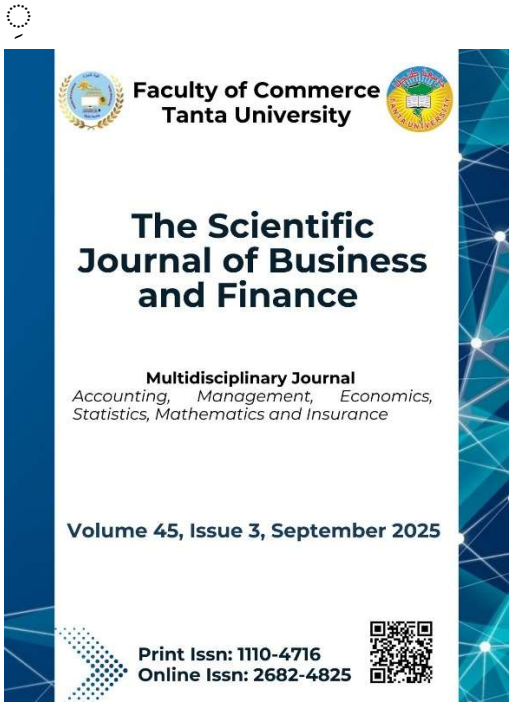

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INVESTIGATING THE BARRIERS FOR IMPLEMENTING GREEN SUPPLY CHAIN MANAGEMENT

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Abstract

The Industrial Revolution marked a significant shift in production and consumption, leading to environmental degradation due to industrial activities. In response, Green Supply Chain Management (GSCM) has emerged as a critical approach to mitigate environmental impacts while maintaining efficiency. However, implementing GSCM faces numerous barriers, particularly in high-pollution industries like petrochemicals. This study aims to identify and rank the key barriers to GSCM adoption in Egypt's petrochemical industry using the Analytic Hierarchy Process (AHP). Through a literature review, 16 barriers were consolidated into five categories: Economic, External Stakeholders, Information/Awareness, Design/Process, and Management/Behavior. A structured questionnaire was administered to 89 industry professionals, and AHP was applied to determine the relative importance of these barriers.

The results revealed that "lack of new technology, materials, and processes for GSC" was the most critical barrier, followed by "high investment and low return-on-investments" and "lack of management commitment." Economic barriers were deemed the most influential category, highlighting financial constraints as a major hurdle. External Stakeholders and Design/Process categories also ranked highly, while Information/Awareness barriers were considered less critical. Sensitivity analysis confirmed the robustness of these findings.

The study underscores the need for financial incentives, technological advancements, and stronger regulatory frameworks to facilitate GSCM adoption. Practical implications include targeted policy interventions, green financing mechanisms, and organizational culture shifts to overcome these barriers. This research contributes to the limited literature on GSCM in Egypt's petrochemical sector and provides actionable insights for policymakers and industry leaders to promote

sustainable supply chain practices. Future research could explore sector-specific solutions and longitudinal studies to track progress in GSCM implementation.

Keywords: GSCM ; barriers ; AHP ; petrochemicals

1. Introduction

The Industrial Revolution was a major turning point in human history. It changed how people lived and worked by introducing machines, new technologies, and faster ways to produce goods. This led to better transportation, more jobs, and improved living standards. Industries like textiles, farming, and mining were transformed as machines powered by steam and later electricity made production faster and cheaper. Life for many people improved because products became more available and affordable.

However, while industrialization brought many benefits, it also caused serious harm to the environment. Factories released large amounts of pollution into the air, land, and water. One of the biggest environmental problems is the release of greenhouse gases like carbon dioxide (CO2), which is a major cause of global warming (IPCC, 2021).

Industries also produce a lot of waste, including chemicals and plastics that don't break down easily. This waste often ends up in the oceans or landfills, harming fish, birds, and other animals. For example, plastic pollution in the sea has created large floating garbage and damaged coral reefs (Jambeck *et al.,* 2015). On land, toxic waste can make the soil unusable for farming

(Khan *et al.*, 2008). These problems affect not only animals but also humans who rely on clean land and water for survival.

In response, many businesses are trying to become more eco-friendly. One way they are doing this is by using the "green" approach. This means they try to reduce their impact on the environment in all their activities. These efforts include using less energy, reducing waste, controlling pollution, and switching to renewable energy sources like wind or solar power. Green businesses are also looking for new technologies that are less harmful to the environment and trying to create products that are easier to recycle or reuse.

A key part of business operations is the supply chain—the system that handles how products are made, transported, and delivered. Every step of the supply chain can affect the environment, from getting raw materials to shipping finished goods. For example, using trucks that burn diesel fuel contributes to air pollution, and using materials that are hard to recycle adds to landfill problems. Because of this, companies are under pressure to make their supply chains more sustainable.

When companies include environmental practices in their supply chain, it is called Green Supply Chain Management (GSCM). According to (Sarkis, 2012), GSCM means applying green thinking in every part of the supply chain, such as product design, choosing materials, production methods, packaging, shipping, and waste disposal. The goal is to reduce harm to the environment while still

being efficient and profitable. It means doing business in a way that balances making money with protecting the Earth.

More businesses now see that going green can help them in many ways. (Ghadge *et al.,* 2017) explain that GSCM can lower costs, improve efficiency, attract customers, and meet environmental laws. Companies that care about the environment also build a better reputation and are more likely to gain investor and customer trust. In today's world, customers prefer to buy from companies that are seen as responsible and sustainable.

Problem description & Objective

Switching to GSCM is not easy. It often requires big changes in how a company works, its culture, and its technology. These difficulties are known as barriers. (Ahmed Esmail, 2021) states that identifying and dealing with these barriers is necessary for GSCM to succeed. Companies may face internal resistance, financial limits, and technical challenges. Overcoming these issues takes time, effort, and often support from the government or other organizations.

There are many types of barriers. Some are technological, like not having the right equipment or knowledge. Others are financial, such as high costs and limited funding. Regulatory barriers may come from weak laws or conflicting rules. Organizational barriers include a lack of support from managers or poor communication within the company. Cultural barriers can arise when employees or suppliers are not aware of or committed to environmental goals. Understanding all these barriers is the first step to overcoming them.

In Egypt, the petrochemical industry is an important part of the economy. It creates jobs, exports products, and helps the country grow. But at the same time, it faces increasing pressure to reduce its environmental impact. That is why it is important to study the specific challenges this industry faces when trying to adopt GSCM. If Egypt can improve the environmental performance of this sector, it could become a leader in green industrial practices in the region.

This study will focus on identifying the main barriers to Green Supply Chain Management in Egypt's petrochemical industry. It will use a method called the Analytical Hierarchy Process (AHP), which helps to compare and rank these barriers based on how important they are. The goal is to give useful information to managers and decision-makers so they can overcome these challenges and make their supply chains more sustainable.

The results of this study could also help other industries in Egypt that face similar problems. By understanding what stops companies from going green, the government and businesses can work together to create better policies and training programs. This could lead to stronger environmental laws, more funding for green technologies, and better awareness among workers and leaders.

The adoption of Green Supply Chain Management (GSCM) has become a critical area of research due to increasing environmental concerns, regulatory pressures, and the need for sustainable

industrial practices. However, despite its recognized benefits, the implementation of GSCM faces numerous barriers that vary across industries, regions, and organizational contexts. Several researchers have emphasized the necessity of conducting further studies on these barriers to develop tailored strategies that address industry-specific challenges.

Jasneet *et al.* (2018) highlighted the importance of context specific research, stating "Context-specific studies related to the barriers can be done. Industry specific analysis considering nature, type, size of industry, and country wise analysis could be performed, and comparisons made against each other." This suggests that a one-size-fits-all approach may not be effective, and deeper investigations into sector specific barriers are essential for meaningful progress in GSCM adoption.

Similarly,(Zayed *et al.,* 2021) recommended that "future research should dig deeper into collecting and analyzing data specific to each industry, as this would help in better understanding specific trends in specific industries and suggest better solutions tailored to each sector." Their findings reinforce the idea that industry specific barriers must be examined in detail.

However, despite these advancements, there remains a significant gap in research concerning certain industries, particularly in developing economies. A comprehensive review of the literature reveals a major research gap.

