JIP
Jurnal Ilmiah PLATAX
Universitas Sam Ratulangi
Terakreditasi Ristekdikti No: 28/E/KPT/2019
ISSN : 2302-3589 (Online)
E_mail : jip_platax@unsrat.ac.id

Sustainable Supply Chain Strategies to Enhance the Global Competitiveness of Clove Commodities in North Sulawesi

Indrie Debbie Palandeng[1]*, Maria V. J. Tielung[1], Shinta Jeanette C. Wangke [1], Johan Reineer Tumiwa [1,2].

[1] *Department of Management, Faculty of Economics and Business, Sam Ratulangi University – Indonesia*
[1,2] *Institute of Economics, Faculty of Economics and Business, University of Debrecen – Hungary*
**Corresponding author:* indriedebbie76@unsrat.ac.id

Manuscript received: 19 Dec. 2025. Revision accepted: 3 Apr. 2026

Abstract. This study develops an integrated sustainable supply chain strategy to strengthen the global competitiveness of clove commodities in North Sulawesi. The research employs a qualitative descriptive approach involving farmers, collectors, exporters, and government institutions to examine supply chain conditions, identify internal and external strategic factors, and formulate actions required to improve long-term competitiveness. Using SWOT, IFAS–EFAS, and TOWS analysis, the study reveals that intrinsic product quality, traditional knowledge, and strong social networks form the core strengths of the upstream actors, while major weaknesses include aging trees, inconsistent post-harvest quality, limited logistics infrastructure, and restricted market access. Externally, the clove sector has strong opportunities through premium global markets, digital supply chain transformation, certification potential, and product diversification; yet it faces significant threats such as international competition, price volatility, climate risks, and non-tariff trade barriers. The formulated strategies emphasize modernization of cultivation and post-harvest practices, digital traceability systems, structured replanting programs, cooperative-based distribution models, certification clusters, and the development of value-added derivative products. The study contributes a strategic roadmap that integrates sustainability, digitalization, and institutional collaboration to enhance supply chain efficiency, stabilize farmer welfare, and elevate the global market position of North Sulawesi cloves.

Keywords: Clove supply chain; sustainable supply chain; competitiveness; TOWS strategy; IFAS–EFAS; North Sulawesi; agricultural value chain; digital traceability

INTRODUCTION

Background

Cloves are one of the most important plantation commodities and a key source of livelihood for local farming communities in North Sulawesi. The region contributes significantly to national clove production due to its favorable agro-climatic conditions, large plantation areas, and long-standing cultural traditions related to clove cultivation. Despite this potential, the clove supply chain in North Sulawesi continues to experience persistent inefficiencies, primarily reflected in fluctuating farm-gate prices, unstable production cycles, aging trees, and the dominance of intermediaries in trade [1] [2] [3].

Price fluctuations are influenced by seasonal harvesting patterns, unpredictable weather, and inconsistent supply, making farmers highly vulnerable to income instability. Additionally, structural issues such as limited access to modern farming inputs, inadequate post-harvest facilities, and weak market linkages reduce the ability of farmers to achieve higher value creation. The distribution chain remains long and fragmented, with collectors and traders playing dominant roles in price-setting. This often results in limited bargaining power for farmers and reduced competitiveness in both domestic and international markets [4] [5].

Global market dynamics further underline the importance of transforming the clove supply chain. Consumer preferences are shifting toward sustainable, traceable, and high-quality products. Digital transformation, including traceability systems and integrated logistics platforms, has become a crucial determinant of global competitiveness. For North Sulawesi, strengthening the supply chain through sustainability principles, modern post-harvest handling, and institutional coordination is necessary to maintain relevance in increasingly competitive global spice markets [6] [7] [8].

Given these challenges and opportunities, the modernization of the clove supply chain is essential not only for improving efficiency and stability but also for enhancing the welfare of farmers and supporting regional economic growth. A strategic, integrated, and sustainability-oriented framework is therefore needed to ensure that North Sulawesi cloves can attain stronger global positioning [9] [10].

Problem Statement

Although North Sulawesi possesses substantial natural and cultural advantages for clove production, the region continues to face systemic barriers that weaken its supply chain performance. Key problems include:

- Declining productivity due to aging clove trees and limited replanting programs.
- Inconsistent post-harvest quality caused by traditional drying methods without standardized moisture control.
- Inefficient logistics and inadequate infrastructure, including poorly maintained plantation roads and limited storage facilities.
- Dependence on intermediaries for market access, resulting in low price transparency and weak bargaining power for farmers.
- Limited exposure to digital supply chain systems, certifications, and export networks.
- Fragmented coordination among government institutions, leading to overlapping programs and unintegrated data systems.

These issues collectively hinder the region's ability to compete in premium global spice markets and limit opportunities for higher economic value.

Research Gap

Existing studies on agricultural supply chains, including cloves, have largely focused on operational efficiency and market linkages. While these findings provide valuable insights into value chain performance, they do not fully address the broader contemporary challenges related to sustainability, digital integration, global certification requirements, climate variability, and farmer empowerment.

Most prior works have not presented a comprehensive strategic model that combines:

- Internal and external factor analysis,
- Digital supply chain transformation,
- Sustainability practices (economic, social, environmental),
- Institutional coordination,
- Export readiness and global competitiveness frameworks.

Furthermore, there has been limited research specifically examining the clove commodity in North Sulawesi despite the region's status as a major production center. As a result, there is a lack of integrative strategies tailored to the unique socio-cultural, geographic, and economic characteristics of the region's clove ecosystem [11].

This study addresses this gap by integrating SWOT, IFAS, EFAS, and TOWS analysis to produce a holistic and actionable strategic model for enhancing the global competitiveness of the North Sulawesi clove supply chain [12] [13].

Research Objectives

This study aims to formulate a strategic framework for developing a sustainable and globally competitive clove supply chain in North Sulawesi. The specific objectives are:

1. To examine the structure and performance of the clove supply chain involving farmers, collectors, exporters, and government institutions.

2. To identify internal strengths and weaknesses as well as external opportunities and threats influencing the clove supply chain.
3. To quantify internal and external factors using IFAS and EFAS to determine the region's strategic position.
4. To formulate comprehensive supply chain strategies using the TOWS matrix to strengthen competitiveness and sustainability.
5. To propose a roadmap that integrates digitalization, modern agriculture, and policy interventions for long-term supply chain improvement.

Research Contributions

This study contributes to theory and practice in several ways:

Theoretical Contributions

- Introduces an integrative framework combining sustainable supply chain management and strategic analysis tools (SWOT, IFAS–EFAS, TOWS) for agricultural commodities.
- Enhances academic understanding of how digitalization, certification, and sustainability interact to shape competitiveness in global value chains.
- Provides empirical evidence from a major spice-producing region, offering insights into supply chain behavior from multiple levels: farmers, intermediaries, exporters, and government agencies.

Practical Contributions

- Offers actionable strategies for improving supply chain efficiency, product quality, and traceability.
- Provides recommendations for government institutions on policy alignment, digital data integration, replanting initiatives, and export facilitation.
- Proposes a roadmap for developing premium value-added products, certification clusters, and sustainable farming practices.
- Supports farmer empowerment by highlighting key areas for modern training, financial access, and cooperative strengthening.

Supply Chain Management

Supply Chain Management (SCM) is an integrated approach that manages the flow of goods, information, and financial resources from suppliers to end consumers. The core objective of SCM is to synchronize demand with supply while optimizing time, cost, and service quality. In the contemporary global business environment, companies must adopt strategic supply chain methods to improve visibility, responsiveness, and operational efficiency [14] [15] [16].

Modern SCM emphasizes not only logistics activities but also coordination across procurement, production, distribution, inventory management, and demand forecasting. A well-functioning supply chain ensures the availability of goods when needed, minimizes excess inventories, reduces operational waste, and enhances customer satisfaction. Companies with superior supply chain systems consistently achieve stronger competitive positions due to faster lead times, reliable service, and improved product quality [17] [18].

Integrated supply chain processes including accurate planning, efficient sourcing, effective production, and timely delivery create organizational flexibility and allow rapid adaptation to market changes. Collaboration among supply chain partners enhances decision-making accuracy, reduces variability, and mitigates the risks associated with the bullwhip effect. Therefore, SCM plays a critical role in shaping profitability, differentiation, and long-term business sustainability [19] [20].

