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Unboxing: Exploring the Challenges of Green Supply Chain Initiatives in Thailand

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Abstract: *Background:* The increasing global focus on sustainability has made Green Supply Chain Management (GSCM) a critical strategy for businesses to balance environmental responsibility with operational efficiency. Despite its benefits, GSCM adoption in developing countries faces significant challenges. This study addresses the gap by investigating these barriers within the Thai context, providing actionable insights for policymakers and businesses. *Methods:* A mixed-methods approach was employed, including a survey of 480 business owners, executives, and supply chain employees, and expert analysis using Interpretive Structural Modeling (ISM). The ISM technique was used to determine the relationships and hierarchy among key barriers to GSCM implementation. *Results:* The findings reveal that weak legal frameworks, insufficient supplier engagement, and a lack of social responsibility are the most significant barriers. Secondary factors, such as low consumer demand and minimal competitive pressure, exacerbate these challenges. The ISM analysis highlighted the cascading effects of foundational barriers on other dimensions of GSCM adoption. *Conclusions:* Strengthening environmental regulations, promoting supplier collaboration, and embedding sustainability in corporate culture are key to overcoming GSCM barriers to sustainably enhance Thailand's competitiveness.

Keywords: green supply chain; barriers; business; operations

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1. Introduction

In the current context, rapid economic growth must go hand in hand with a global focus on sustainable practices. Businesses across industries are adopting green supply chain management (GSCM) as a key strategy to enhance environmental performance while maintaining competitiveness [1]. GSCM integrates environmentally friendly practices into supply chain operations, aiming to reduce their ecological impact and promote sustainability across sectors [2]. Recognizing the benefits of GSCM, Thailand, a developing country, is increasingly interested in the concept of GSCM across both public and private sectors. This is because the country faces environmental issues, such as industrial emissions, inefficient waste management, and natural resource depletion. The government has been promoting the circular economy approach and trying to integrate GSCM concepts at policy and industrial levels. However, many businesses, especially small and medium-sized enterprises (SMEs), have difficulty achieving these goals due to several limitations. As a result, Thailand still faces significant challenges in implementing green supply chains [3].

Thailand's economic growth has been accompanied by increasing environmental concerns, prompting the government and private sectors to prioritize green practices. The

country has made strides toward developing a circular economy, yet various obstacles impede the effective adoption of GSCM initiatives. These barriers can be categorized into several dimensions, including regulatory, organizational, technological, and cultural factors [4,5]. For instance, while policies promoting green practices exist, a lack of stringent enforcement and inadequate support mechanisms often hinder their effectiveness [6].

Organizationally, many companies in Thailand lack the necessary resources, knowledge, and commitment to implement GSCM practices effectively. This is particularly true for small and medium-sized enterprises (SMEs), which often struggle with limited financial and technical capabilities [7]. Additionally, technological barriers, such as the insufficient availability of eco-friendly technologies and systems, further complicate the transition to sustainable supply chain practices [8].

Culturally, traditional business practices and mindsets can pose significant challenges to adopting GSCM in Thailand. The prevailing focus on short-term profits often overshadows long-term sustainability goals, leading to stakeholder resistance to change [9]. Moreover, the lack of awareness and understanding of GSCM benefits among both consumers and businesses can hinder the demand for sustainable products and practices.

This study aimed to identify and analyze the challenges of green supply chain initiatives from the perspectives of business owners, executives, and logistics and supply chain employees in Thailand and determine the contextual relationships between the challenges of green supply chain initiatives from the perspectives of logistics and supply chain professionals and the environment. The data were analyzed using interpretive structural modeling (ISM). This study not only provides a better understanding of the GSCM challenges in Thailand but also supports the development of government and relevant agencies' policies and guidelines in line with environmental goals.

This paper is presented in the following sequence: Section 2 is a literature review, which presents information on green supply chain management (GSCM) and the challenges of initiating a green supply chain. In Section 3, the methodology used for the study is presented. In Section 4, the findings of this study are presented as mean and standard deviation and ISM. Section 5 is the discussion, Section 6 is the conclusion, and the last section (Section 7) covers the study limitations.

2. Literature Review

2.1. Green Supply Chain Management (GSCM)

Supply chain management (SCM) has evolved into a critical area of study and practice, gaining prominence as organizations strive for operational efficiency and competitive advantage [10]. A supply chain is a system that links various activities, from sourcing raw materials, production, transportation, and delivery of goods to the end consumer. All activities are related in the form of a supply chain [11]. The supply chain covers both internal and external organizations, such as manufacturers, distributors, and logistics service providers. The main goal of SCM is to increase operational efficiency, reduce production costs, and create customer satisfaction [12].

An emerging trend in SCM is sustainability, reflecting the growing recognition of environmental and social responsibilities [13]. Green supply chain management (GSCM) has emerged as a vital framework for organizations seeking to enhance their green practices while maintaining operational efficiency [14]. GSCM refers to the systematic integration of green practices into supply chain operations, encompassing the sourcing, production, and distribution of goods and services [1].

GSCM involves the redesign of supply chain processes to minimize environmental impact while maximizing economic performance [15]. Research indicates that companies adopting green practices can enhance their brand reputation, reduce costs, and comply

with regulatory requirements [2]. Moreover, the pressure from stakeholders has prompted organizations to prioritize sustainability in their supply chain strategies [1]. According to [16], GSCM incorporates green practices at various levels, ultimately aiming to create a circular economy where waste is minimized and resources are reused.

