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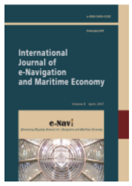

Original article

Structural Analysis of Factors Affecting Implementation of Green Supply Chain in Vietnam using AHP and FSM Methods

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Abstract

The green supply chain has become a central concern for global businesses, particularly in maritime industries, where sustainable development is pursued as both an economic growth strategy and a means of environmental preservation. This study seeks to identify the key challenges to implementing green supply chain in Vietnam. The Analytical Hierarchy Process (AHP) is employed to assess the significance of various factors, while Fuzzy Structural Modeling (FSM) is used to explore their interrelationships. Five major factors - economic, technological, organizational, governmental, and social - are identified as critical to the implementation of green supply chain. The study highlights that the organizational factor is the most crucial, with customer pressure, particularly regarding environmental standards from export countries, being the most influential sub-factor. The findings provide important insights for developing government policies, offering support to businesses, and guiding investment decisions in green supply chain.

Keywords: Green supply chain, Vietnam, FSM, AHP, Organizational factor, Customer pressure.

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1. Introduction

In recent years, the concept of the green supply chain has gained increasing significance as businesses worldwide seek to integrate environmental considerations into their operations. This shift is driven by growing global awareness of environmental sustainability and the need for companies to adopt practices that minimize ecological impact while maintaining economic viability (Srivastava, 2007). In Vietnam, a country experiencing rapid industrialization and economic growth, the implementation of green supply chain is particularly crucial. Over recent years, GSCM adoption in Vietnam has gained momentum as the country aligns itself with global sustainability trends. This progress is motivated by rising environmental awareness, regulatory pressures, and the growing importance of sustainable practices in international trade. Vietnam's commitment to sustainable development has led to the integration of green practices within various supply chain, particularly in key sectors like manufacturing, textiles, and agriculture (Li and Qamruzzaman, 2023). The government has enacted several policies to encourage businesses to adopt greener practices, such as the Law on Environmental Protection 2020, which mandates stricter environmental standards across industries. Additionally, international trade agreements, such as the European Union-Vietnam Free Trade Agreement (EVFTA), have heightened the need for compliance with environmental standards, pushing companies to adopt GSCM to remain competitive in the global market (Eurocham, 2024). As Vietnam continues to expand its role in the global market, there is an increasing need to align its supply chain practices with international environmental standards to maintain competitiveness and ensure long-term sustainability (Nguyen & Smith, 2020). However, the adoption of GSCM in Vietnam is not without challenges since many small and medium-sized enterprises (SMEs) face difficulties in implementing green practices due to limited financial resources, lack of expertise, and insufficient technological infrastructure (Chen et al., 2023). Moreover, while the regulatory framework is evolving, enforcement remains inconsistent, leading to variations in the adoption of GSCM across different regions and industries .

The necessity for research into green supply chain implementation in Vietnam stems from the complex interplay of factors influencing this process. While the benefits of green supply chain are widely recognized, the challenges associated with their implementation - such as economic constraints, technological limitations, organizational readiness, government regulations, and social pressures - are less understood, particularly in the context of a developing economy like Vietnam. This research is therefore essential to identify, analyze, and prioritize these factors, providing valuable insights for both policymakers and businesses.

The primary purpose of this study is to conduct a structural analysis of the factors affecting the implementation of green supply chain in Vietnam. To achieve this, the research employs two advanced analytical methods: the Analytical Hierarchy Process (AHP) and Fuzzy Structural Modeling (FSM). AHP is utilized to measure and analyze the priorities among the identified factors, enabling a systematic evaluation of their relative importance. FSM, on the other hand, is used to simulate the relationships among these factors within a complex system, revealing how they interact and influence each other. Together, these methodologies provide a comprehensive framework for understanding the dynamics of green supply chain implementation in Vietnam.

The structure of this paper is as follows: The next section reviews the relevant literature on green supply chain management, with a focus on factors influencing its implementation in developing countries, particularly Vietnam. Following the literature review, the methodology section details the application of AHP and FSM, explaining how these methods are employed in the study. The results section presents the findings, highlighting the most critical factors and their interrelationships. Finally, the discussion and conclusion sections explore the implications of these findings for policymakers and businesses in Vietnam, offering recommendations for enhancing green supply chain practices.

By addressing the factors that influence green supply chain implementation, this research contributes to the growing body of knowledge on sustainable supply chain management in developing economies and offers practical guidance for businesses and policymakers seeking to improve environmental practices in Vietnam.

2. Literature Review

Numerous research articles have been published that focus on the empirical examination of factors affecting the implementation of the green supply chain. The factors that influence the green supply chain differ from one nation to another (Rusli et al, 2012). Moreover, they transform gradually due to advancements in technology and shifts in policies. Nevertheless, the most of existing research indicates that the five following macroeconomic (categorized into Organizational, Social, Technology, Government, and Economic factor) and twelve criteria determinants play a significant role in determining the implementation of the green supply chain. A summary of these key factors and their criteria is illustrated in the figure below.