Supply Chain Strategy

A supply chain strategy must align with the company's overall business goals to ensure optimal performance. Strategic planning involves selecting appropriate suppliers, managing inventories efficiently, and determining production and distribution capacities that respond effectively to customer demand. Operational decisions in supply chain activities include quality control, replenishment, and supplier relationship management [21] [22] [23].

Several techniques and methods enhance supply chain efficiency, such as Just-in-Time (JIT), Vendor Managed Inventory (VMI), and risk-pooling mechanisms. The adoption of modern technologies including big data analytics, the Internet of Things, and blockchain strengthens supply chain visibility, improves coordination, and reduces transaction costs [24] [25].

SCM is closely connected to logistics, and the two must operate cohesively to support business success. Strong integration between supply chain and logistics enables companies to optimize costs, accelerate delivery times, improve product quality, and increase customer satisfaction. Because industries operate in increasingly dynamic environments, adaptability and responsiveness have become essential capabilities [26] [27].

Sustainability has also become a critical element of modern supply chain strategy. Beyond economic efficiency, companies must incorporate environmental and social considerations, comply with regulatory standards, reduce emissions, and develop long-term value for stakeholders [28].

Sustainable Supply Chain

A sustainable supply chain integrates economic, social, and environmental pillars into the management of materials, processes, and flows across an entire value network. Sustainable practices aim to minimize environmental impact, promote ethical labor standards, and ensure long-term resource availability [7] [29].

Digitalization significantly accelerates the transition to sustainable supply chains. Technologies such as blockchain, IoT, and Industry 4.0 systems improve transparency, support traceability, facilitate real-time monitoring, strengthen quality control, and reduce waste. Digital traceability systems are increasingly demanded by global markets, especially in agricultural commodities where consumer trust and product authenticity are critical [30] [31].

Sustainable supply chains also incorporate life-cycle assessment, eco-efficiency, and green innovation. These practices help companies reduce environmental risks, meet international certification standards, and enhance their global competitiveness. In agricultural contexts, sustainable supply chain management ensures consistent product quality, fair distribution of value, and improved farmer welfare [32] [33].

Competitive Advantage

Competitive advantage refers to the ability of a firm or sector to deliver superior value through productivity, innovation, quality, and responsiveness. A competitive economy must deliver high levels of productivity and ensure that industries can adapt efficiently to global market dynamics [34] [35] [36].

At the firm level, competitive advantage emerges from superior product quality, innovative capabilities, operational efficiency, market access, and resilience. In the context of sustainability, environmentally responsible practices and long-term resource management contribute to stronger competitiveness through enhanced reputation, reduced risk, and increased operational reliability [36] [37].

Technological transformation is a major driver of modern competitive advantage. Digital infrastructure such as blockchain traceability, smart logistics, digital marketplaces, and

intelligent energy systems supports transparency and efficiency across the supply chain. Companies operating in volatile environments benefit from flexible and adaptive strategies, as rigid cost-focused approaches are no longer sufficient in dynamic global markets [38] [39].

For agricultural commodities, competitive advantage depends on product consistency, compliance with global standards, branding differentiation, and integration into international value chains. Strengthening these elements is essential for improving the global market position of regional commodities such as North Sulawesi cloves [40] [41].

Global Value Chain and Agricultural Supply Chains

Agricultural supply chains in developing regions often face structural barriers, including fragmented distribution networks, reliance on intermediaries, limited access to finance, and weak linkages to global markets. Although value chain frameworks emphasize efficiency and upgrading, achieving competitiveness requires broader interventions such as farmer empowerment, collective action, and improved institutional support [42] [43].

Smallholder farmers play a central role yet often have limited capacity to meet global market standards due to constraints in technology, information access, and capital. Collective action through cooperatives or cluster-based certification improves bargaining power, enables standardization, and supports direct integration with exporters [44] [45].

Digital transformation improves market access, reduces asymmetry of information, and shortens distribution chains by enabling direct farmer-to-buyer transactions. Moreover, global value chains reward authenticity, origin-based quality, traceability, and sustainable practices key attributes associated with North Sulawesi cloves [46] [47].

Integration of Supply Chain, Logistics, Digitalization, and Sustainability

The modern supply chain operates as an interconnected system that integrates logistics operations, digital platforms, sustainability principles, and institutional support. Effective logistical infrastructure such as well-maintained plantation roads, standardized drying facilities, and efficient export terminals reduces transportation costs and enhances reliability [48] [17].

At the upstream level, structured replanting programs, improved cultivation practices, and modern post-harvest techniques ensure consistent product quality. At the downstream level, traceability systems, digital platforms, and compliance with international certifications strengthen access to premium markets [49] [50].

Institutional collaboration among government agencies, cooperatives, and academic institutions is essential for aligning policies, developing technological solutions, and promoting export readiness. Digital data integration enhances transparency and supports real-time monitoring across the supply chain [51] [52].

The alignment of sustainability, digital innovation, and supply chain strategy forms the foundation of competitive agricultural value chains and is crucial for positioning North Sulawesi cloves in global markets.

METHODOLOGY

Research Design

This study employs a qualitative descriptive research design to explore, analyze, and interpret the structure, challenges, and potential strategies for strengthening the clove supply chain in North Sulawesi. The qualitative approach is used to gain deep insights from the main actors directly involved in the supply chain, including farmers, collectors, exporters, and government institutions. The research integrates strategic analysis tools SWOT, IFAS, EFAS, and TOWS to formulate comprehensive and applicable strategies based on empirical realities [53] [54].

The qualitative design enables the exploration of perceptions, experiences, operational practices, and socio-cultural conditions that shape the dynamics of clove production and distribution. The strategic analysis approach identifies internal and external factors, evaluates their significance, and synthesizes the most appropriate strategies for enhancing competitiveness and sustainability [55] [56].

Research Setting and Informants

The study was conducted in Minahasa Regency, one of the central clove production areas in North Sulawesi. The region is known for its long-standing agricultural traditions, favorable agro-climatic conditions, and extensive clove plantations. Minahasa serves as both a production and distribution center, making it a representative setting for understanding supply chain performance [57] [58].

Informants were selected using purposive sampling based on their involvement, expertise, and direct role within the clove supply chain. A total of thirteen key informants participated in the study:

- Six clove farmers from different villages across Minahasa, representing diverse farm sizes, cultivation practices, and experience levels.
- Four collectors (pengepul) who operate at village and sub-regional levels and are responsible for aggregating products from farmers and distributing them to larger buyers or exporters.
- Two exporters who manage quality control, documentation, market access, and international trade processes.
- One representative from a government institution, responsible for agricultural development, supply chain policies, and regional economic programs.

These informants were chosen because they represent the full spectrum of upstream, midstream, and downstream actors within the clove supply chain, allowing for a holistic understanding of structural dynamics, constraints, and potential strategies.

Data Collection Techniques

In-Depth Interviews

Primary data were collected through semi-structured in-depth interviews. Different interview guides were prepared for farmers, collectors, exporters, and the government to align questions with their roles. The interviews explored topics including:

- Farming conditions, productivity, and cultivation practices
- Post-harvest handling and product quality
- Distribution flow, pricing mechanisms, and transaction systems
- Infrastructure, logistics, and institutional support
- Market access, export challenges, and global standards
- Sustainability practices and environmental considerations
- Perceptions on opportunities, threats, and future prospects

Interviews were conducted directly in farms, collectors' warehouses, exporters' facilities, and government offices. Respondents shared narratives involving personal experiences, operational challenges, and expectations for improvement. Local dialects and cultural expressions (e.g., Manado language) were preserved in meaning by translating them contextually for analysis.

Documentation

Secondary data were collected from:

- Regional statistical reports

- Agricultural and trade policy documents
- Past research related to clove value chains
- Government programs on replanting, certification, and export facilitation
- Plantation production data and geographical records

Documentation complemented primary data and provided essential context for conducting IFAS, EFAS, and SWOT analyses.

DATA ANALYSIS

SWOT Analysis

SWOT analysis was used to identify and categorize:

- Strengths
- Weaknesses
- Opportunities
- Threats

across all supply chain actors (farmers, collectors, exporters, and government). This framework facilitated a clear understanding of internal capabilities and external environmental factors affecting the clove value chain.

