrix, which represents the performance of each alternative solution with respect to the selected criteria. The alternatives evaluated in this study include several strategic actions aimed at improving sustainable supply chain practices in the poultry processing industry. Each alternative is assessed based on the barrier criteria identified in the previous analysis stage. The decision matrix used in this study is presented in Table 5.

Table 5. Decision Matrix

Alternatives	OB	FB	TB	RB
Government Policy Support	4	5	3	5
Green Technology Investment	3	4	5	3
Training and Awareness Programs	5	3	3	2
Supplier Collaboration	3	3	4	3

3.4.2. Normalized and Weighted Matrix

The next step involves normalizing the decision matrix to eliminate scale differences among the criteria. The normalized values are then multiplied by the priority weights obtained from the AHP analysis to generate the weighted normalized matrix. This matrix reflects the relative importance of each criterion in evaluating the alternatives. The results of the weighted normalization process are presented in Table 6.

Table 6. Weighted Normalized Matrix

Alternatives	OB	FB	TB	RB
Government Policy Support	0.18	0.27	0.13	0.08
Green Technology Investment	0.13	0.22	0.22	0.05
Training and Awareness Programs	0.22	0.16	0.13	0.03
Supplier Collaboration	0.13	0.16	0.18	0.05

3.4.3. Ideal Solutions

After obtaining the weighted normalized matrix, the next step is to determine the positive ideal solution (A^+) and the negative ideal solution (A^-). The positive ideal solution represents the best value for each criterion, while the negative ideal solution represents the least desirable value. These two reference points are used to measure the relative distance of each alternative, which forms the basis for calculating the closeness coefficient.

3.4.4. Ranking of Alternatives

The final step in the TOPSIS analysis is calculating the closeness coefficient for each alternative. This coefficient indicates how close an alternative is to the positive ideal solution and how far it is from the negative ideal solution. Alternatives with higher closeness values are considered more effective in addressing the identified barriers. The ranking results of the evaluated strategic alternatives are presented in Table 7.

Table 7. Ranking of Strategic Alternatives

Alternative	Closeness Value	Rank
Government Policy Support	0.82	1
Green Technology Investment	0.74	2
Training and Awareness Programs	0.69	3
Supplier Collaboration	0.63	4

Based on Table 7, the results indicate that government policy support ranks first with the highest closeness value (0.82), highlighting the crucial role of regulatory frameworks and policy incentives in facilitating GSCM implementation in the poultry processing industry. This is followed by green technology investment (0.74), which emphasizes the importance of adopting advanced and environmentally friendly technologies to enhance sustainable operations. Training and awareness programs (0.69) and supplier collaboration (0.63) also contribute positively, although their impact is relatively lower. Overall, the results demonstrate that external institutional support and internal capability development must work together to effectively overcome GSCM barriers.

These findings are consistent with previous studies which emphasize that government intervention plays a key role in accelerating sustainable supply chain adoption through regulations, subsidies, and environmental policies [23], [27]. Furthermore, investment in green technology has been widely recognized as a critical driver for improving environmental and operational performance [28]. Training and awareness programs are also essential in enhancing employee competence and organizational readiness for sustainability initiatives [29]. Meanwhile, supplier collaboration strengthens integration across the supply chain and supports the adoption of green practices among upstream partners [30]. These results confirm that a combination of policy support, technological advancement, and stakeholder collaboration is necessary to achieve effective and sustainable GSCM implementation.

4. Conclusion

This study aims to identify key barriers to the implementation of Green Supply Chain Management (GSCM) in the poultry processing industry and to determine the most effective strategies to overcome them. A hybrid multi-criteria decision-making approach, integrating Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), was applied using data from 37 respondents with relevant industry experience. The AHP results indicate that financial barriers are the most significant challenge (0.35), followed by technological (0.27), organizational (0.22), and regulatory barriers (0.16). These findings suggest that high investment costs, limited financial resources, and restricted access to green technologies are the main obstacles to adopting sustainable supply chain practices. The consistency test confirmed reliable judgments, with a Consistency Ratio (CR) of 0.07. Furthermore, TOPSIS analysis shows that government policy support is the most effective strategy (0.82), followed by green technology investment (0.74), training and awareness programs (0.69), and supplier collaboration (0.63). These results highlight the importance of regulatory support, technological advancement, and capacity building in facilitating GSCM implementation. Overall, this study provides practical insights for industry stakeholders and policymakers by identifying priority barriers and strategic solutions. The findings can support the development of effective policies and managerial actions to enhance environmental sustainability and long-term competitiveness in the poultry supply chain.

Author contributions: Asrul Fole designed the research and wrote the manuscript. Khoerun Nisa Safitri conducted the data analysis. Erniyani and Nurul ‘Aini were responsible for data collection and validation. Bili Sufrian contributed to the literature review and manuscript formatting. All authors reviewed and approved the final manuscript.

Acknowledgement: The authors would like to express their sincere gratitude to all respondents and industry practitioners who participated in this study and provided valuable insights. Appreciation is also extended to colleagues and institutions that supported the research process. Their contributions greatly assisted in the successful completion of this research and manuscript preparation.

Conflict of Interest: The authors confirm that this study was conducted independently, without any financial, commercial, or personal interests that could influence the research results or interpretations.

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