Several factors drive the adoption of GSCM practices across industries. Regulatory pressures significantly influence organizations to implement green practices to comply with environmental laws and standards [6]. Additionally, the growing consumer awareness regarding environmental issues has led to increased demand for sustainable products, prompting companies to adopt green practices to remain competitive [8]. Furthermore, the potential for cost savings through resource efficiency and waste reduction acts as a strong motivator for companies to implement GSCM practices [4].

2.2. Challenging Factors for Green Supply Chain Initiatives

Implementing an effective and efficient green supply chain for business organizations is a significant challenge, especially in Thailand. One factor is the lack of awareness and understanding of the benefits of GSCM among senior executives, which may lead to insufficient support for sustainability initiatives [9]. In addition, resource constraints, particularly among small and medium-sized enterprises (SMEs), often limit their ability to invest in green technologies and practices [5]. Another major obstacle is insufficient collaboration among supply chain partners. Research indicates that effective GSCM requires close collaboration between suppliers, manufacturers, and distributors, but many organizations struggle to build these relationships [17]. Finally, the perceived high costs associated with implementing green practices may discourage organizations from adopting GSCM, especially when the financial benefits are not immediately apparent [1].

Green practices and supply chain initiatives have received increasing scholarly attention. Table 1 presents our literature review related to green supply chain initiatives.

Table 1. Summary of challenging factors for green supply chain initiatives.

Authors (Year)	Country	Analysis Methods	Law	Customers	Social Responsibility	Competitors	Suppliers
Walker and Preuss [18]	UK	Literature review				✓	
Dube and Gawande [19]	India	Synthesize secondary data and discussion with academicians and industrial experts	✓	✓			✓
Jayant and Azhar [20]	India	Interpretive structural modeling (ISM)		✓	✓		✓
Ojo, Mbowa [21]	Nigeria	Frequency and hierarchical model	✓	✓			
Niemann, Kotze [22]	Mozambique	Semi-structured interviews	✓		✓		
Thumnong and Nalin [23]	Thailand	Structural equation modeling (SEM)	✓				✓
Akhtar, P. [24]	Pakistan	Partial least squares structural equation modeling (PLS-SEM)				✓	
Tumpa, T.J. et al. [25]	Bangladesh	Hierarchical cluster analysis	✓	✓			
This present study	Thailand	Interpretive structural modeling (ISM)	✓	✓	✓	✓	✓

This study examines the challenges of green supply chain initiatives, including laws, customers, social responsibility, competitors, and suppliers, which can be summarized as follows:

1. Laws: The absence of stringent environmental regulations and the ineffective enforcement of existing laws may hinder the adoption of green supply chain management (GSCM) practices. Companies often find it challenging to comply with vague regulations, which discourages them from investing in green technologies and processes [6]. In addition, there are no incentives for adopting green practices in organizations, and no penalties for non-compliance may discourage businesses from complying with GSCM [26]. Therefore, the regulatory framework in Thailand may not provide the necessary support for organizations to transition to green practices [22,23,25];
2. Customers: While environmental awareness is increasing, customer demand for green products remains limited. Many consumers prioritize cost over sustainability, which may lead companies to hesitate to invest in green supply chains [23,27]. In addition, few consumers have knowledge or understanding of the benefits of green practices, which is a reason why businesses do not adopt green practices [19–21,28];
3. Social responsibility: An organizational culture that emphasizes short-term profit rather than long-term sustainability may hinder GSCM initiatives. Many organizations view sustainability as a secondary concern rather than an integral part of their business strategy [9]. Additionally, a lack of effective stakeholder engagement can lead companies to overlook the importance of partnerships with community and environmental organizations, limiting GSCM implementation [5,20,22,24];
4. Competitors: In some cases, the lack of competitive pressure may make a company feel that it is not necessary to adopt GSCM practices because its competitors are not adopting them. Therefore, such a lack of competitive pressure hinders sustainability innovation [8,24]. Investing in green practices increases the cost, making organizations hesitant to adopt GSCM practices, especially if their competitors are not adopting them as well [7,18];
5. Suppliers: Many companies rely on suppliers who may not have the capacity or willingness to adopt green practices. If a supplier lacks the necessary technology or commitment to sustainability, this can pose challenges for companies trying to implement GSCM [26]. The cost implications associated with sourcing from environmentally responsible suppliers can be a significant obstacle. Companies may face higher prices for environmentally friendly materials and components, which may discourage them from adopting GSCM [4,19,20,29].

The current study explores the challenges facing green supply chain implementation to consider their importance and interrelationships, as understanding the different barriers or challenges is essential to understanding their potential impact on the success of green supply chain projects.

2.3. Interpretive Structural Modeling (ISM)

ISM was first introduced by Warfield in 1973 [30] and has evolved into more complex structural models since then [31]. It involves using drawings and mathematical equations to solve complex problems [32,33] and is suitable for using visual representations to explain complex systems in an easily understandable way [34]. ISM requires specifying the relationship of each directly and indirectly related element, indicating the primary connection and overall relationship of these elements [35].