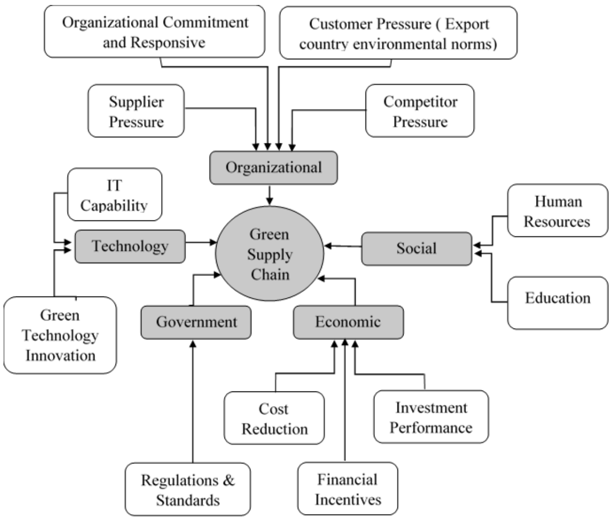

Figure 1: Key factors affecting Green supply chain

2.1 Factors affecting the implementation of the green supply chain

Economic factor refers to the influence of economic conditions or trends on adopting of green supply chain. Economic factor encompasses various aspects of economic activity and performance including production, consumption, investment, employment and monetary policy. Rao and Holt (2005) demonstrated a positive link between green practices in the supply chain and economic performance, noting that green logistics activities enhance competitiveness and economic health. Similarly, Khan and Qianli (2017) discovered that economic health is well connected with green logistics operations while green packaging management under the supply chain process is helpful to geared sound economic health for both companies and the whole country. Myers et al. (2007) posited that a thorough analysis of the political economy landscape enables significant tariff savings and as well as market opportunities which is essential to evaluate political risk, social risk and market risk and minimize their effects through awareness of their impact and cost in global supply chain. Numerous studies have been conducted on the circular economy including Bastein et al. (2013), MacArthur (2013), Genovese et al. (2017) which shows that circular economics represents a competitive sustainable strategy to foster economic growth without resource challenges through environmental conservation, energy efficiency and cost-effective waste management.

The technology factor refers to the impact of technology on various aspects of society, economy and industry. It encompasses the development, adoption and utilization of technological innovations and systems to improve efficiency, productivity and outcomes across different domains. Mudgal et al. (2010) discovered that industries need to develop and update themselves on new trends and technologies when adopting a green supply chain. According to a study by Shi and Gregory (1998), advancements in communication and transportation technologies enable multinational corporations to streamline their global operations with greater effectiveness and efficiency. The research presented by Thun (2010) suggested that the more integrated the flow of information between customers and suppliers, the easier it becomes to balance supply and demand in a global chain. A study conducted by Frohlich and Westbrook (2001) suggested that the introduction of new technology simplifies and reduces the cost of collaboration allowing companies to integrate different aspects of their operations more quickly and work together more closely than they could in the past.

Organizational factor refers to elements within a company or institution that influence its functioning, behavior, and performance. These factors can include various aspects such as commitment and responsiveness, culture, policies, and procedures, communication channels, decision-making processes, and the overall environment within the organization. Robinson and Malhotra (2005) suggested that perceived organizational culture is key to a sustainable competitive advantage in green supply chain. The empirical analysis of Kamolkittiwong and Phruksaphanrat (2015) revealed that many firms had to adapt their organizational strategy, specifically green strategy to enhance their brand image because of customers' green purchasing needs. When considering the impact of green strategy, the empirical analysis of Olson (2008) and Head (2014), and Insch (2011) revealed that formulating green strategies in an organization complements the success of an organization, enhances its operations, minimize on the environment and towards sustainable development.

Government factor refers to the influence that government policies, regulations or interventions have on a specific industry, sector or business activity. In the context of research or analysis, the term "government factor" is often used to describe the role of government and the policies, regulations or measures that government entities enact to affect a particular business sector or enterprise. Meng et al. (2021) found that government subsidies could reduce green product’s prices and increase benefits to the manufacturer. Sun and Li (2021) established that government’s participation could promote the green behavior of logistics businesses. Kausar et al. (2017) have explored that “Government policies and support” are examined as foremost enablers in adopting a sustainable supply chain. Mudgal et al. (2009), and Mudgal et al. (2010) claimed that the support of the government plays a key role in providing subsidies for processes and encouraging employees to implement strategic supply chain management in their organizations because it sets the regulatory laws every Indian organization. The legislative authority gives support in fulfilling monitory requirements to provide education and training to manpower about sustainable development. People are gaining more interest in environmental issues because of government support (Balasubramanian, 2012).

Social factor refers to the various aspects of human society and interaction that influence individual behavior, attitudes and lifestyles. These factors encompass a wide range of dimensions including cultural norms, social structures, education and human resource. Social factor can have significant effects on people's choices, preferences and actions in life. Drumwright (1994) expored that the public is increasingly influenced by a company’s reputation with respect to the environment when making purchasing decisions. With respect to the research studying on the effect of society to implementation of green supply chain, Beamon (1999), Delmas (2001), Sharma and Vredenburg (1998) supported the idea that public pressure and stakeholders are causing firms to review their environmental supply practices.