There is a need for more industry specific and country specific studies on GSCM barriers. While some sectors (e.g., automotive, electronics, and textiles) have been extensively studied, others, such as the petrochemical industry, remain underexplored, especially in regions like Egypt.

The primary objective of this study is to investigate and rank the barriers to GSCM implementation in the Egyptian petrochemical industry.

2. Literature review

2.1 Green supply chain management (GSCM)

In words of (Zhu *et al.,* 2012), GSCM is a tremendous concept to instill environmental thinking in traditional Supply Chain Management. Also, (Oliveira *et al.,* 2018), stated that green supply chain is a concept that is gaining increasing popularity day by day because of its commitment to sustainability for the companies. (Elnakib and Elzarka, 2014) highlighted that sustainability of natural resources became a priority for governments, international organizations and multinational companies.

To clearly understand the concept of green supply chain management, (Srivastava, 2007) defined GSCM as integrating environmental thinking into supply chain management, including product design, material sourcing, and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life.

Emmett *etal.* (2010) explained the concept of GSCM as it implies the integration of environmental considerations within traditional SCM, including product design; procurement; supplier selection, manufacturing, and production processes; logistics and the delivery of the final product to the consumer; and end-of-life management of the product.
Sarkis *et al.* (2011) defined GSCM as integrating environmental concerns into the inter-organizational practices of SCM, including reverse logistics.

The intended objective of GSCM is described by (Jing *et al.,* 2019) as it is making a continuous improvement and create economical, ecological and social benefits by mitigating environmental footprints, and optimizing the consumption of resources while keeping a check on waste.

Rosyidah *et al.(* 2022) added that GSCM aims to decrease energy consumption, emissions and waste covering all the actors of the value chain-vendors, manufacturers and distribution channel partners. Manufacturing industries are facing both local and global pressure to implement green practices in their operations and supply chains (Luthra *et al.,* 2013).

GSCM does not operate in isolation but is closely linked to other corporate environmental practices such as Environmental Management Systems (EMS), Life Cycle Analysis (LCA), and Industrial Ecology. For instance, EMS adoption often involves assessing suppliers' environmental impacts, which aligns with GSCM objectives (Darnall *et al.,* 2008).

Many researchers spotlighted the benefits of applying GSCM concepts as (Drohomeretski *et al.,* 2014) "GSCM helps firms reduce environmental risks and improving environmental efficiency thus enabling them to get better market share". And (Johari *et al.,* 2019) "An efficient circular supply chain can ameliorate the damaging effects of harmful wastes and consequently lead to environmental sustainability".

But Despite the evidence of benefits of implementing SSCM, organizations are still reluctant to adopt sustainable practices due to internal and external barriers in terms of organization boundaries (Elzarka and Elbarky, 2015).

Hamdy *et al.* (2018) confirmed that many of the companies operating in Egyptian industries are still considering sustainable practices within SCM as a burden to their performance or profitability. For the Egyptian industries the research of (Elzarka, 2020) a study on using lean, agile, resilient and green (LARG) index to assess the sustainability of Egyptian FMCGs supply chains is a great guideline and highlighted the importance of GSC barriers as the research concluded that the 'green' paradigm was the least implemented despite its importance in supply chain sustainability.

It is recommended to critically analyze all barriers, prioritize them and work on the most influential barrier first (Ghadge *et al.* 2017).

Tseng *et al.* (2019) provides a literature review on GSCM, analyzing trends and future challenges. Their metadata analysis of 880 papers reveals a sharp increase in GSCM research post, with China and the United States being the top contributors. The study identifies influential authors like Sarkis and Zhu.

Tseng *et al*.(2019) content analysis classifies GSCM literature into five categories: conceptual development, drivers and barriers, collaboration with supply chain partners, mathematical optimization models, and assessment of GSCM practices and performance.

2.2 GSCM implementation barriers

In recent years, several researchers have made tremendous efforts to study and identify the most significant barriers to implementing GSCM practices across various industries.

Rahman *et al.* (2023) studied the GSCM barriers within the construction sector in Bangladesh, identified 16 barriers from literature sources and surveying specialists of the construction sector. The barriers are categorized as internal/external. (ISM) and the MICMAC approach were used to analyze survey results. The results highlight the need for stronger government policies, such as incentives and stricter regulations, alongside organizational efforts to improve awareness, training, and top-management engagement. Collaboration among stakeholders including policymakers, businesses, and educational institutions is crucial to fostering a sustainable supply chain system.

Hebaz *et al.* (2021), (Zayed *et al.,* 2021) and (Wong *et al.,* 2023) used the same categorization way for barriers as internal/external. (Hebaz *et al.,* 2021) identified 32 barriers from literature review and ranked them based on the number of citations in the published papers. The results revealed that high implementation costs, lack of resources, and insufficient top management commitment are the most critical barriers.

With 10 barriers identified from literatures, (Zayed *et al.,* 2021) investigates the barriers to Sustainable Supply Chain Management (SSCM) implementation in Egyptian industries using Interpretive Structural Modeling (ISM) to analyze interrelationships among these barriers. The research identifies financial constraints and lack of government support as the most critical barriers, acting as independent drivers with high influence on other barriers. These are followed by barriers such as lack of top management commitment and employee awareness, which have both driving and dependence power. And dependent barriers like resistance to change and supplier unawareness, which are influenced by other factors but have minimal impact themselves.

The study of GSCM implementation barriers in Malaysian construction industry using mean, standard deviation to rank the 24 identified barriers is the work of (Wong *et al.,* 2023).

The most pressing challenges within internal organizational factors, appeared to be a lack of leadership commitment, insufficient awareness, and the absence of structured sustainable practices. External barriers, including low public awareness and a shortage of green suppliers are the most barriers hindering progress.

On the other hand, high costs, which often appeared as a major barrier in many researches is ranked lower compared to leadership and knowledge gaps, suggesting that commitment and insufficient awareness may be more critical than financial constraints.

Jasneet *et al.* (2018) worked on Canadian manufacturing firms using Pareto analysis. 54 barriers were initially identified from the literatures then 36 barriers selected for analysis after discussion with supply chain experts including academic professors and industry managers. The barriers were classified in six categories multiple M's (man, machine, method, material and money), supply chain processes, stakeholders, sustainability area, organizational hierarchy, and others (execution). The findings reveal that awareness and action-related barriers, such as the difficulty in translating environmental attitudes into practice and limited knowledge of reverse logistics, are the most critical. Commitment and cost issues, including high expenses for hazardous waste disposal and a lack of corporate social responsibility, also rank highly. Additionally, knowledge gaps such as insufficient eco-literacy and training further hinder progress. The study employs Pareto analysis to distinguish the "vital few" barriers from the "useful many," emphasizing that financial constraints are less significant than behavioral and organizational challenges.

(Ahmed Esmail, 2021) studied the barriers withing food and beverage industry in Egypt using analytic hierarchy process (AHP) method. The researcher started with 39 barriers and after carrying out a discussion through a decision group consisting of four experts, the experts accepted all the identified barriers, and a total of 18 barriers were selected as common.

The categorization of barriers used by (Ahmed Esmail, 2021) was based on the conclusion of Hahn *et al.* (2015) that "Sustainability is not an easy task because of tensions that might arise among economic, social, and environmental objectives" so the barriers categorized into five types of tensions: economic, change, psychological, temporal, and structural.

The AHP results revealed that economic tensions were the most significant, with inflation and currency exchange rates emerging as the top barrier, highlighting the impact of Egypt's economic instability on GSCM adoption. Change tensions ranked second, driven by internal resistance to new practices and technological gaps, while psychological tensions, stemming from political uncertainty and mistrust among stakeholders, ranked third. Temporal tensions, arising from misaligned short-term and long-term goals, and structural tensions, related to supply chain coordination issues, were less critical.

Majumdar *et al.* (2018) study objective was to investigate the GSCM barriers in textile industry in south-east Asia. The analysis tool used is interpretive structural modeling (ISM) to study 12 barriers filtered from 36 and identified using a questionnaire sent to supply chain managers of leading textile companies to rank the most important barriers. The 12 barriers classified based on the literature review and the classification was strategic, supplier, technology, external stakeholder, human resource and economic.