IFAS (Internal Factor Analysis Summary)

The IFAS analysis quantified internal factors—strengths and weaknesses—derived from interviews and documentation. Each factor was assigned:

- Weight (0.0–1.0): representing its relative importance
- Rating (1–4): indicating the effectiveness of the current response
- Score: calculated through weight × rating

The total IFAS score reflects the overall internal strategic position of the clove supply chain.

EFAS (External Factor Analysis Summary)

Similarly, EFAS measured external opportunities and threats affecting the supply chain. Each factor received:

- A weight based on its impact on the supply chain
- A rating based on the effectiveness of existing strategies
- A score representing its influence

The combined EFAS score indicates whether the external environment provides more opportunities or challenges.

TOWS Matrix Formulation

The TOWS matrix was used to synthesize internal and external factors to formulate strategic alternatives:

- SO (Strength–Opportunity) strategies: leverage existing strengths to capture opportunities
- ST (Strength–Threat) strategies: use strengths to mitigate external threats
- WO (Weakness–Opportunity) strategies: address weaknesses by utilizing opportunities
- WT (Weakness–Threat) strategies: minimize weaknesses while avoiding threats

This framework resulted in a set of aggressive, adaptive, diversification, and defensive strategies relevant for actors across the clove supply chain.

Validity and Reliability

To ensure the credibility and reliability of findings, the study employed:

Triangulation of Sources

Cross-verification of information from different actors helped validate emerging themes and reduce bias.

Member Checking

Key informants reviewed portions of the interpreted data to confirm accuracy and contextual correctness.

Documentation Support

Statistical and policy documents were used to verify information, strengthen the analysis, and support strategic formulation.

Analytical Rigor

Systematic use of matrices (SWOT, IFAS, EFAS, TOWS) ensured structured interpretation and minimized subjectivity in deriving strategic recommendations.

RESULTS AND DISCUSSION

Profile of Minahasa Regency

Minahasa is one of the oldest regencies in North Sulawesi Province, with Tondano as its capital. Geographically, it is located in the central part of North Sulawesi and is bordered by North Minahasa to the north, Manado and Tomohon to the west, South Minahasa to the south, and Southeast Minahasa to the east. Its geographical location positions Minahasa as one of the region's economic support centers.

The topography of Minahasa consists of hilly, mountainous, and lowland areas, making it suitable for high-value agricultural and plantation activities such as cloves, coconut, coffee, and nutmeg. The region has a tropical climate with high rainfall throughout the year, which supports plantation cultivation.

Minahasa is known for its multicultural society consisting of several sub-ethnic groups, including Tombulu, Tonsea, Tontemboan, Tondano, Tolour, Tonsawang, Pasan, and Ponosakan. Although these groups have distinct languages, they share similar cultural values and collective identity as Tou Malesung. A key cultural value is Mapalus, a tradition of mutual cooperation widely practiced in agriculture, social activities, and customary affairs. This collaborative spirit is especially visible during clove harvesting and land preparation.

The agricultural and plantation sectors form the backbone of Minahasa's regional economy, contributing approximately 30% to the Gross Regional Domestic Product (GRDP). The regency's primary commodities include cloves, coconut, maize, and coffee. Cloves serve as a major source of household income and support downstream industries such as kretek cigarettes, essential oils, and derivative products.

Minahasa also has freshwater fisheries around Lake Tondano, contributing to local food supply chains. The combination of plantation agriculture, fisheries, and tourism gives Minahasa a diverse economic potential.

Based on official agricultural data, Minahasa has approximately 20,000 hectares of clove plantations. Production areas are spread across multiple districts, including Kombi, Kakas, Eris, Sonder, and Romboken. This distribution underscores Minahasa's importance as a major clove-producing region within North Sulawesi.

Below is the English version of Table 1 from your manuscript all data preserved exactly, no reductions.

The data confirm that cloves remain a strategic commodity in Minahasa's economy with strong and sustainable production prospects. Clove cultivation is unevenly distributed across districts. Kombi has the largest plantation area, followed by East Lembean, Tombulu, Tombariri, and East Tombariri—indicating these districts are major production hubs

Table 1 Plantation Potential and Production of Minahasa Regency, 2025

No	District	Land Area (Ha)	(TBM)	(TM)
1	North Tondano	245.00	12.00	76.00
2	East Tondano	784.50	-	156.00
3	West Tondano	128.40	7.00	68.00
4	South Tondano	436.25	-	8.00
5	Remboken	143.75	30.00	15.00
6	Kombi	7,367.25	656.00	1,885.00
7	Eris	1,795.00	365.00	805.00
8	East Lembean	5,561.50	665.00	1,532.00
9	Kakas	1,998.00	102.00	1,238.00
10	West Kakas	1,498.00	37.00	499.00
11	East Langowan	97.50	15.00	55.00
12	West Langowan	63.75	-	-
13	South Langowan	1,626.00	109.00	716.00
14	North Langowan	10.75	-	-
15	Tompaso	127.75	-	3.00
16	West Tompaso	46.75	5.00	7.00
17	Kawangkoan	413.50	-	236.00
18	West Kawangkoan	766.00	-	349.00
19	North Kawangkoan	517.50	15.00	35.63
20	Sonder	2,842.00	370.00	2,798.00
21	Tombariri	3,362.73	400.00	647.00
22	East Tombariri	3,072.30	236.00	1,028.00
23	Mandolang	2,149.00	175.00	485.00
24	Pineleng	2,852.00	-	4,721.00
25	Tombulu	4,352.82	1,144.00	1,417.00
		42,258.00	**3,313.00**	**14,529.63**

Districts with relatively small areas, such as West Langowan and North Langowan, contribute minimally to overall production. Productivity in several districts, including Pineleng, East Lembean, Sonder, and Kombi, is relatively high, suggesting that age structure and cultivation practices significantly influence yield capacity.

The ratio of immature (TBM) to mature plants (TM) offers insights into long-term production prospects. Districts like Tombulu, East Lembean, and Eris have notable areas of immature clove trees, signaling future increases in production capacity [15].

Overall, Minahasa possesses strong potential for developing its clove sector due to its extensive plantation areas, diverse production centers, and continuous regeneration of young trees. Strengthening cultivation practices, modernizing post-harvest handling, and improving market access will be key to ensuring that cloves remain a primary commodity supporting farmer welfare and regional economic development.

Minahasa cloves possess distinctive qualities influenced by local geographic conditions and traditional cultivation systems. They are known for their fragrant aroma, bright to glossy dried flower appearance, and brown to dark-brown color. These characteristics make them highly desirable for both domestic industries and export markets [59] [60].

Standard handling of harvested cloves follows national quality guidelines, including moisture control and sorting procedures. The long-standing cultural tradition of manual sun-drying—combined with inherited agricultural practices plays an important role in maintaining premium quality.

Farmer Interview Results

Clove Farming Conditions

Interview Questions

1. *Can you describe the size of the clove land you currently manage?*
2. *What is the condition of your clove trees (age, productivity per tree, harvest cycle)?*
3. *How has your harvest trend been in the past five years—has it increased, decreased, or remained stable?*
4. *Is clove farming your family's main source of income, or do you have other side businesses?*

Farmer's Response

The farmer stated that the clove land managed by the family covers approximately two hectares, which is considered relatively large. The clove trees on this land are mostly 20–25 years old. When the trees were younger, yields were significantly better; however, as the trees have aged, productivity has gradually declined. During peak harvest seasons, yields may still reach around 30–40 kilograms per tree, but production fluctuates and is not stable each year. Compared to earlier years, the harvest volume has decreased particularly over the past five years due to unfavorable and increasingly unpredictable weather patterns.

The farmer explained that prolonged rainy periods or extended heatwaves have a substantial impact on flowering and fruit development, resulting in lower yields. Rising maintenance costs, particularly the increasing prices of fertilizers and pesticides, also place pressure on the household's finances. As a result, the farmer must manage resources carefully to maintain profitability.

Despite these constraints, clove farming remains the primary source of income for the family. All household expenses are fulfilled from clove plantation earnings. The farmer does not engage in additional side businesses, as the family has always focused on clove cultivation. Although the challenges are considerable, the farmer emphasized that clove farming continues to be the family's only viable source of livelihood.