ISM begins with identifying the variables relevant to the problem or issue. Deciding on the relationships between the factors is a crucial step based on the judgment of experts with in-depth knowledge of the research topic. Experts assess whether a particular factor

directly or indirectly affects other factors based on their understanding of the domain. If one factor affects another, experts identify and confirm this relationship based on practical evidence or observations and then expand on it using cluster problem-solving techniques. The researcher then selects relevant sub-relations based on the context of the study. Once the set of components and contextual relationships has been identified, a structural self-interaction matrix (SSIM) is developed based on pairwise comparisons of the variables. The next step involves converting the SSIM into a reachability matrix (RM) and examining the transmission values, which leads to a complete matrix model. The structural model called ISM is then decomposed and extracted [35].

ISM is interpretive since group discussion determines how the elements relate. Therefore, ISM is suitable for analyzing data from experts in the context of a research problem. The method is structured because it creates a comprehensive structure of the entire complex of elements (based on relations) by considering possible pairwise interactions. This method is considered modeling since the complete structure and individual relationships between elements are represented as a digraph [36,37]. We used this approach to identify and organize the complex relationships between elements that act as the challenges of initiating a green supply chain. ISM allowed us to analyze the influence between various components, which revealed the connection between factors. Thus, we determined whether factors were independent or dependent on other factors in promoting operations to achieve an organization's objectives more efficiently [17,38].

3. Methodology

Data Collection

This study employed a mixed-method approach. The quantitative component involved surveying a target group consisting of business owners, executives, and logistics and supply chain employees in Thailand, totaling 480 participants. The survey focused on identifying factors that hinder green supply chain initiatives. Although the exact size of the target population was unknown, the sample size was calculated to ensure a representative subset using Equation (1) [39]:

$$\mathrm{n} = \frac{\sigma^2\left(Z^2\right)}{e^2} = 167 \quad (1)$$

where n = sample size; z is at a 99% confidence level (z = 2.58); σ^2 = variance = ¼ (Max−Min) = ¼(5 − 1) = 1; and e = error value = 0.05 (Max−Min) = 0.05(5 − 1) = 0.2.

Based on this calculation, a minimum sample size of 167 was required. However, data were collected from 480 respondents to enhance accuracy and reliability. Data were collected using a questionnaire with closed-ended questions and a 5-level rating scale from 1 (min) for the lowest value to 5 (max) as the highest value and analyzed using mean and standard deviation [40].

After, qualitative research on the target sample group, consisting of 5 experts in logistics, supply chains, and the environment, was conducted to identify the relationship of each factor pair that are the challenges of green supply chain initiatives and analyzed using ISM. The questionnaire was reviewed by experts in fields related to the research. As a result of this analysis, the index of item objective congruence (IOC) was 0.89, which is higher than the common threshold of 0.50, indicating that the questionnaire is valid [41].

ISM is an interactive learning process in which a set of different and directly related elements are structured into a comprehensive systematic model. It is a suitable modeling technique for analyzing the influence of one variable on the other variables. It uses drawings and mathematical equations to solve problems [32,42]. ISM is an effective tool to identify and inspect the relationships among specific elements within a system [30].

This study examined the importance and relationships of the factors that are the challenges of green supply chain initiatives. It is a well-accepted method for identifying the relationship between specified factors. Researchers use this methodology to understand the direct and indirect relationships between different variables in a business. ISM is a qualitative technique that relies on expert insights to establish and structure relationships among variables without requiring a large statistical sample size. Its effectiveness is determined by the depth and diversity of expert input rather than the quantity of participants. Studies typically include 5 to 20 experts to balance diverse perspectives with manageability, while more specialized fields often find a smaller panel of 5–7 experts sufficient. Therefore, using ISM with a sample size of five experts adheres to standard practices and is adequate for effectively modeling complex relationships. For this study, even though there were only five factors and the experts' opinions may be sufficient to link the five factors, the use of interpretive structural modeling (ISM) forces experts to systematically formalize their reasoning, transforming qualitative data into structured data, making the analysis more reproducible and transparent. We, therefore, chose to use ISM to analyze the qualitative data in this research. This study conducted the steps detailed in Section 4.

4. Findings

4.1. Quantitative Research Results

4.1.1. Demographic Information

The demographic information is summarized using the descriptive statistics frequency, means, and percentages in Table 2.

Table 2. Demographic data analysis results.

Demographic Information	Number	Percentage
1. Sex		
Male	271	56.46
Female	209	43.54
2. Status		
Business Owner/Executive	149	31.04
Logistics and Supply Chain Employee	331	68.96
3. Work experience		
Less than 5 years	65	13.54
5–10 years	327	68.13
More than 10 years	88	18.33
4. Business type		
Manufacturing	167	34.79
Transportation	311	64.79
Others, such as Warehouse	2	0.42

In Table 2, the demographic data of the 480 samples show that the majority of respondents were men (271 people, 56.46 percent), and the rest were women (209 people, 43.54 percent). Of the respondents, the majority were logistics and supply chain employees (331 people, 68.96 percent), along with business owners/executives (149 people, 31.04 percent), and those with 5–10 years of work experience (327 people, 68.13 percent). The majority of businesses were in transportation (311 people, 64.79 percent).