The results identified within the twelve key barriers that "complexity of green process and system design" emerging as the most fundamental driver due to technological challenges. Other critical barriers included "lack of consumer support and encouragement", "lack of guidance and support from regulatory authorities", and "high implementation and maintenance cost", which represent

market, legal, and economic barriers, respectively. The ISM hierarchy revealed that these driving barriers influence intermediate barriers like "slackness in enforcement of legislation" and "lack of economic benefits", which in turn affect "lack of top management commitment". The study highlighted “complexity of green process and system design” as the most influential barrier and "lack of green suppliers" as the most dependent.

On the same way (Chotia *et al.,* 2023) studied the barriers to GSCM in cement industry in India. The study used interpretive structural modeling (ISM) and MICMAC approach. 25 barriers were identified from literatures and the barriers further validated by conducting an expert survey and end up with 14 barriers classified based on management, environmental, technological, financial. Results indicated that lack of environmental performance metrics, high investment and low ROI proposition, lack of government policies to ensure easy loans by commercial banks, fear of failure, inadequate CSR consciousness of top management and lack of strategic planning as barriers with highest driving power in the cement industry.

Green procurement, green design, green production, green management and green information was the way that (Banihashemi *et al.,* 2022) used to classify the 18 identified barriers to study them on the construction sector. Among the five main categories, Green Design emerged as the most important, followed by Green Management and Green Production, whereas Green Information was considered the least significant.

The most critical obstacle across all categories was the lack of laws, regulations, and government support, emphasizing the need for policy intervention. This was closely followed by the shortage of skilled designers, contractors, and planners, and a lack of training and awareness regarding green supply chains. These results underline the importance of both structural support and human capital development for successful GSCM implementation.

Khurshid *et al.* (2024) barriers classification was Economic/Financial, Organizational, Technical & knowledge, Supply Chain, Market, Governmental, Society & Environmental, applied on textile industry in China and the q-ROFS approach used. The study highlighted that no single barrier is solely responsible for hindering sustainability; rather, it is the interplay of factors such as lack of top management support, weak regulatory enforcement, limited digital infrastructure, and the desire to avoid cultural change that create the most significant hurdles.

Singh *et al.* (2024), (Sudarshan *et al.,* 2019), (Agarwal *et al.,* 2021) and (Panigrahi *et al.,* 2024) studied individually the barriers on different industries like the agri-food supply chain, rubber and Aluminum. The common point is that all of them used no categorization for the barriers.

Singh, *et al.* (2024) in hisstudy analyzed barriers to sustainable agro-food supply chains in India using Interpretive Structural Modeling (ISM) and MICMAC analysis. The results identified twelve key barriers, with "inadequate physical infrastructure" and "transparency and traceability" emerging as the most critical due to their strong driving power and weak dependence on other factors. These barriers significantly impact the entire supply chain, highlighting the need for improved infrastructure and traceability systems to enhance efficiency and food safety. Other barriers, such as "lack of coordination among departments" and "difficulty in implementing government schemes," were found to have strong interdependencies.

Sudarshan *et al,* (2019) concludes that implementing Green Supply Chain Management (GSCM) practices is essential for reducing environmental impact, but several barriers hinder its adoption. Through a hybrid approach combining TOPSIS, AHP, and ISM methodologies, the study identifies and ranks the most critical barriers to GSCM in the Indian industries. The top barriers include lack of government support, market competition, lack of bank credits for green products, lack of top management commitment, and lack of technical expertise. These barriers were found to have the highest impact on GSCM implementation, both directly and indirectly, as revealed by the ISM and MICMAC analyses.

Agarwal *et al*.(2021) provides a comprehensive analysis of the barriers to implementing Green Supply Chain Management (GSCM) in the Indian rubber industry, using Interpretive Structural Modeling (ISM) and MICMAC analysis. The results highlight that the lack of government support systems and limited forecasting and planning are the most critical barriers, acting as root causes due to their high driving power and low dependence. These barriers significantly influence other barriers, such as inflexible organizational systems, market competition, and poor human resource quality, which are classified as linkage barriers with both high driving and dependence power.

Panigrahi *et al.* (2024) identifies and analyzes the key barriers hindering the adoption of Green Supply Chain Management (GSCM) practices in the Indian aluminum sector using a hybrid approach combining Interpretive Structural Modeling (ISM) and the Best-Worst Method (BWM). The results highlight three most critical barriers, lack of enforcement of environmental laws and policies, lack of environmental certifications and training for employees, and lack of advanced technologies for environmental protection. These barriers were found to have the highest influence on GSCM implementation, with lack of enforcement of environmental laws and policies being the most significant due to its regulatory and systemic impact.

2.3 Identifying the most common GSCM barriers

To gather relevant academic literature, a systematic literature review was conducted using ResearchGate. The primary keyword used was "Green Supply Chain Management Barriers". Search filters were applied to include articles published between 2018 to 2024 to focus on recent research. The initial search yielded a large number of results, which were further refined by reviewing abstracts and selecting only those studies that address barriers to implementing green supply chain management in different industries. Duplicates, irrelevant studies, books, presentations and literature reviews papers were excluded, ensuring that the final selection of literature was directly applicable to the research objectives.

The industries covered in these studies included cement, food and beverage, aluminum, rubber, textile, agrifoods, fast-moving consumer goods (FMCG), and construction, representing many manufacturing and production sectors. Additionally, the selected research papers are applied on industries from multiple countries, such as India, Malaysia, Bangladesh, Egypt, Canada, China, and various South-East Asian countries (Sri Lanka, Vietnam, Philippines, etc.), providing a geographically diverse prospective on the identified GSCM barriers.

The number of barriers studied in each paper varied significantly, ranging from 8 to the maximum of 36 noticed on a study carried out on Canadian manufacturing firms by (Jasneet *et al.,* 2018). A total number of 268 barriers were identified across all 14 papers. Upon review, it became clear that many of these barriers were repeated or have very close meanings. Keywords were extracted from the barriers' descriptions, and related barriers were grouped under common keyword. This process helped in consolidating the most frequently used barriers. This approach of identifying and categorizing GSCM barriers followed the same way used by (Govindan *et al.,* 2013).

The reviewed papers employed different ways for categorizing the GSCM barriers, which can be summarized as follows:

1. No Categorization – Some studies, such as (Singh *et al.,* 2023), (Sudarshan *et al.,* 2019), (Agarwal *et al.,* 2021), and (Panigrahi *et al.,* 2024), presented barriers without any categorization. These papers listed barriers with any grouping.
2. Internal / External Categorization – Another group of studies, including (Rahman *et al.,* 2023), (Wong *et al.,* 2023), (Zayed *et al.,* 2021), and (Hebaz *et al.,* 2021), categorized barriers based on Internal and External barriers. Internal barriers were defined as those located within the organization (e.g., lack of management commitment, financial constraints, employee resistance), while External barriers were those located outside the organization (e.g., suppliers' limitations, no government policies, low customer demand).
3. Multi Categorization – The remaining six studies adopted a more detailed approach, categorizing barriers based on their nature as per clarified in Table (1)

Table1. Six papers categorized the barriers based on the following

Jasneet *et al.* (2018)	Ahmed Esmail (2021)	Majumdar *et al.* (2018)	Chotia *et al.* (2023)	Banihashemi *et al.* (2022)	Khurshid *et al.* (2024)
Multiple M's (Money/Method/ Man)	Economic	Economic	Financial		Economic/Financial
Stakeholders		External Stakeholder/Supplier		Procurement	Governmental/ Market
Knowledge				Information	Society & Environmental
Sustainability			Environmental		Supply Chain
SC Processes	Change	Technology	Technological	Design/Production	Technical & knowledge/
Organizational	Structural/Temporal	S. Management	Management	Management	Organizational
Social	Psychological	Human Resources			

After consolidating the barriers from all the fourteen papers, sixteen key barriers identified as the most frequently studied barriers within the reviewed papers. These barriers were then organized into five categories (Economic, External Stakeholders, Information & Awareness, Design & Process, and Management & Behavior) to facilitate the study process and for better understanding the results.

Table 2. List of GSCM barriers collected from literature and their classification.