The study of sub-factors that have been researched by key articles is summarized in the following table:

Table 1: Summary of sub-factors

No	Factors	Description	Authors
I	**Economic**		
1	Financial Incentives	The use of monetary rewards or incentives to motivate certain actions or outcome	Montabon et al. (2007),Dauvergne et al. (2018)
2	Investment performance	The measurement and evaluation of the effectiveness of investment	Duong et al (2020), Zhu et al. (2005)
3	Cost reduction	Any strategies that contributes to lowering the expenses in operation	Zhu et al. (2012), Vanalle et al (2017)
II	**Technology**		
4	IT capability	The capacity to leverage IT effectively to enhance operational and gain competitive advantage	Rai et al. (2006), Fawcett et al. (2007)
5	Green technology innovation	The development and implementation of innovative technologies that promote environmental sustainability	Abdullah et al. (2016), Rennings et al. (2006)
III	**Organizational**		

6	Customer pressure	It encompasses the various expectations and requirements made by customers	Luthra et al. (2015), Jayaram and Avittathur (2015)
7	Organizational commitment and responsive	It pertains to employee's dedication to organization and the organization's ability to respond effectively to its external environment	Van Hoek (1999), Cai et al. (2016)
8	Competitor pressure	It encompasses strategies of competing businesses that impact the operations of a company	Huang et al. (2009), Shubham and Murty (2018)
9	Supplier pressure	It encompasses expectations or imposed by suppliers regarding the provision of resources necessary for the operation of business	Zhu and Xu (2019), Lee et al. (2018)
IV	**Government**		
10	Regulations & Standards	The legal and regulatory framework governing business operations and practices within a particular industry	Diabat and Govindan (2011), Bhool and Narwal (2013)
V	**Social**		
11	Education	It plays a crucial role in shaping knowledge, skills and behaviors	Agi and Nishant (2017), Zhang et al. (2020)
12	Human resources	Individuals who make up the workforce of an organization and the strategies used to manage them effectively	Pham and Pham (2017), Gahlot et al (2023)

2.2 Research gap

The research gap highlighted in the statement underscores several critical areas that have not been adequately addressed in existing literature. Previous studies have identified various motivators for green supply chain initiatives; however, these investigations tend to be narrowly focused on specific industries or individual company perspectives, rather than considering the broader framework of sustainable development. This limitation is further compounded by the lack of comprehensive research in Vietnam that systematically organizes these motivators, measures their relative importance and explores their cause-and-effect relationships. The identified gaps in the literature suggest a need to conduct research that goes beyond mere identification of factors and delves deeper into their interconnections and significance. By systematizing and evaluating these critical factors affecting green supply chain, researchers can provide valuable insights into how sustainable practices can be effectively implemented and sustained within the Vietnamese context. Furthermore, the implications of addressing these research gaps extend to the development of a process model for green supply chain advancement. This model would encompass a holistic view, incorporating Economic, Technology, Organizational, governmental and Social factor. Such an integrated approach is essential for developing robust strategies that promote sustainable development while aligning with the unique socio-economic and regulatory landscape of Vietnam. In summary, bridging these research gaps is crucial not only for advancing academic knowledge but also for informing practical strategies that can drive meaningful progress towards green supply chain initiatives in Vietnam. The proposed research aims to contribute by filling these gaps, providing a comprehensive understanding of critical factors and developing actionable frameworks to guide sustainable supply chain development in the region.

3. Methodology

This study explores the relationship between Economic, Government, Social, Organizational, and Technology factor and the implementation of green supply chain in Vietnam. To ensure intuitive and reliable results, we use a combination of the Analytic Hierarchy Process (AHP) and Fuzzy Structural Modeling (FSM) to evaluate the priorities among these factors. In this section, we will explain why we chose the two methods AHP and FSM, and describe the steps of their implementation. The process of selecting experts for the survey and the subsequent data collection are detailed in the following section.

3.1 Introductions of method used

The method integrates the AHP and FSM to assess factors influencing the green supply chain. AHP, pioneered by Thomas Saaty in the 1970s, employs pairwise comparisons to prioritize decision factors, offering a structured approach to evaluate and rank criteria. Conversely, FSM utilizes fuzzy set theory and interpretive structural modeling to model relationships among variables, accommodating uncertainty through a fuzzing function in its matrices (Tazaki & Amagasa, 1979). This combination allows researchers to not only evaluate preferences but also quantify uncertainty in relationships, enhancing the depth and comprehensiveness of the analysis of influencing factors in green supply chain research. Managers and administrators can leverage these findings to formulate effective strategies, policies, and plans for developing green supply chain.

This study utilizes AHP to determine the weight of the factors under consideration. A pair-wise comparison matrix is used to establish the relative significance of the elements. Table 2 presents the importance scale that respondents referred to when evaluating the preference between factors. Respondents were asked, "To what extent do you believe factor A is more important than factor B?" Based on the survey responses, an importance matrix was constructed. The interaction between row i and column j in the matrix reflects how much more or less important factor i is compared to factor j. The preference scale ranges from 1 to 9, with higher values indicating a greater relative importance of i over j.

Table 2: Measure of the importance of factors

Level of importance	Definition
1	Equal importance
3	Somewhat more important
5	More important
7	Very much more important
9	Absolutely more important
2, 4, 6, 8	Intermediate values

Additionally, the AHP matrix must adhere to the principles of reciprocity, homogeneity, and transitivity. To determine the importance of each element, individual responses were aggregated into a single response value using the geometric mean, after which the importance was calculated. The consistency of these responses was then evaluated using the following equations.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3.1)$$

$$CR = \frac{CI}{RI} \quad (3.2)$$

CR: Consistency Ratio

CI: Consistency Index

RI: Random Consistency Index

The consistency ratio value $CR < 0.1$ is acceptable.