4.1.2. The Importance of Challenges in Green Supply Chain Initiatives

This is a study of the challenges in green supply chain initiatives from the perspectives of business owners, executives, and logistics and supply chain employees in Thailand. The data were analyzed using five levels of intervals by means, namely, 1.00–1.80 = least, 1.81–2.60 = less, 2.61–3.40 = medium, 3.41–4.20 = high, and 4.21–5.00 = highest. The data were analyzed using mean and standard deviation. The results are shown in Table 3.

Table 3. The importance of challenges in green supply chain initiatives.

	Factors	$\overline{x}$	S.D.	Level of Importance
1.	Laws: The absence of stringent environmental regulations and the ineffective enforcement of existing laws may hinder the adoption of green supply chain management (GSCM) practices. In addition, there are no incentives for adopting green practices in organizations, and no penalties for non-compliance may discourage businesses from complying with GSCM.	4.34	0.75	Highest
2.	Customers: While environmental awareness is increasing, customer demand for green products remains limited. Many consumers prioritize cost over sustainability, which may lead companies to hesitate to invest in green supply chains. In addition, few consumers have knowledge or understanding of the benefits of green practices, which is a reason why businesses do not adopt green practices.	3.98	0.76	High
3.	Social responsibility: An organization that emphasizes short-term profit rather than long-term sustainability may hinder GSCM initiatives. Many organizations view sustainability as a secondary concern rather than an integral part of their business strategy. Additionally, a lack of effective stakeholder engagement can lead companies to overlook the importance of partnerships with community and environmental organizations, limiting GSCM implementation.	4.27	0.82	Highest
4.	Competitors: In some cases, the lack of competitive pressure may make a company feel that it is not necessary to adopt GSCM practices because its competitors are not adopting them. Therefore, such a lack of competitive pressure hinders sustainability innovation. Investing in green practices increases the cost, making organizations hesitant to adopt GSCM practices, especially if their competitors are not adopting them as well.	4.00	0.72	High
5.	Suppliers: Many companies rely on suppliers who may not have the capacity or willingness to adopt green practices. If a supplier lacks the necessary technology or commitment to sustainability, this can pose challenges for companies trying to implement GSCM. The cost implications associated with sourcing from environmentally responsible suppliers can be a significant obstacle. Companies may face higher prices for environmentally friendly materials and components, which may discourage them from adopting GSCM.	4.31	0.78	Highest
	Total	4.18	0.77	High

Quantitative research on the target sample group of business owners, executives, and logistics and supply chain employees in industrial businesses participating in the green industry project in Thailand, totaling 480 people, was based on of opinions on factors that hinder green supply chain initiatives. The results of the analysis of the importance level of the obstacles to the initiative of a green supply chain that entrepreneurs give importance to found that laws factors, supplier factors, and social responsibility factors had the highest

mean scores of 4.34, 4.31, and 4.27, respectively, followed by competitor factors ($\overline{x}$ = 4.00) and customer factors ($\overline{x}$ = 3.98) in rank order. When considering the S.D. values, it was found that all factors had values between 0.72 and 0.82, indicating the nature of the data and the distribution of the data in that set had a variety of opinions.

After, qualitative research on the target sample group, consisting of five experts in logistics and supply chains and the environment, was conducted to identify the relationship of each factor pair of challenges in green supply chain initiatives and analyzed using ISM, with the results detailed in Section 4.2.

4.2. Qualitative Research Results

4.2.1. Experts' Profiles and Their Responses

As shown in Table 4, the sample of this study was five logistics and supply chain and environment experts, most of whom were professors in education and had working experience of 15 years or more, who identified the relationship of each pair of factors that hinder green supply chain initiatives and analyzed them using ISM, as detailed in Section 4.2.2.

Table 4. Experts' profiles.

Sex	Qualification	Specialized Expertise	Experience (Years)	Age (Years)
Female	Education—Associate Professor (PhD)	Logistics and Supply Chain, Economics	30	65
Male	• Education—Professor (PhD). • Manager—Supply Chain	• Project Management • Logistics and Supply Chain • Industrial Engineering	27	59
Female	Education—Assistant Professor (PhD)	Logistics and Supply Chain, Accounting and Finance	21	53
Female	Education—Assistant Professor (PhD)	Logistics and Supply Chain, Business Administration	18	49
Male	Education—Assistant Professor (PhD)	Industrial Management, Environmental Engineering	15	46

4.2.2. ISM Research Implementation Flowchart

The research operation based on ISM is detailed in Figure 1.

To determine the relationship between factors that challenge green supply chain initiatives, we studied and selected each factor using the word "affects" to define the relationship between different factors. From five factors, 10 comparison pairs or 20 relationships were created. Experts determined the relationship between the factors and compared them to the primary and dependent variables. Answers for each pair were either "Yes (Y)" or "No (N)", and the meanings are defined as follows:

Yes (Y) means factor i affects factor j;

No (N) means factor i does not affect factor j.