Sr. No.	Category	Barriers	References
1	Economic	High investment and low return-on-investments	6,1,2,3,5,7,8,9,12,13
2		Lack of financial capabilities (internal/External e.g. Bank loans)	11,12,2,4,5,6,7,13
3		Local & Global Financial Crisis	3,13
4	External Stakeholders	Supplier related factors (Flexibility to change, unawareness, Certifications, Lack of green suppliers, Price, Integration, Source of eco-friendly materials, No proper rewarding)	13,1,2,3,4,6,8,9,10,11,12,14
5		Customer related factors (lack of Customer demand, Unawareness, Lack of pressure, Price)	13,1,2,3,5,6,7,8,10,12
6		Lack of related laws and regulations and government support	11,1,2,3,4,5,6,7,8,9,10,13,14
7		Not enough awareness and pressure from the local community	7,3,9,13
8	Information/ Awareness	Unwillingness to exchange information among supply chain partners.	3,2,7,10,12
9		Lack of awareness of the environmental impacts on business.	2,6,3,4,5,8,9,11,12,13
10		Lack of training courses about implementing GSC	5,1,2,3,6,7,9,10,11,12,14
11	Design/ Process	Lack of new technology, materials and process for GSC	2,3,6,9,13
12		Complexity of green process and system design	6,2,13
13		Lack of availability of standardized sustainable measurement systems	8,2,6,7.9,11,13
14	Management/ Behavior	Lack of management commitment and approach to green supply chain adoption.	12,1,2,3,4,5,6,7,8,9,10,11,13,14
15		Fear of failure.	2,5,6,7,10,13
16		Reluctance and resistance to change among internal stakeholders.	1,3,5,7,8,12,13

[1] (Rahman *et al.,* 2023); [2] (Jasneet *et al.,* 2018); [3] (Ahmed Esmail, 2021); [4] (Singh *et al.,* 2023) ; [5] (Sudarshan *et al.,* 2019); [6] (Majumdar *et al.,* 2018); [7] (Chotia *et al.,* 2023); [8] (Wong,*et al.,* 2023) ; [9] (Zayed *et al.,* 2021); [10] (Agarwal *et al.,* 2021); [11] (Banihashemi *et al.,* 2022); [12] (Khurshid *et al.,* 2024); [13] (Hebaz *et al.,* 2021); [14] (Panigrahi *et al.,* 2024).

3. Methodology

The research began with reviewing literature to identify and classify the most frequently mentioned GSCM barriers. This was followed by validating this structure through discussion with industry experts from the petrochemical industry in Egypt. Then, a questionnaire was developed to collect data required to conduct AHP. The steps of the methodology followed in this research are illustrated in figure (1).

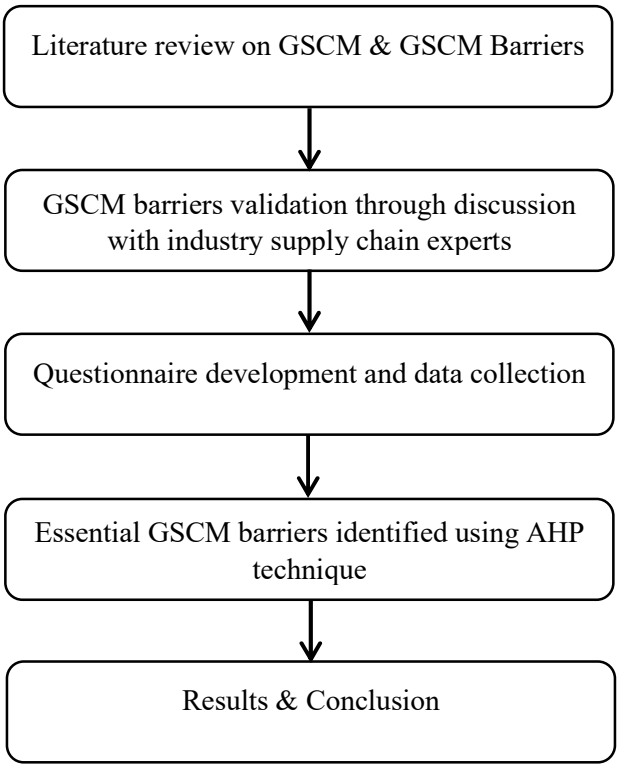

Figure1. Research methodology steps

3.1 Identified GSCM Barriers Validation

After conducting an extensive literature review and making a list of 16 common barriers, and categorizing these barriers in five major groups, the validation process was a critical phase to ensure the relevance of the identified barriers with the petrochemicals industry in Egypt and to confirm that these barriers are not only theoretical barriers but also relevant to the real atmosphere of the petrochemicals industry.

This validation carried out by unstructured interviews and consultation with three experts working in a key managerial position in the Egyptian petrochemicals sector. The experts were selected based on the following criteria:

Each participant held a senior managerial position in the Egyptian petrochemical industry, with at least 25 years of experience in positions directly linked to GSCM. Participants were chosen

from different functional areas (sales, production, procurement) to capture multidisciplinary insights and avoid bias toward a single operational focus. All participants worked for petrochemical firms in Egypt, ensuring their feedback reflected the sector's practical challenges rather than theoretical assumptions. Their long experience also guaranteed familiarity with evolving industry barriers.

The primary objective of these discussions was to evaluate the relevance of the selected barriers and their categorization to the Egyptian petrochemicals industry, also getting the experts feedback on the identified barriers.

The validation process was carried out to check with the expert three main points. First, the experts were asked to assess whether the sixteen barriers are representing real challenges facing the petrochemicals companies in Egypt. Secondly, the experts reviewed the proposed five categories to determine whether the barriers' grouping is relevant to the category description. Finally, the consultants asked to propose any additional barriers that the consultants may find them a real industry challenges and a real barrier to GSCM that may have been missed within the literature review.

After conducting theses interviews, the managers confirmed that the 16 barriers are representing the key challenges in the Egyptian petrochemical industry to GSCM implementation, and the five categories are also relevant. They also provided suggestions to refine certain barrier definitions for greater clarity and proposed slight adjustments in some wording. These recommendations were incorporated into the final barriers list. By engaging industry managers in the validation process, this study ensured that the identified barriers and categories are not only theoretical but also aligned with the actual experiences and challenges faced by professionals in the field.

3.2 Designing the questionnaire for the barriers pairwise comparisons

Following the guidelines proposed by (Taherdoost, 2022), a structured, self-administered questionnaire was developed to make pairwise comparisons for the categories and the 16 barriers of GSCM within Egypt's petrochemical industry. The questionnaire was designed to facilitate getting the practitioners' feedback to analyze this feedback as per the Analytic Hierarchy Process (AHP) approach, which relies on pairwise comparisons to determine the relative importance of different barriers.

The questionnaire was divided into three main sections. The first section focused on demographic information, gathering essential details about the respondents. Participants were asked about their organization location, job level, and their role. This information helped in ensuring that the responses have the degree of diversity that is required for such studies.

The second section of the questionnaire dealt with categories pairwise comparison, where respondents were asked to evaluate the relative importance of broad barrier categories. The third and most detailed section focused on barriers comparison. All pairwise comparisons were conducted using Saaty's scale (Table 3) to indicate how many times more important or dominant one element is over another element.

Table 3. The Fundamental Scale

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement slightly favor one activity over another
5	Strong importance	Experience and judgement strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over Another
9	Extreme importance	The evidence favoring one activity over another

Source: (Saaty, 1980).

The questionnaire was developed in English. Then, it was translated into Arabic using back translation technique as per the guidelines of (Kowal, 2024). Following that, the questionnaire was made in English and Arabic language in same form and reviewed by two supply chain professionals and academic to assess clarity, relevance, and logical flow.

The selection of these professionals was based on specific criteria to ensure their qualifications and appropriateness for the validation process. Supply chain professionals were chosen based on their industry experience (a minimum of 10 years in relevant roles supply chain), and familiarity with the survey context. The Academic has deep research background, PhD qualifications, a strong publication record, and long experience in survey design and validation. This selection criteria helped ensure that the feedback provided was both credible and constructive.

The professionals and academic feedback led to making the questionnaire in Arabic language only to facilitate the understanding of the question and shorten the whole process time of reading and entering the feedback. They also suggest some modifications in wording and shortening of some long questions.

3.3 Target Population and Sampling

The target population for this study comprises professionals working in the petrochemical industry across Egypt, with a specific focus on individuals engaged in supply chain management, and related operational functions. The study aimed to include participants from various organizational levels to ensure a comprehensive understanding of green supply chain barriers.