The primary objective of the FSM method is to provide a formal hierarchical procedure by creating a graphical representation of the system. Based on fuzzy set theory, FSM is more effective than Interpretive Structural Modeling (ISM) for problems without clear boundaries, as it allows the subordination degree to range between 0 and 1. Respondents were asked, "To what extent do you believe Factor A influences Factor B?" The resulting subordination matrix, formed from these fuzzy values, must adhere to the principles of irreflexivity, asymmetry, and transitivity. To determine which elements belong to specific layers in the hierarchy and to assess the degree of relationships among elements, the threshold value p and the fuzzy structure parameter λ are established. The Top level set $L_t(s)$, Intermediate level set $L_i(s)$, Bottom level set $L_b(s)$ and Isolation Level set is $L_{is}(s)$ are then identified using the following equations.

$$L_t(s) = \{S_k \setminus \ \vee_{j=1}^{n} a_{kj} < P \leq \vee_{i=1}^{n} a_{ik}\} \qquad (3.3)$$

$$L_i(s) = \{S_k \setminus P < \ \vee_{j=1}^{n} a_{kj},\ P \leq \vee_{i=1}^{n} a_{ik}\} \qquad (3.4)$$

$$L_b(s) = \{S_k \setminus \ \vee_{j=1}^{n} a_{ik} < P \leq \vee_{i=1}^{n} a_{kj}\} \qquad (3.5)$$

$$L_{is}(s) = \{S_k \setminus \ \vee_{j=1}^{n} a_{kj} < P,\ \vee_{i=1}^{n} a_{ik} < P\} \qquad (3.6)$$

The computation of the Independence Degree involves determining the degree of relation between each pair of factors using the equation (3.7):

$$[a\bullet_j^*] = [a\bullet_j] \wedge [\overline{a\bullet_{i1}}] \wedge \ldots \wedge [\overline{a\cdot_{\epsilon'}}] \qquad (3.7)$$

$$\overline{\mu_A} = \frac{1-\mu_A}{1+\lambda\mu_A} \qquad (3.8)$$

[ ]: *Column vector*

μ_A: *Subordinate degree*

$[a\cdot_j^*]$: *Revised vector of* $[a\cdot_j]$

$\overline{\mu_A}$: *Transpose subordinate degree*

$[a\cdot_j]$: *A vector that has others subordinate to it*

$[\overline{a\cdot_{i1}}]$: *Subordinate vector/ Transpose vector*

Below is a diagram depicting the sequential processes that executed in AHP & FSM:

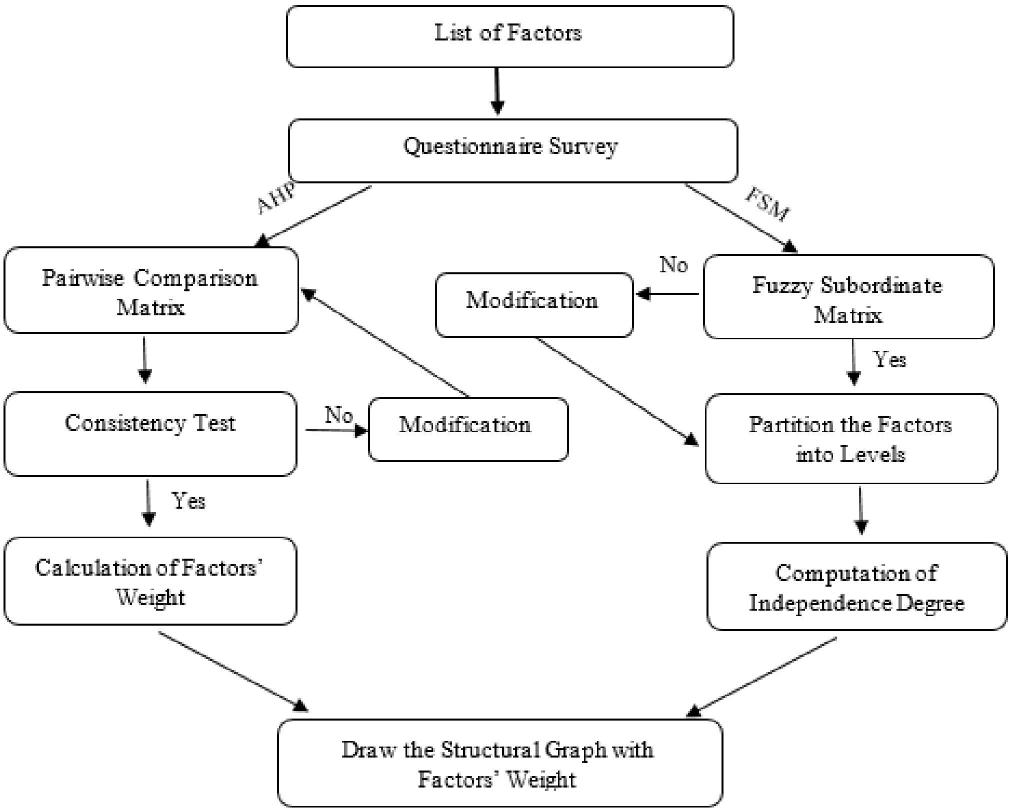

Figure 2: Methodology Flowchart

3.2 Selection of experts

Mohammad and Hairunnizam (2022) emphasize the importance of selecting survey participants with expertise and deep understanding of the researched problem to ensure rational and accurate judgments. Researchers should assess the knowledge and expertise of participants based on their high-quality publications. Participants must be willing and familiar with using AHP/FSM methods in decision-making processes, as these concepts can be challenging for those unfamiliar with them.