Production Constraints

Interview Questions

1. *What are the biggest challenges you face in clove cultivation (e.g., seeds, fertilizer, plant care, pests/diseases)?*
2. *How is the condition of agricultural infrastructure (plantation roads, irrigation, storage)?*
3. *Are production costs increasing? What is the impact on profits?*
4. *During peak harvest seasons, do selling prices drop? How do you handle this?*

Farmer's Response

The farmer described several major challenges in clove cultivation. Access to fertilizer especially high-quality fertilizer has become increasingly difficult, and prices have risen substantially. Pest attacks, particularly stem borers, frequently damage the clove trees and require additional expenditure on pesticides.

Infrastructure limitations further complicate production activities. The plantation road has long been in poor condition, making it difficult to transport harvested cloves. During harvest periods, the farmer often relies on motorcycle taxis or manually carries the produce from the plantation due to damaged roads.

Production costs continue to rise each year, including labor, fertilizers, and pesticides, which reduces profit margins. During peak harvest seasons, clove prices often fall sharply. To

mitigate losses, the farmer typically stores the harvested cloves for one to two weeks before selling them, hoping to obtain a slightly better price.

Strengths of North Sulawesi Cloves

Interview Questions

1. *In your view, what are the advantages of North Sulawesi cloves compared to other regions?*
2. *Have buyers or exporters ever given positive feedback?*
3. *How important is cultural tradition in maintaining quality?*

Farmer's Response

The farmer explained that cloves from North Sulawesi have long been recognized for their superior quality. The aroma is very strong, and the distinctive fragrance can be sensed immediately. The oil content in North Sulawesi cloves is also high, which makes them highly valued by buyers.

According to the farmer, exporters have praised the excellent quality of local cloves, noting their good color, uniform size, and unique aroma that is difficult to find in cloves from other regions. The farmer attributes these advantages partly to traditional cultivation practices that have been passed down through generations.

Knowledge regarding proper harvesting such as identifying the right time to harvest and applying correct sun-drying techniques has been inherited from parents and grandparents. The drying process remains traditional, relying on sunlight but using techniques refined through family experience. These cultural practices play an important role in maintaining the consistent quality of North Sulawesi cloves.

Government and Institutional Support

Interview Questions

1. *Have you received assistance from the government or related institutions (seeds, fertilizers, tools)?*
2. *Have you ever attended training programs related to clove farming?*
3. *Do you have access to credit or financial support?*
4. *What types of support do you need most?*

Farmer's Response

The farmer mentioned that government assistance had been received in the past, mainly in the form of seedlings. However, the amount was limited and the quality was not particularly good. The farmer has not participated in modern agricultural training programs, resulting in continued reliance on traditional cultivation methods.

Access to credit remains a significant challenge. Borrowing from banks is difficult due to numerous administrative requirements and the need for collateral. As a result, the farmer struggles to obtain financial support for improving or expanding production.

Marketing Patterns

Interview Questions

1. *To whom do you typically sell your dried cloves?*
2. *How is the payment system arranged?*
3. *Do you have access to buyers outside the region or export markets?*
4. *Do you feel the selling price is fair?*

Farmer's Response

The farmer typically sells dried cloves directly to local collectors, as this is the most practical option. Collectors often come to pick up the product either from the farmer's home or directly from the plantation. The payment system is usually cash-based; however, the collectors determine the price.

The farmer has never had direct access to buyers outside the region or to export markets and remains heavily dependent on collectors. During peak harvest seasons, selling prices tend to drop significantly, which results in lower income despite the high level of effort and costs required to maintain the plantation.

Sustainability and Environmental Practices

Interview Questions

1. *What practices do you use to maintain soil and environmental sustainability?*
2. *Do you apply organic or environmentally friendly materials?*
3. *How do you manage waste or plant residues?*
4. *How do you prevent land degradation?*

Farmer's Response

The farmer employs several environmentally conscious practices. Organic fertilizer is used whenever possible, and the use of chemical inputs is minimized. Dry leaves and weeds are processed into compost rather than being burned. Replanting older clove trees is considered essential to ensure regeneration and long-term productivity.

The farmer also avoids land-clearing by burning, as such practices degrade soil quality and pose environmental hazards. Sustainable management is viewed as crucial to maintaining the long-term viability of the plantation.

Clove Collectors (Pengepul) Informants

Clove Distribution Chain

Interview Questions

1. *Can you explain in detail how the clove distribution flow operates from farmers to the market or exporters?*
2. *Which actors are typically involved (small collectors, large collectors, traders, exporters)?*
3. *What transaction mechanisms are commonly used with farmers (cash, advance purchase/tebasan, credit)?*
4. *How long do cloves typically remain in your possession before being sold onward?*

Collector's Response

The collector explained that cloves are generally obtained directly from farmers. After purchasing from them, the collector consolidates the products before distributing them to larger traders or directly to exporters when connections are available. The typical distribution flow is: Farmers → Small collectors → Large collectors → Major traders or exporters.

In everyday practice, the actors involved include farmers at the village level, small collectors who gather cloves in small volumes, and larger collectors who move the products to city traders or exporters depending on the volume and market demand.

Regarding transactions with farmers, the collector stated that two primary systems are used: cash payments and advance purchasing (tebasan) in which payment is made before the cloves are harvested. In some cases, collectors also provide loans or financial assistance to farmers, which are later deducted from the sales proceeds during the harvest.

Cloves generally remain in the collector's storage for 3–7 days before being sold to larger traders or exporters because fast cash flow is important in this business. However, when market prices decline, the collector may store cloves for several weeks while waiting for the price to stabilize.

Challenges in Collection and Distribution

Interview Questions

1. *What challenges arise when collecting cloves from farmers price fluctuations, inconsistent supply, or quality variation?*
2. *How is the condition of transportation access from production centers to warehouses or markets?*
3. *Have storage issues such as humidity or mold ever occurred?*
4. *How do weather and climate conditions affect distribution?*

Collector's Response

The collector indicated that the most common challenge is the rapid fluctuation of clove prices, which makes working capital difficult to manage. Supply from farmers is not always steady; sometimes deliveries are delayed due to heavy rain or because farmers are unable to harvest quickly.

Quality inconsistency is also a frequent problem, as some farmers deliver cloves that are well-dried while others bring produce that is still moist. Transportation from the plantation areas to the warehouse is difficult because many roads are damaged, resulting in higher transportation costs.

The collector must also be vigilant about storage conditions because high humidity can lead to mold, which reduces the quality of cloves. Weather is another major factor; during prolonged rainy seasons, cloves are harder to dry, leading to delays in distribution to markets or exporters.

Maintaining Clove Quality

Interview Questions

1. *What steps do you take to ensure clove quality before selling (drying, sorting, storage)?*
2. *Are there specific quality standards required by buyers or exporters?*
3. *How do you handle mixed batches of wet and dry cloves?*
4. *Have buyers ever complained about quality, and how were those issues resolved?*

Collector's Response

According to the collector, quality control is carried out by drying the cloves again to ensure they reach the required moisture level. After drying, the cloves are sorted to separate high-quality products from lower-quality ones. Exporters typically require low moisture content, uniform size, and cleanliness, so collectors must ensure these standards are met before selling.

When farmers supply cloves mixed with wet and dry materials, the collector separates them and dries the wet cloves again. Complaints from buyers have occurred in the past, usually related to quality not meeting expectations. In such cases, the collector takes responsibility by replacing the product or offering discounted prices to maintain good business relationships.

Efficiency of the Distribution Chain

Interview Questions

1. *Is the clove distribution chain currently efficient, or does it remain long and costly?*

2. *What factors reduce efficiency (multiple intermediaries, high transport costs, weak cooperative institutions)?*
3. *How can the chain be shortened to improve farmers' prices?*
4. *Can digitalization (online platforms/marketplaces) help improve efficiency?*

Collector's Response

The collector stated that the current distribution chain is still long and expensive. There are too many intermediaries between farmers and exporters, and transportation costs are high due to poor infrastructure. Cooperative institutions are not yet strong or consistently functional, making price coordination difficult.

To shorten the chain, the collector suggested creating direct links between farmers and exporters or large traders, allowing farmers to receive better prices. Digitalization is considered a promising solution; using online B2B platforms or marketplaces could help collectors and farmers sell directly to buyers, reduce intermediaries, improve efficiency, and stabilize prices.