Disproportionate stratified random sampling techniques were employed to ensure adequate representation of key decision-makers while maintaining regional diversity. The target population of petrochemicals professionals was stratified into three groups: senior managers (50%), middle managers (40%), and junior staff (10%), with a total sample size of 100 participants.

This approach intentionally oversampled top management despite their smaller proportion in the overall population due to their strategic decision-making roles and their ability to provide insights into high-level supply chain challenges and corporate policies.

Middle managers, who oversee day-to-day operations, were selected to offer perspectives on tactical and process-related issues while junior staff members were included to provide ground-level insights into execution and implementation challenges.

Geographically, the study targeted professionals from major petrochemical companies, located in Alexandria, Cairo, Port Said, and Suez. These regions were chosen since each company presents unique logistical dynamics, port interactions, and supply chain strategies. By incorporating participants from these diverse locations, the study aimed to capture regional variations in supply chain operations, ensuring that findings are not limited to a single geographic area.

3.4 Analytic Hierarchy Process (AHP) & Sensitivity Analysis

The Analytic Hierarchy Process (AHP) steps defined by (Saaty, 1980; 2008; 1987) is applied in this study to systematically evaluate and prioritize the 16 identified barriers hindering the implementation of GSCM. These barriers are categorized into five categories, The five categories include: Economic (3 barriers), External Stakeholder (4 barriers), Information & Awareness (3 barriers), Design & Process (3 barriers), and Management & Behavior (3 barriers).

The AHP framework begins with the construction of a three-level hierarchy. The top level represents the primary objective: Ranking of the barriers to GSCM implementation. The second level consists of the five categories. The third level contains the 16 specific barriers as illustrated in figure (2).

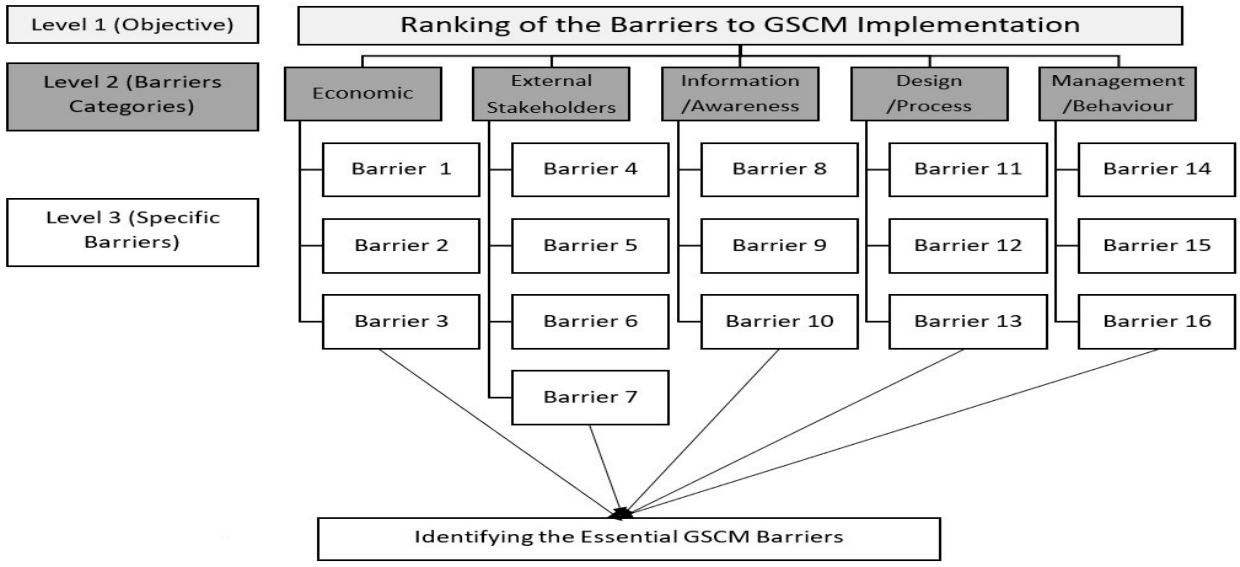

Figure 2. AHP three levels hierarchical decision levels used in the study

By analyzing the data collected, pairwise comparison matrices were developed **at two levels:**
1. Inter-category comparison (Level 2): The five categories are compared to determine their relative importance in influencing GSCM adoption.

2. Intra-category comparison (Level 3): Barriers within each category are compared to assess their relative significance.

The number of pairwise comparisons was calculated using the formula n(n-1)/2 where n is the number of the elements being compared.

- For level 2 with 5 categories: $\frac{5X4}{2} = 10$ comparisons.
- For the four categories with 3 barriers: $\frac{3X2}{2} = 3$ comparisons each (total 12 comparisons).
- For External Stakeholder category with 4 barriers: $\frac{4X3}{2} = 6$ comparisons.

The total number of comparisons is 28 comparisons.

The geometric mean method is employed to calculate the local priority weights for each barrier within its respective category. The normalized geometric mean of each row in the pairwise matrix yields the relative weights of the barriers.

Following this, consistency check is made for each pairwise comparison matrix by calculating relative weights, Consistency Index (C.I.), and Consistency Ratio (C.R). Saaty (1980) introduced the Consistency Index (CI) and Consistency Ratio (CR) and recommended a threshold of CR ≤ 0.10 for acceptable consistency. The justification was based on Monte Carlo simulations. Alinezhad & Amini (2011), Reinforced the use of CR ≤ 0.10 in various decision-making studies, especially when criteria are subjective. Ishizaka & Labib (2009), highlighted that a CR ≤ 0.10 is a practical threshold widely accepted in both theoretical and applied AHP studies.
The global weight of each barrier is obtained by multiplying its local weight (within its category) by the weight of its respective category. The barriers are then ranked based on their global weights, identifying the most critical obstacles requiring immediate intervention.
Sensitivity analysis is a critical component of the Analytic Hierarchy Process (AHP) that examines how changes in criteria weights and pairwise comparison judgments affect the final ranking of alternatives. Since AHP relies on subjective human judgments, small variations in these inputs can lead to different outcomes. Sensitivity analysis helps decision-makers understand the robustness of their decisions, identify influential criteria, and assess the stability of the ranking under different scenarios. (Saaty *et al.*, 2001)
Several approaches can be used to conduct sensitivity analysis in AHP, the most famous approach is weight Adjustment Method. This method involves systematically varying the weights of criteria while keeping other parameters constant to observe changes in the ranking of alternatives (Triantaphyllou *et al.*, 1997).

4. Results

4.1 Demographic data results

The study initially targeted 100 participants, with 89 completed responses received, yielding an 89% response rate. This high response rate strengthens the reliability of the findings, as it minimizes bias and ensures correct data for analysis.

52% of participants were top-level managers with over 15 years of experience, ensuring that strategic insights were well-represented. Another 42% were mid-level managers with more than 10 years of experience, providing operational and tactical perspectives. The remaining 6% were junior staff with less than 10 years of experience, offering execution-level viewpoints. This distribution aligns with the study's objective of capturing a wide range of expertise, from high-level decision-making to practical implementation challenges.

The disciplines of the participants are distributed within different areas as illustrated in figure (3).

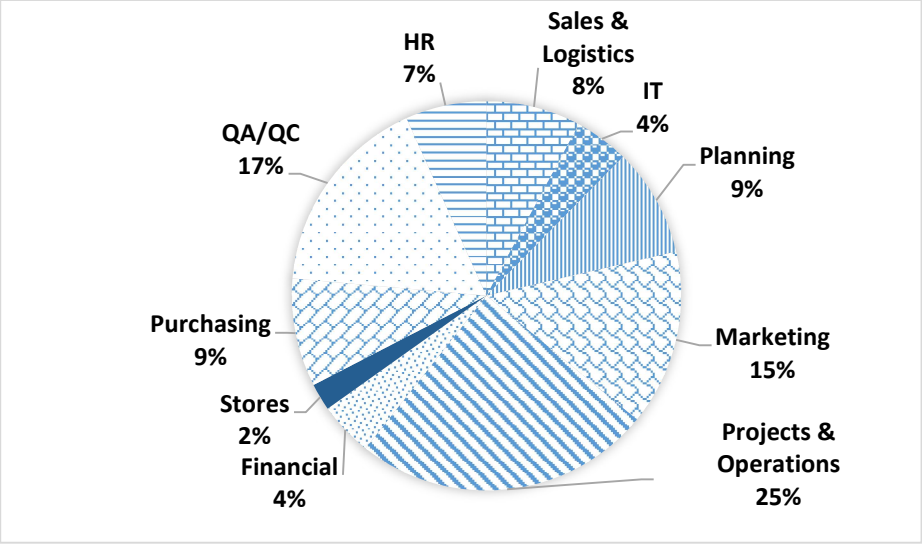

Figure 3 .The disciplines distribution of the questionnaire participants

4.2 Pairwise comparisons results

At first, a pairwise comparison matrix was developed to evaluate the relative importance of the selected GSCM barrier categories. Each category is compared against the others based on the survey responses. The five categories analyzed include Economic, External Stakeholders, Information/Awareness, Design/Process, and Management/Behavior barriers.