Enthusiasm and willingness of participants are vital for accurate and reflective responses. The number of experts needed for AHP and FSM methods varies; while Calik (2021) suggests a minimum of three experts for consistency, Shafi Salimi and Edalatpanah argue that too many experts can cause confusion and increased costs. Karczmarek et al. (2021) recommend more experts for greater accuracy but acknowledge the challenges of synthesizing numerous evaluations.

The authors use a rigorous screening process to identify experts with practical knowledge of green supply chain. Although some studies suggest 10 experts, the complexity and diversity of the topic may require more to avoid insufficient data. The number of experts also depends on the diversity and consensus of opinions. The study will continue gathering data until sufficient consensus is achieved. The authors employ surveys, personal interviews, and group workshops for expert selection. The results of the expert selection process are presented in the table below:

Table 3: Selection of experts for questionnaire survey

	Experts	Description
1	Experts from Logistics sectors	Those who make decisions to implement Green supply chain for their Logistics activities and have an understanding of AHP & FSM
2	Experts from Ports	Those who make decisions to implement Green supply chain for their port operation and have an understanding of AHP & FSM
3	Experts from Manufacturing companies	Those who make decisions to implement Green supply chain or directly participate in the process of implementing GSC into business operations
4	Researchers & Academics	Those who are members of Vietnam Logistics Business Association, researching Green supply chain and factors affecting its implementation & utilizing AHP - FSM in their research

During the survey process and after receiving feedback from experts, we identified the following four groups: experts from the Logistics sectors, experts from Ports, experts from Manufacturing companies, researchers & academics. These experts all have diverse knowledge regarding the practical application of GSC.

This study surveyed 45 experts from various sectors in Vietnam: 15 from logistics, 15 from manufacturing, 10 from ports, and 5 researchers/academics. All participants were required to complete questionnaires for both AHP and FSM methods; they have at least 5 years of practical experience, with 84.4% having 5-10 years and the rest over 10 years, ensuring high-quality and accurate data. A limitation of the study is the inability to survey policymakers.

Based on the professional experience of the experts, to serve the purpose of calculation, we divide the significance attributed to their opinions as shown in the table below:

Table 4: Weight of Expert's Idea

Working Seniority	<5 years	5-10 years	>10 years
Weight	1	2	3

Among the four expert groups surveyed, those from logistics and manufacturing provided the highest number of responses. These experts hold diverse positions across various fields in Vietnam, influencing decisions on implementing green supply chain. After receiving 45 responses, a pilot study was conducted to evaluate their quality and consistency. This small-scale pretest revealed two inconsistent responses, which were clarified through direct consultation with the respective experts, maintaining the total number of responses at 45. This rigorous evaluation ensures objectivity and accuracy, reflecting the experts' viewpoints. However, the inability to access policymakers' opinions remains a minor limitation.

3.3 Data collection

The choice of method depends on the research model, the complexity of the decision-making process, and the data's nature and connectivity. Common data collection techniques include surveys, group discussions, and interviews. Interviews, conducted face-to-face or online, involve presenting experts with questions and recording their responses, suitable for gathering qualitative information from a few knowledgeable individuals (Peng et al., 2021). Workshops and group meetings are also employed to observe consensus or dissent among experts, consolidating diverse perspectives. Surveys involve creating and distributing questionnaires for experts to express their preferences regarding criteria and choices (Mohammad and Hairunnizam, 2021).

The two tables below display the instructional information given to experts concerning how to clarify the pairwise comparison process of AHP method and how to compare the impact of one factor on the remaining factors of FSM method.

Table 5: Explaination of pair-wise comparision in questionare survey of AHP

Compare 2 items	Item	Important scale	Item
A is absolutely more important than B	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
A is strongly more important than B	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
A is fairly more important than B	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
A is weakly more important than B	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
The importance of A and B is the same	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
B is weakly more important than A	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
B is fairly more important than A	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
B is strongly more important than A	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B
B is absolutely more important than A	A	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	B

Table 6: Comparing the impact of one factor on the others factors (FSM method)

Factors	Decision for implementation of GSC	Social	Government	Technology	Organizational
	1.0	1.0	1.0	1.0	1.0
	0,9	0,9	0,9	0,9	0,9
	0,8	0,8	0,8	0,8	0,8
	0,7	0,7	0,7	0,7	0,7
	0,6	0,6	0,6	0,6	0,6
Economic	0,5	0,5	0,5	0,5	0,5
	0,4	0,4	0,4	0,4	0,4
	0,3	0,3	0,3	0,3	0,3
	0,2	0,2	0,2	0,2	0,2
	0,1	0,1	0,1	0,1	0,1
	0	0	0	0	0

Question: Determine how "Economic" affects the remaining five factors and circle the appropriate scale

4. Results and discussion

In the course of this research, we undertake the meticulous calculation of data and the analysis of various factors impacting GSC, disseminating these insights across multiple tables.

This study surveyed 45 experts from various sectors in Vietnam: 15 from logistics, 15 from manufacturing, 10 from ports, and 5 researchers/academics. All participants were required to complete questionnaires for both AHP and FSM methods; they have at least 5 years of practical experience, with 84.4% having 5-10 years and the rest over 10 years, ensuring high-quality and accurate data.