After the experts identified the relationship between variables, we checked for data completeness and only collected data for every pair of factors specified by experts that matched at least 51% for further data analysis. Thus, the five factors were determined as follows:

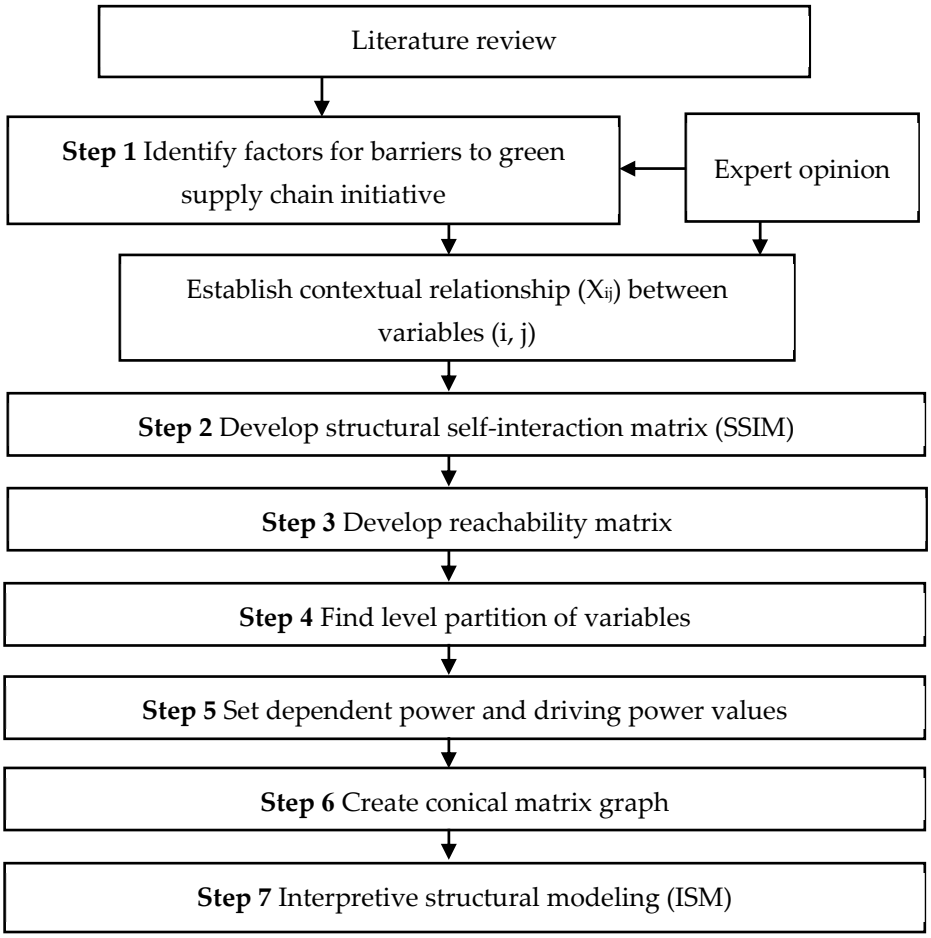

Figure 1. Flow diagram for preparing ISM.

Step 1: Identifying factors that pose barriers to green supply chain initiatives.

[C1] Laws: The absence of stringent environmental regulations and the ineffective enforcement of existing laws may hinder the adoption of green supply chain management (GSCM) practices. Companies often find it challenging to comply with vague regulations, which discourages them from investing in green technologies and processes [6]. In addition, there are no incentives for adopting green practices in organizations, and no penalties for non-compliance may discourage businesses from complying with GSCM [26]. Therefore, the regulatory framework in Thailand may not provide the necessary support for organizations to transition to green practices [19,21,22,25,29];

[C2] Customers: While environmental awareness is increasing, customer demand for sustainable products remains limited. Many consumers prioritize cost over sustainability, which may make companies hesitant to invest in green supply chains [27,29]. In addition, few consumers have knowledge or understanding of the benefits of green practices, which is a reason why businesses do not adopt green practices [19–21,25,28];

[C3] Social responsibility: An organizational culture that emphasizes short-term profit rather than long-term sustainability may hinder GSCM initiatives. Many organizations view sustainability as a secondary concern rather than an integral part of their business strategy [9]. Additionally, a lack of effective stakeholder engagement can lead companies to overlook the importance of partnerships with community and environmental organizations, limiting GSCM implementation [5,20,22,24];

[C4] Competitors: In some cases, the lack of competitive pressure may make a company feel that it is not necessary to adopt GSCM practices because its competitors are not adopting them. Therefore, such a lack of competitive pressure hinders sustainability innovation [8,24].

Investing in green practices increases the cost, making organizations hesitant to adopt GSCM practices, especially if their competitors are not adopting them as well [7,18];

[C5] Suppliers: Many companies rely on suppliers who may not have the capacity or willingness to adopt green practices. If a supplier lacks the necessary technology or commitment to sustainability, this can pose challenges for companies trying to implement GSCM [26]. The cost implications associated with sourcing from environmentally responsible suppliers can be a significant obstacle. Companies may face higher prices for environmentally friendly materials and components, which may discourage them from adopting GSCM [4,19,20,29].

Step 2: Structural self-interaction matrix (SSIM) development.

Data obtained from determining the relationship of various factors were matched to reduce complexity and create a relationship table between variables i and j (Table 5). Here, "i" indicates the variable row, and "j" refers to the variable in the matrix column. We used the symbols V, A, O, and X to represent the relationship between two variables. The meaning of the symbols can be described as follows:

Table 5. Structural self-interaction matrix (SSIM).

I	**J**				
	C1	**C2**	**C3**	**C4**	**C5**
C1	-	V	O	V	O
C2		-	O	O	A
C3			-	V	X
C4				-	O
C5					-

V is used when the variable i affects variable j;
A is used when the variable j affects variable i;
O is used when the variables i and j affect each other;
X is used when the variables i and j do not affect each other.