Market Opportunities (Domestic and Export)

Interview Questions

1. *How is domestic clove demand trending in recent years?*
2. *Are there export opportunities from North Sulawesi that remain untapped?*
3. *What factors are needed to penetrate global markets (certification, organic quality, regional branding)?*
4. *What support do you expect from government or trade associations?*

Collector's Response

The collector explained that domestic clove demand has remained relatively stable, although it fluctuates based on seasonal and international price trends. Export opportunities from North Sulawesi remain significant, particularly to European countries and East Asia, which are still underexploited.

To enter global markets, the most important factors include high product quality, proper certification (such as organic certification), and strong regional branding. The collector hopes for government support in areas such as training, assistance with certification processes, and market facilitation so that farmers and collectors can better access domestic and export markets.

Exporter Interview Results

Export Market Access and Procurement Patterns

Interview Questions

1. *Can you explain the export market flow for cloves originating from North Sulawesi?*
2. *What countries are the main export destinations, and what factors influence demand?*
3. *How do exporters typically source cloves from collectors or farmers?*
4. *What are the primary requirements you expect from suppliers?*

Exporter's Response

According to the exporter, cloves from North Sulawesi are primarily distributed to international markets in Europe and East Asia, where demand is consistent due to the region's high-quality aroma and oil content. Exporters generally obtain supplies from large collectors who have already consolidated produce from smaller collectors and farmers. The exporter emphasized that supply availability depends heavily on the harvest cycle and weather conditions, which influence both quality and volume.

The exporter stated that buyers abroad are highly concerned about moisture content, uniformity of size, dryness level, and cleanliness. Therefore, exporters require suppliers to

ensure that cloves are fully dried and properly sorted. Exporters also highlighted that documentation and quality certification can influence the ease of accessing certain global markets.

Quality Requirements and Quality Challenges

Interview Questions

1. *What quality indicators are most important for the export market?*
2. *How often do you encounter quality issues in cloves supplied from collectors or farmers?*
3. *What are the most common quality problems, and how are they resolved?*

Exporter's Response

The exporter explained that moisture content is the most important indicator of quality. Cloves must be dried to a specific moisture level to prevent mold growth during long-distance shipping. Exporters also require cloves with consistent size, uniform color, and free from impurities such as stems, dust, or foreign particles.

Quality inconsistency is a recurring challenge because some cloves delivered by collectors may still be partially moist or mixed with lower-grade produce. When this occurs, exporters must either re-dry the product or reject the batch. This situation results in additional operational costs and delays in fulfilling export orders. The exporter stressed that proper drying and sorting at the farmer and collector level would significantly improve efficiency and reduce losses.

Export Logistics and Documentation

Interview Questions

1. *What logistical challenges do you face in exporting cloves?*
2. *How do storage, packaging, and transportation conditions influence product quality?*
3. *What documents are required for exporting, and do you face administrative obstacles?*

Exporter's Response

The exporter noted that the primary logistical challenge is delays in obtaining high-quality cloves from collectors during periods of unstable weather. Storage facilities must maintain a dry environment because humidity can damage the cloves before container loading.

Exporters typically package cloves in multi-layered sacks to protect them from moisture. Transportation from warehouse to port also needs careful handling, especially during rainy seasons.

Regarding documentation, exporters must prepare export permits, quality certificates, fumigation reports, and customs clearance forms. Administrative delays sometimes occur due to slow processing of documents and inspections, which can disrupt shipment schedules.

Global Market Opportunities and Competitive Position

Interview Questions

1. *How competitive are North Sulawesi cloves in the global market?*
2. *What opportunities exist to expand export volumes?*
3. *What improvements are required from farmers and collectors to enhance competitiveness?*

Exporter's Response

The exporter confirmed that cloves from North Sulawesi have a strong competitive position internationally because of their aroma and oil content, which are highly valued by

buyers. Opportunities to expand exports include entering additional markets in the Middle East and Southeast Asia, where demand for high-quality cloves is growing.

However, improvements are needed at the farmer and collector levels, especially in consistent quality control, moisture reduction, and compliance with international standards. The exporter emphasized the importance of training programs, certification support, and stronger coordination across the supply chain to enhance global competitiveness.

Exporter Challenges and Needed Support

Interview Questions

1. *What are the greatest challenges faced by exporters?*
2. *How can government institutions support the export sector?*
3. *What improvements in infrastructure or policy would assist the export process?*

Exporter's Response

The exporter stated that the most significant challenges are inconsistent supply quality, unpredictable weather, and frequent fluctuations in international prices. Exporters require stable supply from collectors and farmers to meet contractual obligations with foreign buyers.

The exporter suggested that government institutions can support the export sector by facilitating international certifications, improving port logistics, ensuring faster administrative processing, and providing better information about global market trends.

Infrastructure improvements especially in transportation routes and storage facilities would also help maintain clove quality and reduce logistical bottlenecks. These improvements are essential to strengthening the long-term sustainability of the export supply chain.

Government Informant

Government Role and Coordination in the Clove Supply Chain

Interview Questions

1. *What is the role and coordination mechanism of the local government in maintaining the sustainability of the clove supply chain in North Sulawesi?*
2. *How does the government facilitate the connection between farmers, traders, and exporters?*
3. *How is the management of production, distribution, and export data handled across institutions?*

Government's Response

According to the government informant, the local government has made efforts to maintain the clove supply chain in North Sulawesi, although institutional coordination still needs to be strengthened. The Department of Agriculture provides farmer development such as training, seed assistance, and supervision of harvest quality. The Department of Trade is responsible for pricing and market access, while the Department of Industry and Cooperatives supports farmer groups and cooperatives to process clove-based derivative products rather than selling raw materials.

However, coordination among agencies remains weak. Information from one department often does not align with another, causing programs to run separately. There should be a permanent coordination forum that brings together all related departments, exporters, and farmer representatives to synchronize policies.

Regarding mechanisms connecting farmers, traders, and exporters, the government has previously organized business-matching events and export training programs in several regencies, although these have not been conducted regularly. A digital platform that directly

connects farmers with exporters is seen as essential to shorten the long distribution chain that suppresses farmer prices.

Data management remains a major challenge. Production data is held by the Department of Agriculture, trade data by the Department of Trade, and export data by Customs and the Port of Bitung. These datasets are often inconsistent, making accurate planning difficult. The informant stated that although the government has good intentions, stronger cross-agency coordination, digitalization of supply chain data, and a direct connection mechanism between farmers and exporters are urgently needed for an efficient and sustainable clove supply chain.

Government Programs to Strengthen the Clove Supply Chain

Interview Questions

1. *What programs and government support have been implemented to strengthen the clove supply chain in North Sulawesi?*
2. *How do these programs support farmers, traders, cooperatives, and exporters?*
3. *What are the main limitations faced by the government in implementing these programs?*

Government's Response

The government informant explained that several programs have been implemented to strengthen the clove supply chain, although expansion is still needed. For farmers, the government provides training through the Department of Agriculture, teaching proper tree maintenance, effective drying techniques, and good storage practices to ensure high product quality. The government also distributes superior seedlings and fertilizer subsidies, although not all farmers receive them due to limited budgets. Some regions, such as Minahasa and Talaud, have also benefited from replanting programs aimed at replacing old, unproductive clove trees.

For traders and cooperatives, the government provides training in business management and logistics to improve distribution efficiency. The government also encourages the establishment of clove cooperatives so that farmers can sell directly without passing through many intermediaries.

For exporters, support includes participation in international trade promotions through the Ministry of Trade and Indonesian Embassies abroad. Assistance with export certifications such as Fair Trade and Organic Certification is also available, though the cost remains high and requires additional subsidies.

The government is collaborating with universities such as Sam Ratulangi University and research institutions on studies related to productivity, clove oil processing, and value-added derivative products. Digitalization initiatives, such as developing apps for price information and market demand, are underway but still in early stages due to limited internet access in rural areas.

Government Strategy for Global Competitiveness

Interview Questions

1. *What long-term strategies has the provincial government developed to increase the global competitiveness of North Sulawesi cloves?*
2. *What are the priority areas—productivity, distribution efficiency, branding, or export promotion?*
3. *How is the government collaborating across ministries to support export expansion?*

Government's Response

The government informant reported that the Provincial Government of North Sulawesi is developing a comprehensive strategy to increase the global competitiveness of cloves. Based on the 2024 Regional Government Work Plan, clove is designated as a strategic regional commodity alongside coconut and nutmeg, with policy direction focused on sustainable industrialization and downstream processing.