Table 7: Demographic characteristics of respondents

Characteristics	Details	Number of respondents	Percentage of respondents
Response rate	Questionnaire Survey	35	100 %
	Interview	10	100 %
Affiliations	Experts from logistics sectors	15	33,3 %
	Experts from ports	10	22,2 %
	Experts from manufacturing companies	15	33,3 %
	Researchers & Academics	5	11,1%
Working seniority	Less than 5 years	0	_
	5-10 years	38	84,4%
	More than 10 years	7	15,6 %

With the provided data from experts, we have calculated the influence of each factors to the green supply chain implementation using both AHP and FSM method.

4.1. AHP

4.1.1 Calculating the weight of factors

To evaluate the importance of factors enabling the implementation of green supply chain, the weights of five factors were determined. Respondents were given questionnaires of pairwise comparison of criteria. The expert's opinions were synthesized, and the weighted average method was employed based on their expertise to derive the weight of each factor.

Table 8: Weighted matrix

	Organizational	Government	Economic	Social	Technology
Organizational	1.00	4.23	3.68	3.91	7.53
Government	0.24	1.00	2.98	3.13	5.36
Economic	0.27	0.34	1.00	1.51	4.39
Social	0.26	0.32	0.66	1.00	3.52
Technology	0.13	0.19	0.23	0.28	1.00
Sum	1.90	6.07	8.55	9.83	21.80

This data table serves as the basis for calculating the importance of each factor influencing GSC implementation. However, relying solely on this data table is insufficient for evaluation. The next step involves normalization, which scales the weighted matrix to a uniform range for analysis.

4.1.2 Normalized weight of factors

Table 9: Normalized weight of factors

	Organizational	Government	Economic	Social	Technology	Average
Organizational	0.53	0.70	0.43	0.40	0.35	0.48
Government	0.12	0.16	0.35	0.32	0.25	0.24
Economic	0.14	0.06	0.12	0.15	0.20	0.13
Social	0.13	0.05	0.08	0.10	0.16	0.11
Technology	0.07	0.03	0.03	0.03	0.05	0.04

According to the findings, the Organizational factor occupies the highest priority. However, the Government factor still maintains the second most influential position, indicating the role of government policies and regulations in regulating green supply chain implementation. The Economic and Social factor have nearly equivalent levels of influence, ranking third and fourth respectively. Finally, Technology has the lowest impact among the five factors.

4.1.3. Consistency test

To ensure the reliability of these results, a consistency test was conducted:

Table 10: Consistency test

	Organizational	Government	Economic	Social	Techology	Weighted Sum	Priority	WS/P
Organizational	0.48	1.02	0.49	0.41	0.30	2.71	0.4795	5.6463
Government	0.11	0.24	0.40	0.33	0.22	1.30	0.2404	5.4100
Economic	0.13	0.08	0.13	0.16	0.18	0.68	0.1341	5.0864
Social	0.12	0.08	0.09	0.11	0.14	0.54	0.1056	5.0765
Techology	0.06	0.04	0.03	0.03	0.04	0.21	0.0404	5.1819
Total								**26.04**

$$CI=\frac{\lambda\max - n}{n-1} =0.07006$$

$$CR=\frac{CI}{RI}\ 0.062554\ (<0.1)$$

Based on the calculated consistency ratio, a value below 0.1 indicates that the experts' comparisons are consistent and adhere to the principles of the Analytical Hierarchy Process (AHP) method. This validation enhances the reliability of decisions made using AHP analysis. The same methodology was applied to calculate weights for sub-criteria, enabling the determination of global weights by multiplying the local weights of subfactors by their corresponding factor weights.

Table 11: Local and global weight of factors

Main Factor	Factor's weight	Sub-factors	Local weight	Global weight	Global ranks
Organizational	0.48	Customer pressure (export country environmental norms)	0.53	0.2541	1
		Organizational commitment and responsive	0.23	0.1103	3
		Competitor pressure	0.19	0.0911	4
		Supplier pressure	0.05	0.0240	10
Government	0.24	Regulations & Standards	-	0.2404	2
Economic	0.13	Financial Incentives	0.67	0.0898	5
		Investment performance	0.12	0.0161	11
		Cost reduction	0.21	0.0282	9
Social	0.11	Education	0.37	0.0391	7
		Human resource	0.63	0.0665	6
Technology	0.04	IT capability	0.28	0.0113	12
		Green technology innovation	0.72	0.0291	8

4.2. FSM

Upon obtaining feedback from experts, it is imperative to verify whether the opinions meet all three conditions outlined in the Methodology section. Subsequently, after a thorough examination of the data, the revised Fuzzy Matrix table has been compiled as follows.

Table 12: Revised Fuzzy Matrix (A)

	Decision for Implementation of GSC	Organizational	Government	Economic	Social	Technology
Decision for Implementation of GSC	0	0	0	0	0	0
Organizational	0.93	0	0.82	0.78	0.22	0.14
Government	0.87	0.34	0	0.76	0.37	0.28
Economic	0.76	0.01	0.38	0	0.1	0.11
Social	0.7	0.2	0.16	0.23	0	0.05
Technology	0.8	0.07	0.32	0.16	0.08	0

In conventional research studies, the threshold commonly utilized is a significance level of P = 0.5. In alignment with this standard practice, this threshold is similarly applied in the present study. With P = 0.5, the classification results for Top, Bottom, and Intermediate levels are obtained as follows..