Step 3: Reachability matrix (RM) development.

We extracted the data obtained from the SSIM relationship table based on the relationship of using "numbers" instead of symbols to facilitate data analysis from the SSIM and checked for transitivity. Step 3 is concerned with the construction of the reachability matrix. It is a binary matrix since the entries V, A, O, and X of the SSIM are converted into 1 and 0 as per the following rules in Table 6.

Table 6. Reachability matrix.

Symbol	**Relationship from i to j**	**Relationship from j to i**
V	1	0
A	0	1
O	1	1
X	0	0

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0;

- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1;
- If the (i, j) entry of the SSIM is O, then both the (i, j) and (j, i) entries of the reachability matrix become 1;
- If the (i, j) entry in the SSIM is X, then both the (i, j) and (j, i) entries of the reachability matrix become 0.

In Table 7, the symbols V, A, O, and X of the SSIM are converted into 1 and 0. The initial reachability matrix is a fundamental assumption in ISM that leads to the final reachability matrix. It states whether elements C1–C5 are related to elements C1–C5. If an element (i, j) of the final reachability matrix is zero, there will not be any direct or indirect relationships from element i to element j. The initial reachability matrix may not have this characteristic because when there is no direct relationship but an indirect relationship from element i to j, entry (i, j) is also zero. Indirect relationships can be found with diagonal entries set to 1 [43].

Table 7. Initial reachability matrix.

I	J				
	C1	**C2**	**C3**	**C4**	**C5**
C1	1	1	1	1	1
C2	0	1	1	1	0
C3	1	1	1	1	0
C4	0	1	0	1	1
C5	1	1	0	1	1

Step 4: Level partition of variables.

This study determined the level partition of the variables by dividing the data from the RM relationship into two sets:

(1) The reachability set is the selection and consideration of dividing groups of variables in row (i) that have a relationship with other variables in column (j) with a value equal to 1 into the same set. This was performed until all variables were complete;

(2) The antecedent set is the selection and consideration of dividing groups of variables in column (j) that have a relationship with other variables in row (i) with a value equal to 1 into the same set. This was performed until all variables were complete.

Table 8, we considered duplicate variables between the reachability and antecedent sets. If the duplicate variables were identical to the variables in the reachability set in all respects (both in terms of the variables and the number of variables), they were considered level 1. Beginning with level 1, the variables at the highest level were considered the most critical variables. The variables that were already leveled were removed from the set. The remaining factors were repeated to level their importance, which continued until all variables were included. Then, the variables' level partitions were summarized to generate ISM.

Step 5: Dependent power and driving power values.

We classified factors using data from the RM table to analyze the driving power (importance/influence) and the dependent power (dependence) of each factor. The method for calculating the driving power value was based on the sum of the numbers in each variable row. We calculated the dependent power value based on the sum of the numbers in each variable column. This was performed to determine the plot point on the graph, as shown in Table 9.

Table 8. Level partition of variables.

Variables	Reachability Set	Antecedent Set	Intersection Set	Level
		Iteration 1		
C1	C1, C2, C3, C4, C5	C1, C3, C5	C1, C3, C5	
C2	C2, C3, C4	C1, C2, C3, C4, C5	C2, C3, C4	I
C3	C1, C2, C3, C4	C1, C2, C3	C1, C2, C3	
C4	C2, C4, C5	C1, C2, C3, C4, C5	C2, C4, C5	I
C5	C1, C2, C4, C5	C1, C4, C5	C1, C4, C5	
		Iteration 2		
C1	C1, C3, C5	C1, C3, C5	C1, C3, C5	II
C3	C1, C3	C1, C3	C1, C3	II
C5	C1, C5	C1, C5	C1, C5	II

Table 9. Dependent power and driving power values.

I	J					Driving Power
	C1	C2	C3	C4	C5	
C1	1	1	1	1	1	5
C2	0	1	1	1	0	3
C3	1	1	1	1	0	4
C4	0	1	0	1	1	3
C5	1	1	0	1	1	4
Dependent Power	3	5	3	5	3	

Step 6: Conical matrix graph.

We used the values from Table 9 to create a conical decoding graph by setting the dependent power value as the "X" axis and the driving power value as the "Y" axis. The details are presented in Figure 2.

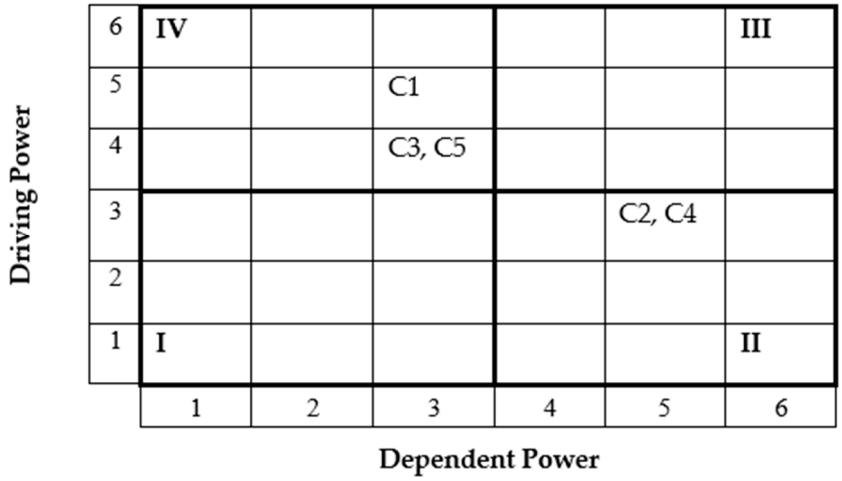

Figure 2. Conical matrix.