Based on this feedback, the AHP weight for each GSCM barriers category is calculated and the categories are sorted. Table (4) presents the pairwise comparison matrix and the weight values for each category.

Table 4 . Pairwise comparison matrix for GSCM barriers categories

	Economic	External Stakeholders	Information/ Awareness	Design/ Process	Management/ Behavior	**Weight Values**
Economic	1	1.226	1.136	1.092	1.265	0.227
External Stakeholders	0.816	1	1.692	1.085	1.218	0.223
Information/Awareness	0.880	0.591	1	0.733	0.689	0.152
Design/Process	0.916	0.922	1.364	1	0.904	0.199
Management/Behavior	0.791	0.821	1.451	1.106	1	0.199
λmax = 5.035 - Consistency Index (C.I) = 0.009 – Random Index (R.I.) = 1.12 - Consistency Ratio (C.R) = 0.008						

The Consistency Ratio (C.R.) is calculated and found to be 0.008 which indicates that the judgments are not random and reflect a reasonable level of consistency.

Similarly, a pairwise comparison matrix was developed to calculate relative weights for each barrier within its corresponding category.

4.3 Global Weights for all GSCM Barriers Categories and the Specific Barriers

Table (5) presents the ranking of specific barriers, determined by their global weights calculated using the Analytic Hierarchy Process (AHP). Each barrier's global weight is the product of its category's relative weight and the barrier's relative weight within that category.

Table 5 . Global Weights and ranks for all GSCM Barriers

Sr. No.	Category	Relative Weight using AHP	Barriers	Relative Weight using AHP	Global Weight using AHP	RANK
1	Economic	0.227	High investment and low return-on-investments	0.343	0.0779	2
2			Lack of financial capabilities	0.317	0.0720	6
3			Local & Global Financial Crisis	0.339	0.0769	4
4	External Stakeholders	0.223	Supplier related factors	0.235	0.0524	13
5			Customer related factors	0.287	0.0641	7
6			Lack of related laws and regulations and government support	0.278	0.0620	9
7			Not enough awareness and pressure from the local community	0.200	0.0446	15
8	Information/ Awareness	0.152	Unwillingness to exchange information among supply chain partners.	0.196	0.0299	16
9			Lack of awareness of the environmental impacts on business.	0.419	0.0638	8
10			Lack of training courses about implementing GSC	0.385	0.0587	10
11	Design/ Process	0.199	Lack of new technology, materials and process for GSC	0.453	0.0899	1
12			Complexity of green process and system design	0.269	0.0533	12
13			Lack of availability of standardized sustainable measurement systems	0.279	0.0553	11
14	Management/ Behavior	0.199	Lack of management commitment and approach to green supply chain adoption.	0.391	0.0778	3
15			Fear of failure.	0.225	0.0448	14
16			Reluctance and resistance to change among internal stakeholders.	0.384	0.0765	5

Among the categories investigated, the design/process category emerges as an important factor, with the barrier "Lack of new technology, materials, and processes for GSC" being the most significant across all barriers. This barrier holds the highest global weight (0.0899) and is ranked first, underscoring the technological and innovation-related challenges that hinder sustainable supply chain transitions.

The economic category is identified as the most influential among all categories, with the highest relative weight (0.227). Within this category, the barrier "High investment and low return-on-

investment (ROI)" is the most highlighted concern, with a global weight of 0.0779 and an overall rank of 2.

In the management/behavior category, "Lack of management commitment and approach to GSCM adoption" is the most critical barrier, with a global weight of 0.0778 and ranking third overall. This highlights the essential role of leadership and organizational culture in driving GSCM activities, within the same category of management/behavior, "Fear of failure" (global weight: 0.0448, rank: 14) exhibits a relatively lower impact.

Finally, the information/awareness category reveals that "Unwillingness to exchange information among supply chain partners" (global weight: 0.0299, rank: 16) is the least significant barrier.

4.4 Sensitivity Analysis:

Saaty (1980) emphasized the importance of sensitivity analysis to test robustness of results under changes in weights. Saaty (1980) did not specify a strict range for the change in the checked value but recommended exploring how the changes in criteria priorities affect final rankings.

Adapting the same way of (Govindan *et al.* 2013), since the economic category has the highest weight over all other categories, the sensitivity analysis carried out on this category to check its effect on the barriers final ranking with changes nearly equal to $\pm$10% and $\pm$50%. The change in the weight of the economic category and the corresponding weights of the other categories are tabulated in Table (6).

Table 6. Sensitivity Analysis - Categories weight based on change of Economic category

% of Change	-56%	-12%	0%	10%	54%
			Weights		
Economic	0.1	0.2	0.227	0.25	0.35
External Stakeholders	0.260	0.231	0.223	0.216	0.188
Information/Awareness	0.177	0.157	0.152	0.147	0.128
Design/Process	0.232	0.206	0.199	0.193	0.167
Management/Behavior	0.232	0.206	0.199	0.193	0.167
Total	1.000	1.000	1.000	1.000	1.000

Changes in the ranking of the specific barriers due to the impact of change of economic category weight is tabulated in Table (7).

Table 7. Ranking for the specific barriers based on change of Economic category.

Sr. No.	Category	Barriers	0.1	0.2	Orig. (0.227)	0.25	0.3
1	Economic	High investment and low ROI	14	4	2	2	1
2		Lack of financial capabilities	16	9	6	4	3
3		Local & Global Financial Crisis	15	5	4	3	2
4	External Stakeholders	Supplier related factors	10	13	13	13	13
5		Customer related factors	4	6	7	7	7
6		Lack of related laws and regulations.	6	8	9	9	9
7		Not enough pressure from the local community	12	15	15	15	15
8	Information/ Awareness	Unwillingness to exchange information	13	16	16	16	16
9		Lack of awareness	5	7	8	8	8
10		Lack of training courses	7	10	10	10	10
11	Design/ Process	Lack of new technology, materials and process	1	1	1	1	4
12		Complexity of green process and system design	9	12	12	12	12
13		Lack of standardized & measurement systems	8	11	11	11	11
14	Management/ Behavior	Lack of management commitment	2	2	3	5	5
15		Fear of failure.	11	14	14	14	14
16		Reluctance and resistance to change	3	3	5	6	6

As noticed from the results tabulated in Table (7), the change in specific barriers ranking resulted from the sensitivity analysis indicated that the variations in the weight assigned to the Economic category do not significantly alter the final ranking of the green supply chain management (GSCM) barriers. The top ranked barriers remained at their original highest rank layer.