Table 13: Relation of success factors

A1

Decision for Implementation of GSC	Lt					
Organizational		Lb				
Government			Li			
Economic				Li		
Social					Lb	
Technology						Lb

For analyzing the relationships between elements, the most suitable threshold value was determined as 0.50, while the parameter value λ, governing the influence degree among factors, was set to 0.5.

Upon categorizing the factors, a specific computation is employed to evaluatethe influence one factor exerts over others. Utilizing this algorithm, we eliminate rows containing factors in the top-level set and columns containing factors in the bottom-level set, thereby discerning the degree of subordination. The resulting revised matrix is as follows.

A2

	Decision for Implementation of GSM	Government	Economic
Organizational	0.93	0.82	0.78
Government	0.87	0	0.76
Economic	0.76	0.38	0
Social	0.7	0.16	0.23
Tech	0.8	0.32	0.16

After categorizing the levels of factors as described above and revising the matrix, the elimination process outlined in the Methodology section is applied to ascertain the relationships between the levels, as depicted in the following table.

A3

	Government	Economic
Organizational	0.82	0.78
Government	0	0.76

Based on these results, it can be concluded that Technology, Economic and Social Factor directly influence GSC implementation. Meanwhile, the Economic factor is influenced by the Government which is influenced by the Organizational.

Structure graph for A2 and A3

The depicted figure presents the ultimate structural graph delineating the chosen factors exerting influence on green supply chain, accompanied by their respective weights. Notably, it becomes apparent that Technology, Economic, and Social factor wield significant direct influence, notably propelling the overarching objective of "Implementation of green supply chain in Vietnam" These factors are further identified as primary drivers behind the implementation of GSC. Moreover, the Government factor is observed to exert direct impact on Economic considerations.

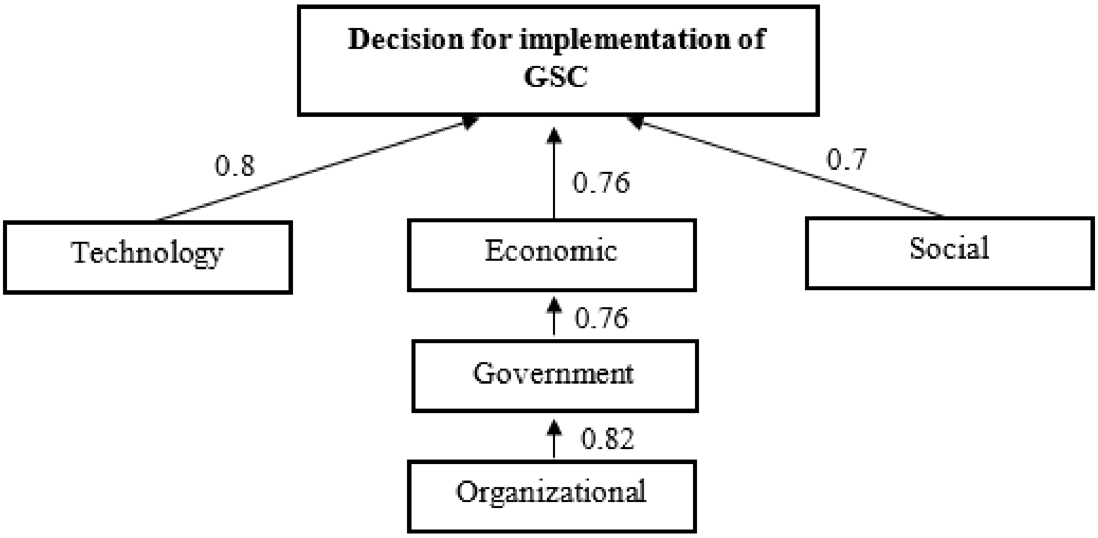

Figure 3: Implementation of GSC in Vietnam structure graph

The computation of influence levels and causal relationships among sub-factors has been executed in a similar manner. Presented below are the graphs depicting the outcomes of these analyses.

4.2.1 Economic

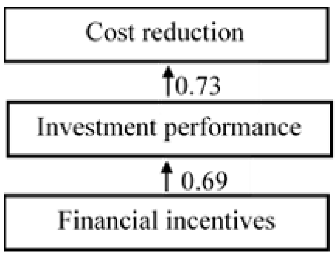

Figure 4: Economic structure graph

Financial incentives like tax credits, subsidies, and grants motivate businesses to invest in green technologies and sustainable practices in their supply chain. These incentives promote actions like sourcing from certified suppliers or implementing recycling programs, boosting brand reputation, customer loyalty, market share, and revenue. Moreover, green investments often lead to long-term cost savings by cutting energy use, waste, and resource consumption.

4.2.2 Social

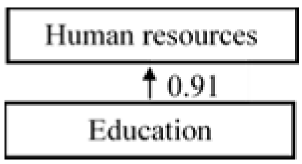

Figure 5: Social structure graph

Education plays a crucial role in shaping investment performance and directly impacts human resources. By teaching sustainability principles, environmental regulations, and green supply chain practices, along with offering training sessions and workshops, organizations equip employees with the skills needed to implement and manage green initiatives. Investing in education and fostering a culture of environmental responsibility helps companies enhance human resources, drive innovation, and achieve sustainable growth in line with their business goals.