Through the Plantation Department, the government is preparing the 2025–2045 North Sulawesi Clove Development Roadmap, emphasizing the replanting of approximately 3,000 hectares of old trees by 2030 and increasing productivity from an average of 700 kg/ha to the genetic potential of Zanzibar varieties at 1,200 kg/ha.

Branding efforts have been strengthened under "Cengkih Sulut – The Ethical Spice of Indonesia," aimed at promoting derivative products such as essential oils, herbal soaps, and aromatic products. The government is also facilitating geographical indication (GI) protection for Minahasa Cloves, currently being processed by the Ministry of Law and Human Rights.

Cross-ministerial collaborations include HACCP and Organic Certification programs supported by the Ministry of Agriculture and global market promotions through the Ministry of Trade's Spice Up the World initiative.

Government Efforts for Sustainability and Farmer Inclusion

Interview Questions

1. *What policies support the sustainability of clove farming, including replanting, environmental protection, and international certification?*
2. *How does the government ensure the participation of small farmers?*
3. *What sustainability practices are being promoted?*

Government's Response

The informant stated that the government is increasingly prioritizing sustainability, not only focusing on harvest outcomes but also on environmental preservation. First, a replanting program for old clove trees has been implemented, supported by the provision of high-quality seedlings to reduce farmers' financial burdens.

Second, the government frequently conducts campaigns to discourage farmers from using burning practices when opening land. They also promote the use of compost-based fertilizers derived from leaves, stems, and weeds, under the Green Agriculture Program.

Third, the Departments of Trade and Industry provide training and mentoring to help farmers meet European and Asian market standards. Small farmers are encouraged to join supply-chain cooperatives to sell directly to exporters, reducing dependency on intermediaries. Youth in rural areas are also involved in digital agriculture training, enabling them to use applications for reporting harvests and accessing price information.

The government also noted that assistance is needed to facilitate international certifications due to their high costs. Associations and certification bodies play an important role in helping farmers and exporters access global markets.

SWOT Analysis

SWOT – Farmers

Farmers benefit from strong cultural knowledge and high-quality natural products, yet remain constrained by structural limitations such as aging trees, inconsistent post-harvest processing, and limited bargaining power. Opportunities arise from global demand, government programs, and digitalization, but climate risks and international competition remain serious threats requiring strategic interventions.

Table 2. SWOT Analysis of Farmers

Category	Factors
Strengths	1. High intrinsic quality of local cloves (aroma, oil content). 2. Traditional knowledge in drying, harvesting, sorting. 3. Strong cultural heritage and intergenerational transfer of skills. 4. Clove farming as main livelihood ensures commitment. 5. Strong social networks with collectors.
Weaknesses	1. Aging clove trees causing declining productivity. 2. Limited access to fertilizer and pesticides. 3. Inconsistent drying and post-harvest quality. 4. Weak bargaining power due to collector dominance. 5. Poor plantation and road infrastructure. 6. Limited access to financial institutions.
Opportunities	1. Premium global market with demand for high-quality cloves. 2. Government replanting and training programs. 3. Digital platforms enabling direct market access. 4. Potential GI branding for Minahasa cloves. 5. Development of downstream products (herbal, essential oil).
Threats	1. Climate extremes affecting flowering and drying. 2. Price volatility and currency fluctuations. 3. International competition (Zanzibar, Madagascar, Sri Lanka). 4. Rising transportation and logistic costs.

SWOT – Collectors

Table 3. SWOT Analysis of Collectors

Category	Factors
Strengths	1. Fast consolidation of cloves from multiple farmers. 2. Skilled in sorting, grading, and re-drying. 3. Flexible payment schemes (cash, tebasan, loans). 4. Established networks with exporters.
Weaknesses	1. Sensitive cashflow due to unstable prices. 2. Quality inconsistencies from farmers requiring rework. 3. Limited storage facilities and humidity control. 4. High transportation costs due to poor infrastructure.
Opportunities	1. Potential to function as midstream quality control hubs. 2. Digital marketplaces expanding buyer networks. 3. Strengthening cooperatives for efficient bulk supply.
Threats	1. International price fluctuations. 2. Increasing export QC demands. 3. Intense competition among collectors. 4. Seasonal rain disrupting drying & logistics.

Collectors play a central role in consolidating supply and ensuring intermediate quality control. However, volatile markets, infrastructure barriers, and quality inconsistencies pressure their operations. Digitalization and cooperative strengthening provide clear pathways to enhance competitiveness, though environmental and market threats must be managed.

SWOT – Exporters

Table 4. SWOT Analysis of Exporters

Category	Factors
Strengths	1. Strong access to international markets. 2. Well-established buyer networks. 3. Proficiency in export documentation and standards. 4. Ability to specify required QC standards.
Weaknesses	1. Unstable upstream supply. 2. High cost of global certifications. 3. Expensive logistics and port handling. 4. Weak regional branding for North Sulawesi cloves.
Opportunities	1. Expansion into premium markets. 2. National export support (Trade Expo Indonesia). 3. GI-based differentiation. 4. Potential downstream essential oil industries.
Threats	1. VStrict Non-Tariff Barriers (NTBs). 2. Competition from certified producing countries. 3. Administrative delays in export processes. 4. Climate-related supply disruptions.

Exporters are positioned to unlock global market value but depend heavily on upstream consistency and quality. Opportunities lie in branding, international promotions, and downstream processing, while threats arise from strict regulations, climate risks, and international competitors.

SWOT – Government Agencies

Table 5. SWOT Analysis of Government Agencies

Category	Factors
Strengths	1. Strong policy support (replanting, export promotion). 2. Access to national programs and funding schemes. 3. Collaboration with universities and research institutions.
Weaknesses	1. Limited extension workforce. 2. Weak inter-agency coordination. 3. Programs often interrupted by annual budgeting cycles. 4. Weak cooperative organizations in rural areas.
Opportunities	1. Growing global demand for ethical, certified spices. 2. Support for Organic, HACCP, and traceability certification. 3. Potential digital integration of supply chain governance. 4. Infrastructure development (ports, rural roads).
Threats	1. Administrative bottlenecks affecting export flow. 2. Market volatility affecting farmer welfare. 3. Limited collaboration with national ministries. 4. Rising climate vulnerability reducing long-term productivity.

Government agencies form the enabling environment for the entire supply chain. While policy frameworks and national programs offer strong potential, institutional coordination gaps and infrastructure limitations remain challenges. Opportunities in digital governance and certification can significantly enhance competitiveness, but climate and administrative constraints pose serious threats.

Integrated Internal and External Factors

This section consolidates all internal and external factors influencing the North Sulawesi clove supply chain. The factors are grouped into internal (strengths and weaknesses) and external (opportunities and threats), forming the foundation for subsequent TOWS strategy formulation.

Internal Factors (Strengths and Weaknesses)

The internal factors reflect the inherent capabilities and limitations within the North Sulawesi clove supply chain based on the integrated perspectives of farmers, collectors, exporters, and government institutions.

Table 6. Internal Factors (Strengths & Weaknesses)

Category	Internal Factors
Strengths	1. High intrinsic quality of cloves (aroma, oil content, uniformity). 2. Strong traditional knowledge in harvesting, drying, and sorting. 3. Cultural heritage and intergenerational skill transfer. 4. Existing market channels through collectors and exporters. 5. Social capital within farmer–collector networks. 6. Government support programs (replanting, training, GI development). 7. Exporters' capability in international documentation and quality standards.
Weaknesses	1. Aging clove trees leading to declining productivity. 2. Inconsistent post-harvest quality (moisture, sorting, drying). 3. Limited access to fertilizer, pesticides, and modern tools. 4. Weak bargaining power among upstream actors. 5. Poor rural and plantation infrastructure increasing logistics costs. 6. Limited access to credit due to collateral requirements. 7. Inadequate storage facilities and humidity control among collectors. 8. Weak inter-agency coordination and fragmented agricultural programs.

The internal factors indicate that the supply chain possesses substantial strengths, particularly product quality, traditional expertise, and established market connections. These elements reflect deep-rooted cultural and experiential assets. However, internal weaknesses are structurally significant and include aging trees, inconsistent drying techniques, limited capital access, and infrastructural constraints. Without addressing these weaknesses, leveraging external opportunities will remain challenging.

External Factors (Opportunities and Threats)

The external factors capture broader market dynamics, environmental conditions, and policy frameworks that influence the supply chain's competitiveness beyond internal control.