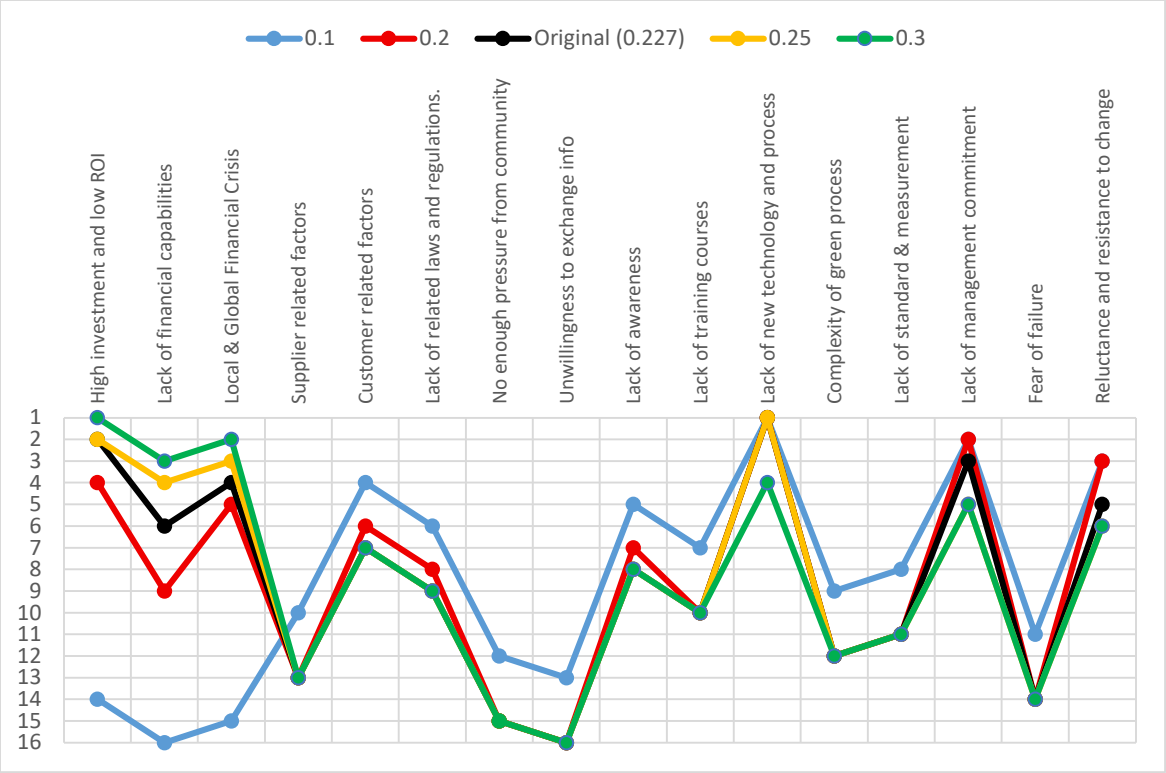

Figure 4 . Ranking for the specific barriers based on change of Economic category.

The sensitivity analysis graph (Fig. 4) shows that the results are clustered in the same areas, indicating minimal dispersion or shift in the ranks of the barriers when the weight of the Economic category is varied. This clustering confirms that changes in Economic category weight do not significantly alter the relative ranks of other barriers.

5. Discussion & Conclusion

5.1 Results discussion

The analysis of Green Supply Chain Management (GSCM) barriers through both categories and specific barriers reveals critical insights into the complex challenges that face the Egyptian petrochemicals industry in adopting green supply chain management (GSCM) practices. The five categories, Economic, External Stakeholders, Information/Awareness, Design/Process, and Management/Behavior, each contain barriers that vary significantly in their impact. Also, from the literature review of similar research which includes GSCM barriers studies across multiple industries and countries, several key agreements and disagreements with the study results have been identified.

The Economic category, which is being ranked first in importance, contains three of the top six most impacting barriers. “High investment and low return on investment” ranked 2, “local and global financial crises” ranked 4, and “lack of financial capabilities” rank 6.

The findings of this study strongly align with similar research regarding the dominance of the economic barriers category. As this mirrors findings from studies such as (Jasneet *et al.,* 2018) in Canadian manufacturing and (Zayed *et al.,* 2021) in Egyptian industries, where financial constraints were identified as the most significant barrier.

Similarly, (Chotia *et al.,* 2023) highlighted high investment requirements as a key barrier in the Indian cement industry, while (Banihashemi *et al.,* 2022) noted funding challenges in the construction sector. This majority of findings across diverse industries underscores the global nature of economic barriers, particularly in capital intensive sectors like petrochemicals. The feedback from similar researches and the results of this study both showed that the financial limitations hinder GSCM adoption by making green supply chain practices appear costly and uncertain in terms of benefits.

As (Zhang *et al.,* 2011) discussed in his research, banks and financial institutions should create dedicated green supply chain financing mechanisms with favorable terms for green supply chain practices investments. Governments can implement incentive programs that reward continuous improvement in green supply chain practices (Geng *et al.,* 2012).

The External Stakeholders category, ranked second in importance, shows the widest dispersion in the ranking of subcategory barriers, with “customer related factors” ranked 7 and “lack of related laws, regulations and government support” ranked 9 posing moderate challenges, while “suppliers related factors” ranked 13 and “not enough awareness and pressure from the local community” ranked 15 with a very low criticality.

The study results align with (Rahman *et al.,* 2023), who identified weak government policies as a major barrier in Bangladesh's construction sector, and (Wong *et al.,* 2023), who emphasized the role of customer demand in Malaysia. The similar researches outcomes support this by highlighting how regulatory gaps and market pressures can either enable or hinder GSCM practices. (Banihashemi *et al.,* 2022) stressed the lack of regulatory support in construction, while (Majumdar *et al.,* 2018) noted the influence of consumer behavior in the textile industry. The agreement here lies in recognizing that external stakeholders, whether governments, customers, or suppliers, play a great role in shaping GSCM practices’ outcomes. However, the study results slightly being different than many other researches by ranking supplier related factors as less critical, which may reflect the Egyptian petrochemical industry's unique supply chain dynamics.

The study results indicate that while companies may see external stakeholders as a major concern, in practice, market-driven pressure like customer impacts create more criticality than regulatory and local community pressure expectations.

Regulatory bodies should implement laws and standards that support the implementation of GSCM practices and provide clear timelines for companies to comply with those laws and standards while allowing flexibility in implementation pathways (Sarkis *et al.*, 2011). Extended producer responsibility is a very good example for a scheme that can secure stable financial income for

environment saving costs and for the costs of innovation activities in green products design and green supply chain processes as being studied and investigated by (Kaffine *et al.,* 2015) and (Zhidebekkyzy *et al.,* 2024).

While supplier-related factors were ranked low (13th) in the study results, studies like (Zayed *et al.,* 2021) and (Banihashemi *et al.,* 2022) identified supplier resistance as a major barrier. This disagreement may reflect differences in industry environments and needs.

The literature review of similar researches outcomes emphasize regulatory shortcomings as an impactful barrier, particularly in developing economies. However, the study ranks "lack of laws and government support" as a moderately critical barrier with rank (9th). This could suggest that petrochemical companies prioritize other barriers like cost over regulations.

Studies such as (Singh *et al.,* 2024) and (Sudarshan *et al.,* 2019) highlight weak enforcement and policy gaps as major hurdles in India, whereas the study shoes that regulatory barriers in Egypt are less severe. This may reflect the petrochemical industry's unique regulatory landscape.

The Design/Process category and The Management/Behavior category got the same weight, and both categories ranked third in importance.

The Design/Process category includes the most severe barrier, lack of new technology and materials, which was ranked as the number one challenge. This finding aligns with previous research conducted in different industries, including textiles and aluminum manufacturing. (Majumdar *et al.,* 2018) discovered similar technological limitations in the textile sector, while (Panigrahi's team, 2024) observed the same challenge in aluminum production.

These consistent findings across various industries suggest a widespread pattern where companies recognize the theoretical benefits of Green Supply Chain Management (GSCM) but struggle with practical implementation due to outdated equipment and traditional material dependencies. The persistence of this issue indicates that many manufacturing sectors remain trapped in legacy systems that are difficult and costly to upgrade, creating a significant gap between environmental goals and actual operational capabilities (Talib *et al.*, 2010; Govindan *et al.*, 2014).

Other barriers within the same category received much lower severity rankings. Measurement system deficiencies were ranked 11, and complexity of green process and system design came in at 12. The findings align with (Govindan *et al.,* 2014) who studied GSCM barriers in Indian industries as his research indicated that the technological obsolescence was identified as the most severe barrier in the technology category, while measurement system deficiencies and design complexities were ranked lower, indicating their relatively lesser criticality.

The Management/Behavior category contains high severity barriers like “lack of management commitment and approach to green supply chain adoption” which is ranked 3 and “reluctance and resistance to change among internal stakeholders” which is ranked 5.

This aligns with (Khurshid *et al.,* 2024) in the textile industry and (Hebaz *et al.,* 2021) in FMCG, where leadership and the desire to avoid cultural change were highlighted as major barriers. Similar research points to short-term profit mentalities and employee reluctance as barriers to sustainability initiatives.