Figure 2 shows that the factors which challenge green supply chain initiatives can be divided into four groups as follows:

- Group 1: These are autonomous factors with low driving power values and low dependent power values. Factors in group 1 are of little to no importance to the structure. This study found no obstacle variables corresponding to group 1;
- Group 2: These are dependent factors with low driving power value and high dependent power value. Factors in group 2 must be supported as they are highly dependent on other factors. This study found that the factors in the second group are [C2] customer factors and [C4] competitor factors;
- Group 3: Linkages are factors with a high driving power value and dependent power value. Factors in this group are essential or highly influential; if supported by other factors, they will have a greater influence. This study found no obstacle variables corresponding to group 3;
- Group 4: Independent factors have high driving power values and low dependent power values. Group factors were considered the most significant and influential factors. Organizations should prioritize and act on factors in this group as a priority since they will have the greatest impact on their business structure. This study found that the factors in the fourth group are [C1] law factors, [C3] social responsibility factors, and [C5] supplier factors.

Step 7: ISM.

This study used ISM to assess the relationships between factors. The elements are arranged in a diagram to show the level of importance and interrelationship of the factors. A relationship between factors is indicated by an arrow, and the level corresponds to Table 8. The details are shown in Figure 3.

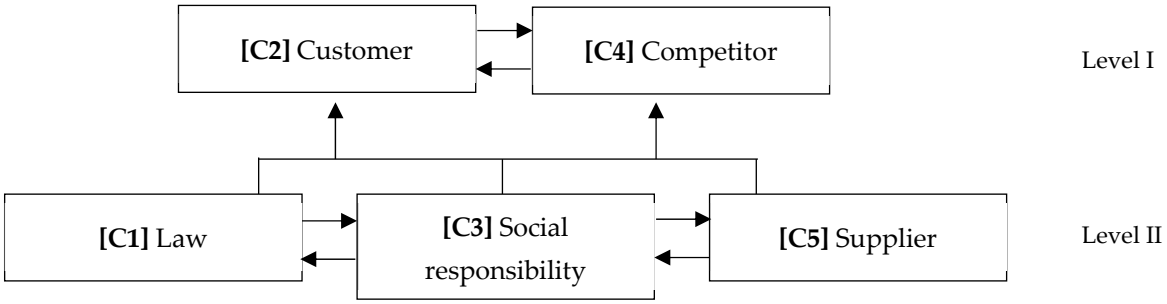

Figure 3. ISM.

Figure 3 represents the ISM factors that are considered barriers to green supply chain initiatives. The five barriers were divided into two levels, with the highest barriers considered the most significant.

5. Discussion

This study identifies five factors that hinder green supply chain initiatives and three factors that are the most important to business owners, executives, or employees in logistics and supply chains, with laws factors, supplier factors, and social responsibility factors displaying the highest mean scores of 4.34, 4.31, and 4.27, respectively. This is consistent with the results of studies by experts in logistics/supply chains and the environment.

The first factor is law. The results of this study are consistent with studies in other developing countries, such as Gawande et al.'s (2014) study of barriers to green supply chain management implementation in India and Niemann et al.'s (2016) study of barriers to green supply chain management adoption in the Mozambican manufacturing industry, which found that a lack of government oversight and strong government law discouraged organizations from adopting GSCM practices [19,22]. Due to the increasing scarcity

of natural resources and concern in the market for "green products and processes", environmental issues have become one of the most important decision-making issues for management in manufacturing organizations. Green business practices are not easy to adopt and implement, as there are many obstacles. Mudgal et al. (2010) studied the trend of green advocacy practices in India and found that the government has not enacted any industry-friendly laws or policies or provided specific benefits to organizations that adopt GSCM practices [44]. This is consistent with Vietnam, which found that government green regulations pose the greatest challenge in implementing green initiatives in supply chain management for the manufacturing industry [45]. In addition, small and medium-sized enterprises (SMEs) found that government regulations and policies were the most significant barriers to adopting GSCM initiatives [20].

Second, although social responsibility is important for sustainable business practices, their implementation in conjunction with supply chain management presents several challenges, including scaling up processes across an organization, increasing costs, and stakeholder complexity [9]. Most organizations focus on short-term profit rather than long-term sustainability. The organization's social responsibility operations are also limited, which affects the implementation of GSCM [5,20,24]. Finally, suppliers must adjust their internal operating models, affecting raw materials or other products. Special production processes and equipment are required to reduce pollution as much as possible, causing production costs to increase. Therefore, suppliers are reluctant to participate in the design process, operation, and technology investments. Research indicates that every supplier was abated by the solitary commitment to initially invest in green technologies [38,46]. The results of this study also echo those of Thumnong and Nalin (2018) in Thailand, where cultural resistance and a focus on short-term profit hindered GSCM adoption. However, this research further elaborates on the interaction between supplier constraints and weak stakeholder engagement, demonstrating the cascading effects of other barriers, such as low consumer demand and minimal competitive pressure. These interdependencies revealed using interpretive modeling (ISM) contribute new insights by structurally linking barriers to their root causes [23]. Suppliers affect the overall efficiency of implementing a green supply chain [33] and reflect the integration of all external departmental issues related to supply chain coordination [21].