Table 7. External Factors (Opportunities & Threats)

Category	External Factors
Opportunities	1. Growing demand in premium international markets (EU, Middle East, East Asia). 2. Potential for Geographical Indication (GI) branding to enhance differentiation. 3. Government programs supporting replanting, training, and downstream processing. 4. Digital transformation opportunities (traceability systems, marketplace integration). 5. Expansion of downstream industries (essential oils, herbal cosmetics, aromatherapy products).
Threats	1. Climate variability affecting flowering and drying cycles. 2. International price volatility and currency fluctuations. 3. Competition from Zanzibar, Madagascar, and Sri Lanka. 4. Strict global standards (moisture, cleanliness, traceability). 5. High logistic and port-handling costs hindering competitiveness. 6. Policy discontinuity caused by short budgeting cycles and inconsistent implementation.

The external environment offers significant opportunities for growth, particularly through premium export markets, GI branding, and digitalization. Government support also strengthens development potential. However, several external threats such as climate risk, global competition, strict international standards, and logistical inefficiencies pose substantial challenges. These threats must be strategically mitigated to unlock the full potential of available opportunities.

TOWS Matrix of the North Sulawesi Clove Supply Chain

The TOWS Matrix synthesizes the internal strengths and weaknesses with external opportunities and threats to formulate strategic directions for building a sustainable and competitive clove supply chain in North Sulawesi. The formulation is based on consolidated findings from farmers, collectors, exporters, and government institutions.

Table 8. TOWS Matrix of the North Sulawesi Clove Supply Chain

Combination	Main Strategic Direction	Specific and Applicable Strategies
S–O (Strength–Opportunity)	Aggressive Strategy: Strengthening Local Competitiveness Use product quality, local culture, and government support to seize premium markets and digitalize the supply chain.	1. Premium Certification and Branding Program – Organic, fair-trade, and traceability certifications through farmer groups. – Strengthening *Geographical Indication (GI) Cengkih Minahasa* and promoting *Ethical Clove of North Sulawesi*. 2. Digital Supply Chain Transformation – Development of a B2B digital platform connecting farmers –collectors–exporters. – Transparent pricing and QR-based traceability systems. 3. Downstream Product Innovation – Diversification into essential oils, herbal soaps, perfumes, and functional beverages. – Collaboration with universities and medium-sized industries.
S–T (Strength–Threat)	Adaptive Strategy: Building a Resilient Supply Chain Use local knowledge and social networks to withstand climate extremes, global price instability, and international competition.	1. Climate-Responsive Cultivation and Post-Harvest Adaptation – Training in *solar dryer dome*, humidity control, and staged drying. – Use of organic fertilizers and botanical pesticides for long-term soil fertility. 2. Farmer–Exporter Partnership System – Minimum price contracts (*offtake agreements*) and quality coaching. – Exporters act as quality mentors and purchase guarantors. 3. Collective Market Diplomacy and Branding

		– Promotion through *Trade Expo Indonesia* and *Spice Up the World*. – Building the global reputation of *Ethical Clove* to compete with Zanzibar and Madagascar.
W–O (Weakness–Opportunity)	Structural Strengthening Strategy	1. Mass Replanting and Green Agriculture – Replanting old trees with superior varieties through agricultural *KUR* funds. – Green agriculture training using compost and liquid organic fertilizers. 2. Digital Cooperatives and Micro-Financing – Establish digital supply-chain cooperatives providing access to real-time, inventory-based financing. – Integration with national price apps to improve farmers' bargaining power. 3. Quality Standardization and Post-Harvest Training – Training on *grading, moisture control,* and export-standard storage. – Implementation of *cluster-based certification*.
W–T (Weakness–Threat)	Protective Strategy: Stabilization and System Resilience Reduce structural weaknesses and mitigate global threats through infrastructure and price-protection mechanisms.	1. Regional Buffer Stock System – Establishing a buffer stock mechanism to stabilize clove prices during harvest peaks. – Collaboration with regional SOEs and local government. 2. Modernization of Infrastructure and Logistics – Rehabilitation of plantation roads, storage facilities, and export infrastructure in Bitung and Minahasa. – Optimization of *dry port* operations to reduce logistics costs by 15–20%. 3. Farmer Income Diversification – Integration of agroforestry (coffee, nutmeg, vanilla) as additional income streams. – Training young farmers to support generational workforce renewal.

Interpretation of TOWS Synthesis

1. The dominance of SO and WO strategies indicates that competitiveness relies on strengthening internal capacities and external digitalization.

2. ST and WT strategies function as system safeguards (resilience and survival) against global and climate pressures.
3. Implementation success requires cross-actor coordination, in which:
   a) Farmers and cooperatives focus on production and quality.

b) Collectors focus on consolidation and logistics efficiency.
c) Exporters focus on branding and market assurances.
d) Government and universities focus on policies, financing, and technological innovation.

Strategic Policy Directions (Integration of TOWS Results)

The strategic policy directions derived from the TOWS synthesis are organized by time horizon. These directions integrate internal capabilities, external opportunities, and structural challenges across the clove supply chain. The roadmap aligns with the phases found in the manuscript.

Table 9. Strategic Policy Directions Based on TOWS Integration

Time Horizon	Strategic Focus	Key Outputs
2025–2026 (Initial Phase)	Digitalization and Premium Certification	• Activation of a traceability platform • Certification of 10 farmer groups
2026–2027 (Consolidation Phase)	Replanting and Digital Cooperatives	• 2,000 hectares replanted • 5 cooperatives becoming fully operational
2027–2028 (Resilience Phase)	Partnerships and Climate Adaptation	• 10 minimum-price contracts • Implementation of modern drying and quality control systems
2028–2030 (Downstreaming Phase)	Downstream Processing and Buffer Stock	• Launch of three value-added clove derivative products for export • Price stability maintained at ±10% range

The Synthesis of Strategic Directions:

1. SO Strategy (Grow): Leading short-term policies through digitalization, certification, and GI branding.
2. WO Strategy (Empowerment): Strengthening institutional foundations and the social capital of farmers.
3. ST Strategy (Resilience): Building an adaptive system to face climate change and global market pressure.
4. WT Strategy (Protective): Ensuring long-term economic and social sustainability through buffer stock systems and infrastructure strengthening.

The results indicate the need for a coordinated, phased development plan involving farmers, collectors, exporters, and government agencies. Digitalization, replanting, certification, and downstream innovation are central to achieving a more resilient and competitive clove supply chain.

IFAS and EFAS Matrix

This section integrates the internal and external factor evaluations of the North Sulawesi clove supply chain. The IFAS (Internal Factor Analysis Summary) identifies internal strengths and weaknesses, while the EFAS (External Factor Analysis Summary) outlines external

opportunities and threats. Together, these matrices provide the foundation for strategic positioning and the development of TOWS-based strategic directions.

Internal Factor Analysis Summary (IFAS)

Table 10. Internal Factor Analysis Summary (IFAS)

No	Internal Factors	Weight	Rating	Score	Remarks
Strengths					
1	Motivation and supply stability	0.08	4	0.32	Farmers maintain relatively stable supply capacity
2	Strong and efficient farmer–collector relationships	0.05	3	0.15	Long-standing trust and strong social ties
3	Fast and flexible distribution	0.05	3	0.15	Adaptive distribution based on market needs
4	Access to global markets & understanding of quality standards (exporters)	0.09	4	0.36	Exporters have multinational buyer networks
5	Export experience and buyer networks	0.08	4	0.32	Strong export capability
6	Government policies & roadmap (replanting, downstreaming, branding)	0.08	3	0.24	Clear institutional and policy support
Subtotal Strengths		**0.47**		**1.60**	
Weaknesses					
1	Old trees & declining productivity	0.08	1	0.08	Requires large-scale replanting
2	Expensive and limited access to fertilizers & inputs	0.05	2	0.10	High costs reduce profitability
3	Weak access to financing & limited capital	0.06	2	0.12	Limits innovation and quality improvement
4	Inconsistent post-harvest quality	0.07	2	0.14	Reduces export compliance
5	Dependence on middlemen for pricing	0.05	1	0.05	Farmer bargaining power remains weak
6	Poor infrastructure & logistics	0.07	2	0.14	High distribution and transport costs
7	Weak inter-agency coordination & insufficient extension officers	0.05	2	0.10	Government program execution lacks synchronization
Subtotal Weaknesses		**0.43**		**0.73**	
Total Internal Score (S–W)	**1.00**		**2.33**		

The IFAS total score of 2.33 reflects a moderate internal capability. While the supply chain benefits from strong product quality, export experience, and policy support, structural weaknesses including aging trees, post-harvest inconsistency, limited financing, and poor logistics reduce overall competitiveness. Strengthening internal capacity is essential before implementing more aggressive or growth-oriented strategies.