This feedback highlights a critical internal organizational challenge that can significantly hinder the implementation of Green Supply Chain Management (GSCM) practices. Without strong commitment from top management, efforts toward GSCM are likely to lack strategic direction and securing the required resources (Talib *et al.*, 2010). Resistance to change is a very critical barrier as it slows down implementation of any green supply chain practice even when policies exist (Luthra *et al.*, 2011).

According to the study outcomes "fear of failure" is ranked 14th from the total of 16 barriers which means it has low criticality compared to other barriers, whereas (Ahmed Esmail, 2021) and (Chotia *et al.,* 2023) highlighted it as a significant psychological barrier. This difference might arise from organizational culture variations.

The Information/Awareness category, ranked fifth in importance, contains medium severity barriers like “lack of awareness of the environmental impacts on business” at rank 8, “lack of training courses about implementing GSC” at Rank 10, while poor information sharing among supply chain partners ranked 16, suggesting that knowledge about green supply chain, training, and collaboration between supply chain partners in the petrochemicals sector are not the primary bottleneck.

The study ranks information/awareness barriers as the least critical, contrasting with studies like (Jasneet *et al.,* 2018) and (Wong *et al.,* 2023), where lack of training and awareness were top concerns. This discrepancy may come from differences in industries nature and location, such as the Egyptian petrochemical industry's focus on training programs and knowledge-sharing platforms which indicates that awareness barriers have been mitigated in this sector, allowing other challenges like economic and Design/Process barriers to take the higher ranks.

These insights suggest that while GSCM barrier categories are consistent, their relative severity is shaped by industry and region-specific factors.

5.2 Implications & limitations

5.2.1 Limitations

While the study provides valuable insights, it is not without limitations. First, its focus on Egypt’s petrochemicals industry limits the generalizability of the findings to other sectors or geographic regions. Petrochemicals companies in Egypt operate within a unique regulatory, economic, and cultural environment that may differ totally from other regions.

Second, the study's reliance on survey data may introduce potential biases. Respondents' assessments of barriers importance may be influenced by their organizational roles, personal experiences, or recent events.

Third, the dynamic nature of the petrochemicals industry means that the relevance of certain barriers may change over time.

Future research could employ more complex techniques to overcome these limitations.

5.2.2 Theoretical implications and future research

The findings of this study yield theoretical implications and highlight areas for future research that can further advance the understanding of barriers to Green Supply Chain Management (GSCM). By addressing these research gaps, scholars can contribute to a more comprehensive theoretical framework, ultimately supporting the development of more effective GSCM strategies.

First, while this study provides valuable insights into GSCM barriers, its findings are based on a specific industrial and regional context. To enhance the generalizability of the results, future research should conduct analyses across multiple industries and diverse geographical regions.

Second, this study employs the Analytic Hierarchy Process (AHP) to assess and rank GSCM barriers. While AHP is a widely used multi-criteria decision-making (MCDM) tool, it has limitations. Future research could mitigate these limitations by adopting alternative methodologies. Employing different analytical tools would not only validate the current findings but also provide a more understanding to GSCM barriers in Egyptian petrochemicals sector.

Third, given the dynamic nature of supply chain operations, the significance of GSCM barriers may shift over time. To capture these changes, more studies should be conducted to reassess barriers at regular intervals. Such an approach would enable researchers to track emerging trends, such as the impact of digitalization or global disruptions on GSCM practices.

By addressing these research directions, scholars can strengthen the theoretical foundations of GSCM while offering practical guidance for policymakers and industry practitioners striving to overcome sustainability challenges in supply chains.

5.2.3 Practical implications

The study's findings carry significant practical implications for stakeholders across the petrochemicals sector, including companies, financial institutions, and government. Addressing Economic barriers requires a specific approach that combines financial incentives with risk-mitigation strategies. Banks and financial institutions can play a crucial role by developing dedicated green financing mechanisms tailored to the needs of petrochemicals companies. These could include low-interest loans, that reduce the costs of GSCM investments. The results of

(Chen *et al.,* 2024) underscore the importance of innovative financial instruments, such as green bonds and sustainability-linked loans, in driving the transition towards more sustainable industrial practices.

Governments, on the other hand, can implement incentive programs such as tax breaks or carbon credits to reward companies that demonstrate measurable progress in sustainability. Additionally, international collaborations and funding from international organizations could help in decreasing the financial gap. Policy interventions, including carbon pricing mechanisms and subsidies for green technologies, are widely recognized as crucial for incentivizing corporate environmental performance and facilitating sustainable supply chain transitions (Chen *et al.*, 2023).

For External Stakeholders, the study underscores the need for stronger regulatory frameworks and market-driven interventions. Extended Producer Responsibility (EPR) schemes could provide stable revenue for environmental initiatives by holding companies accountable for the lifecycle impacts of their products. The effectiveness of EPR schemes in promoting circular economy principles and improving waste management has been widely studied across various industries (Brown *et al.*, 2023; Zhidebekkyzy *et al.*, 2024).

Overcoming Design/Process barriers will require substantial investments in research and development (R&D), particularly in green technologies and materials. Petrochemicals companies should allocate a greater share of their budgets to applied research, focusing on solutions that are both efficient and commercially viable. Cooperation with academic institutions and technology providers can accelerate this process. (Jabbour *et al.*, 2019).

Addressing Management/Behavioral barriers demands a cultural shift within organizations. Top management must take action to include GSCM practices in corporate strategies and performance metrics (Talib *et al.*, 2010).

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المستخلص

مثَّلت الثورة الصناعية تحولًا كبيرًا في الإنتاج، أدى إلى تدهور بيئي بسبب الأنشطة الصناعية. واستجابةً لذلك، برز مفهوم إدارة سلاسل الامداد الخضراء كمنهج للتخفيف من الآثار البيئية مع الحفاظ على كفاءة العمليات. ومع ذلك، فإن تطبيق إدارة سلاسل الامداد الخضراء يواجه عوائق عديدة، خاصة في بعض الصناعات مثل البتروكيماويات. تهدف هذه الدراسة إلى تحديد وترتيب العوائق الرئيسية أمام تبني مفاهيم إدارة سلاسل الامداد الخضراء في صناعة البتروكيماويات المصرية باستخدام تحليل (AHP).

من خلال مراجعة الأبحاث السابقة، تم تجميع 16 عائقًا تم ترتيبها في خمس فئات: عوائق اقتصادية، عوائق مرتبطة بأصحاب المصلحة الخارجيين، عوائق مرتبطة بالمعلومات والوعي، عوائق مرتبطة بالتصميم والعمليات، عوائق مرتبطة بالإدارة والسلوك. تم توزيع استبيان على عدد 89 متخصص في الصناعة، وطُبقت طريقة AHP لتحديد الأهمية النسبية لهذه العوائق.

كشفت النتائج أن عائق نقص التكنولوجيا والمواد والعمليات الخضراء كان العائق الأكثر أهمية، يليه ارتفاع الاستثمارات وانخفاض العائد على الاستثمار للعمليات الخضراء ثم ضعف التزام الإدارة نحو تطبيق الممارسات الخضراء. وصُنفت العوائق الاقتصادية كالفئة الأكثر تأثيرًا. كما حلت فئتا العوائق المرتبطة بأصحاب المصلحة الخارجيين والمرتبطة بالتصميم والعمليات في ترتيب متقدم، بينما اعتُبرت العوائق المرتبطة بالمعلومات والوعي أقل أهمية. وأكد تنفيذ تحليل للحساسية صحة هذه النتائج.

تؤكد الدراسة الحاجة إلى حوافز مالية، وتطوير تكنولوجي اخضر، وأطر تنظيمية أقوى لتعزيز تبني مفاهيم إدارة سلاسل الامداد الخضراء. يقدم البحث رؤى قابلة للتطبيق لصانعي السياسات وقادة الصناعة لتعزيز ممارسات إدارة سلاسل الامداد الخضراء. بالإضافة انه يفتح مجالا للأبحاث المستقبلية لاستكشاف حلول اخري لتطبيق ممارسات إدارة سلاسل الامداد الخضراء بشكل أكبر.

الكلمات المفتاحية: سلاسل الامداد الخضراء ؛ معوقات ؛ البتروكيماويات