In addition, there are two other factors that organizations need to focus on with regard to their customers, who are increasingly environmentally aware, but whose demand for sustainable products may still be limited. Many consumers prioritize cost over sustainability, which may make companies hesitant to invest in green supply chains [27,29], and even if companies do not implement GSCM, consumers will continue to purchase products, which is why businesses do not adopt green practices [41,47]. Customers are unaware of green products, so the low demand identifies the lack of customer awareness about the advantages of implementing GSCM practices [48]. The lack of competitive pressure may make a company feel that it is not necessary to adopt GSCM practices because its competitors are not adopting them. Therefore, such a lack of competitive pressure hinders sustainability innovation [8,24]. Investing in green practices increases the cost, making organizations hesitant to adopt GSCM practices, especially if their competitors are not adopting them as well [7]. According to [49], due to high market uncertainty and competition in international markets, it is very difficult for industries to keep costs low and adopt green practices at the same time. That is why competitors play a very important role in whether or not they adopt green practices [50]. Industries lack green system exposure in both quality and quantity to pursue sustainable goals [48].

While in the UK, a developed country, Walker and Preuss (2008) studied the promotion of sustainability through small business sourcing, where local governments can collaborate

with small businesses in the supply chain to promote products and services, including encouraging businesses to source from local suppliers to improve the local economic situation and sustainably affect national competitiveness.

Therefore, the results of study provide practical implications for the government or relevant agencies in formulating laws or policies to support and promote environmentally friendly business practices. In terms of entrepreneurs, these insights can be used to implement GSCM practices and benefit from supplier and consumer engagement [18]. Although investing in sustainability may increase costs in the short term, the long-term benefits, such as cost savings from resource efficiency and improved reputation, will outweigh the initial costs. These changes could make Thailand a regional leader in sustainability, which will benefit the economy, society, and environment.

6. Conclusions

The three most significant challenges of green supply chain initiatives are law [C1], including weak environmental regulations, weak enforcement, and lack of incentives for compliance; social responsibility [C3], including short-term profit focus and low stakeholder engagement hindering sustainability efforts; and suppliers [C5], whose ability or willingness to adopt green practices is limited due to rising costs and inadequate support, and these three factors have reciprocal effects. There is also a relationship between customers' [C2] limited demand for green products due to low-cost awareness and sensitivity and competitors [C4], with low competitive pressures reducing sustainability investment.

This study suggests that aligning governance frameworks, social responsibility, supplier collaboration, and marketing strategies is essential to overcome barriers to GSCM. Suggested solutions for the context of Thailand, a developing country with many Thai entrepreneurs having low operating costs, include the government and relevant agencies providing financial incentives, such as tax breaks, subsidies, or grants, to companies that adopt GSCM practices, as well as creating laws that promote supplier collaboration and embed sustainability in the business culture. In addition, promoting competitive pressure is an important policy by creating awareness and rewarding businesses that are leaders in GSCM through certification and public recognition. Green procurement policies in government contracts to set market standards will also help encourage businesses that implement sustainability as a competitive advantage.

At the same time, the government and entrepreneurs must work together to create awareness of environmentally friendly products and raise awareness about global warming, such as organizing programs to educate consumers about the benefits of green products and providing discounts or loyalty programs to motivate them to buy green products. In order to set a good policy, further comprehensive research should be conducted on all challenging factors, such as the current laws and regulations that are relevant and those which should be added, as well as suppliers' perspectives on the use of GSCM practices. Future data analysis methods should include in-depth interviews, focus group meetings, and statistical tests with a larger sample. Multiple regression or structural equation modeling (SEM) may be used to obtain the most complete data. When the government and relevant agencies promote both demand and supply, it will create a strong ecosystem for sustainable supply chain practices and increase Thailand's competitiveness at an international level.

7. Study Limitations

This study reveals that the implementation of green supply chains in Thailand is challenging. It concludes the important factors related to green supply chains that hinder their implementation, namely, law, social responsibility, suppliers, customers, and competitors, which are only some of them. These are interesting concepts for other scholars to study. This

study used data from business owners and experts in the logistics and environment sectors in Thailand only. Other perspectives from customers, suppliers, or relevant government agencies, for example, should be studied to make future studies comprehensive and useful for implementing green supply chains in business operations effectively.

In addition, this study used the ISM approach, which required only a small number of respondents. The challenge is that the identified factors may not cover all areas. In the future, the scope of experts should be expanded to cover industry roles to gain more insights and ensure statistical validation with a larger sample, perhaps applying multiple regression or structural equation modeling (SEM), which can draw precise conclusions for the green supply chains of Thailand.

As society and technology are rapidly evolving and changing, barriers to green supply chain initiatives may change over time due to changing regulations, market conditions, and technological advances. The static nature of this study may not be able to fully explain these dynamic changes. Therefore, future studies on barriers to green supply chains should continue and take into account the dynamics of social change and competition in the supply chain, including studying the economic impacts of organizations with and without green supply chains.

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