4.2.3 Technology

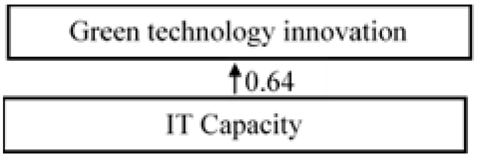

Figure 6: Social structure graph

IT capabilities facilitate seamless collaboration and knowledge sharing among stakeholders in green technology innovation within the supply chain. They play a vital role in driving innovation and shaping the technological landscape in green supply chain. By utilizing data analytics, simulation tools, collaboration platforms, IT integration, and automation, companies can speed up sustainable practices, minimize environmental impact, and gain a competitive edge in an increasingly eco-conscious market.

4.2.4 Organizational

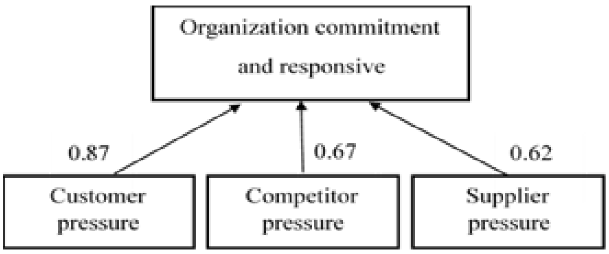

Figure 7: Social structure graph

As customers increasingly demand eco-friendly products, companies are driven to adopt green supply chain practices to meet expectations and maintain or enhance their market position. Pressure from suppliers and competitors also pushes businesses to invest in sustainable initiatives. By responding to these external forces, companies can strengthen relationships with customers and suppliers, enhance competitiveness, and position themselves as sustainability leaders. Integrating environmental factors into supply chain strategies leads to lasting benefits, such as cost savings, improved brand perception, and new market opportunities.

5. Conclusion

The international business community prioritizes green supply chain to minimize environmental impacts and optimize sustainability. Vietnam, a rapidly developing country and major exporter, recognizes the importance of this green transition. The shift from a “brown” to a “green” economy in Vietnam focuses on circular conversion, energy transition, low carbon emissions, and green growth, aiming to achieve Net Zero by 2050. However, with over 96% of domestic enterprises being small and medium-sized and facing numerous constraints, this transition poses significant challenges.

During interviews, businesses expressed uncertainty about specific plans for green transformation despite government emphasis on it. They recognize the need to “green” their production due to high demand and stringent requirements from importing countries. Identifying factors hindering the implementation of green supply chain is crucial. This research aims to provide businesses with insights on where to invest and how to proceed, helping them formulate strategies and plans.

After conducting detailed literature reviews and working with experts, we received a total of 45 responses from experts working in various fields, with experience ranging from 5 years or more. Using the Analytic Hierarchy Process (AHP) method, the study identified five main factors and twelve sub-factors influencing the application of green supply chain in Vietnam. Organizational factor emerged as the most significant, with Customer pressure (export country environmental norms) being the most crucial sub-factor. The order of importance for the main factors is Organizational, Government, Economic, Social, and Technology.

FSM analysis revealed that Technology, Economic, and Social factor directly impact and drive the implementation of green supply chain. The

Organizational factor significantly influences the Government factor, which in turn affects the Economic factor, indicating a cohesive direction for implementing green supply chain in Vietnam.

5.1 Proposed solution

The primary enabler for implementing green supply chain in Vietnam is Organizational factor, driven by Customer pressure (export country environmental norms), competitor pressure, and supplier pressure. These pressures collectively influence Organizational commitment and responsiveness, crucial for meeting green manufacturing standards, especially given Vietnam's participation in numerous free trade agreements (FTAs) with strict environmental regulations, such as the European Green Deal. Adopting green supply chain not only aligns with global market demands but also enhances international competitiveness. To manage a green supply chain effectively, businesses should adopt sustainable practices and prioritize the Environment-Social-Governance (ESG) framework. The Corporate Sustainability Index (CSI), introduced by VCCI in 2016, offers a structured approach for sustainable management tailored to Vietnamese businesses.

Government policies play a pivotal role in supporting business's transition to green supply chain. Deputy Prime Minister Tran Hong Ha emphasizes the government's commitment to long-term green transformation, which includes facilitating regulations, research support, and a national action plan on circular economy development. Proposed initiatives include tax incentives for circular economy products, funding for technology adoption to reduce carbon emissions, and standards for green projects and products. Local initiatives in Hai Phong demonstrate proactive steps towards green growth, with investments in key sectors like economic zones, ports, logistics, industry, technology, tourism, and trade. Policy recommendations focus on refining financial policies, issuing green standards, and improving planning and investment frameworks to support green initiatives.

In terms of workforce development, Vietnam is enhancing training programs for green supply chain management at universities, vocational institutions, and industry-related organizations. Adjusting curricula, offering short-term training courses, and implementing practical initiatives cater to diverse roles from technical personnel to management levels. Academic institutions like the Mekong-Japan Logistics Training Center and Logistics Center of Vietnam Maritime University is providing specialized programs and certifications, preparing professionals for the evolving demands of green supply chain. Combining organizational commitment with supportive government policies is essential for Vietnam's successful adoption of green supply chain, aligning economic growth with sustainable development goals.

5.2 Limitation of work

Due to limited research time, engagement with all relevant government officials, especially policymakers, was not fully achieved, potentially leading to gaps in policy coverage across industries and regions. Thus, this research serves as a foundation for future in-depth studies and expansion.

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