External Factor Analysis Summary (EFAS)

Below is the full EFAS table translated directly from the manuscript and reformatted to journal standards.

Table 11. External Factor Analysis Summary (EFAS)

No	External Factors	Weight	Rating	Score	Remarks
Opportunities					
1	Premium international market demand	0.10	4	0.40	High global interest in high-quality Indonesian cloves
2	Government support for replanting, training, and downstreaming	0.08	3	0.24	Strong policy incentives
3	Digital transformation opportunities	0.07	3	0.21	Traceability and online B2B markets emerging
4	Potential for GI branding	0.07	4	0.28	Strong differentiation potential
5	Downstream product development	0.06	3	0.18	High value-added potential
Subtotal Opportunities		**0.38**		**1.31**	
Threats					
1	Climate variability (rainfall, humidity)	0.08	2	0.16	High risk to drying and flowering
2	Price volatility & exchange rate fluctuations	0.07	2	0.14	Unstable income for farmers
3	Competition from Zanzibar, Madagascar, Sri Lanka	0.07	2	0.14	Strong global competitors
4	Strict international standards & NTBs	0.07	3	0.21	Demanding export requirements
5	High logistics & export costs	0.06	2	0.12	Reduces price competitiveness
6	Policy inconsistency due to budget cycles	0.05	2	0.10	Program continuity at risk
Subtotal Threats		**0.40**		**0.87**	
Total External Score (O–T)	**1.00**		**2.18**		

The EFAS total score of 2.18 indicates that the supply chain faces moderate external opportunities, but these are counterbalanced by significant threats. Premium markets, GI

branding, digitalization, and downstreaming present strong potential for growth. However, climate risk, price volatility, global competition, strict export standards, and logistic inefficiencies remain major external hurdles. The combination of these factors places the supply chain in an average external strategic position, requiring both adaptation and proactive opportunity capture.

Strategic Position Matrix (Integration of IFAS and EFAS)

The integration of the IFAS and EFAS scores provides an overall strategic position for the North Sulawesi clove supply chain. The internal factor score of 2.33 and the external factor score of 2.18 place the industry within the "Average–Average" quadrant, indicating a stability strategy or hold-and-maintain strategy. This position suggests that while the industry has moderate internal capabilities and faces moderate external conditions, it must strengthen structural foundations before moving into more aggressive strategic directions.

Table 12. Strategic Position Matrix (IFAS × EFAS)

Strategic Dimension	Score	Position Category	Implication
Internal (IFAS)	2.33	Moderate Strength	Internal capabilities require strengthening before expansion
External (EFAS)	2.18	Moderate Attractiveness	Opportunities exist but threats are significant
Overall Position	*Average–Average*	Stability Strategy	Maintain performance while preparing for long-term competitiveness

Based on the combined IFAS and EFAS results, the clove supply chain industry falls within the Quadrant II (Stability Quadrant) of the strategic position matrix. This quadrant typically reflects industries that:

1. Possess adequate internal resources but require improvement to compete more aggressively.
2. Face moderate external challenges that limit rapid expansion.
3. Must prioritize capacity building, institutional strengthening, and efficiency improvements.
4. Should avoid high-risk aggressive strategies until structural weaknesses are addressed.

This positioning justifies a focus on stabilization strategies, including:

- Strengthening internal institutional and production capabilities
- Enhancing supply chain coordination
- Reducing inefficiencies in logistics and post-harvest processes
- Addressing structural issues such as aging trees, inconsistent quality, and weak bargaining power
- Preparing the foundation for stronger digitalization and downstream development

These conditions directly support the formulation of the subsequent TOWS-based strategic directions that emphasize structural strengthening, resilience building, and long-term competitive positioning.

Discussion

Identification of Key Issues in the North Sulawesi Clove Supply Chain

Field research findings indicate that the North Sulawesi clove supply chain continues to face several structural and systemic challenges. These include aging plantations resulting in

declining productivity, inconsistent post-harvest quality, dependence on intermediaries for price setting, and limited logistics infrastructure that inhibits access to broader markets. These conditions align with Supply Chain Management (SCM) theory (Pujawan & Mahendrawathi, 2017), which emphasizes the importance of synchronized flows of materials, information, and finances to support efficiency and competitiveness.

From the Internal Factor Analysis Summary (IFAS) perspective, internal weaknesses are primarily driven by old clove trees, dominant use of traditional drying methods, and limited access to digital and financial technologies. Meanwhile, the External Factor Analysis Summary (EFAS) highlights major opportunities, including increasing global demand for premium spices and supportive government programs for replanting, downstreaming, and export promotion. This is consistent with the Green Supply Chain Management (GSCM) framework (Srivastava, 2007), which stresses the importance of integrating environmental and social considerations into supply chain operations.

Sustainable Supply Chain Strategies

Based on the SWOT and TOWS analysis, four main sustainable supply chain strategies are identified as follows:

Table 13. Sustainable Supply Chain Strategies

Strategy Type	Implementation Focus	Main Actors	Implications
SO (Strength–Opportunity)	Optimization of quality through *GI branding* and organic certification	Exporters, Government	Increased export value-added and greater access to premium markets
ST (Strength–Threat)	Supply chain digitalization and adoption of traceability systems to manage global fluctuations	Collectors, Trade Department	Transparency, improved logistics efficiency, and mitigation of price-risk exposure
WO (Weakness–Opportunity)	Replanting of old trees and development of digital farmer cooperatives	Agriculture Office, Farmer Groups	Productivity rejuvenation and strengthening of farmers' bargaining power
WT (Weakness–Threat)	Product diversification (essential oils, clove derivatives) and establishment of regional buffer stock systems	Government, SMEs	Price stabilization and strengthened long-term local economic sustainability

These strategies support the Strategic Fit framework described by Chopra & Meindl (2021), which argues that supply chain strategy must align with market uncertainty and resource availability. The implementation of traceability systems and cooperative digitalization also reflects Industry 4.0 developments, where IoT and blockchain technology strengthen visibility and build trust in international markets.

Enhancing Global Competitiveness of North Sulawesi Cloves

From the perspective of the Resource-Based View (RBV), the competitiveness of North Sulawesi cloves is supported by strong intrinsic qualities high essential oil content, strong aroma, and uniform bud size combined with cultural values such as *Mapalus* that encourage collective labor. However, these advantages remain underutilized due to weak integration between upstream production, post-harvest handling, and branding [61] [62].

This is consistent with Porter's Diamond Model, which highlights that competitiveness is shaped by factor conditions, demand conditions, supporting industries, and firm strategy. While Minahasa has strong natural factor conditions (fertile land and suitable climate), weaknesses remain in firm strategy particularly downstream innovation and digital traceability. Empirical findings show increasing global demand for organic, fair-trade, and traceable spice products, emphasizing the importance of strengthening the national *hilirisasi* roadmap to increase competitiveness in premium markets [63] [64].

Role of Government and Institutional Support

Interviews with officials from the Agriculture Office of North Sulawesi and Minahasa Regency show that government support includes provision of high-quality seedlings, replanting programs, green agriculture training, export facilitation, and the introduction of digital price monitoring systems. However, cross-sector coordination remains limited, resulting in fragmented program implementation.

This aligns with Institutional Theory, which states that institutional effectiveness depends on regulatory strength, social norms, and inter-organizational coordination. Strengthening horizontal and vertical coordination across agriculture, trade, and industry agencies is crucial to building integrated systems and supporting national initiatives such as *Spice Up the World*.

Sustainable Supply Chain Strategy Model

Based on the findings, a sustainable clove supply chain strategy model consists of four interconnected components:

1. Operational Efficiency
    - Modernization of cultivation, drying techniques, and transportation supported by smart logistics.
2. Socio-Economic Sustainability
    - Empowerment of farmers through digital cooperatives and skills development programs.
3. Environmental Sustainability
    - Adoption of organic fertilizers, integrated pest management, and reduction of waste from leaves and stems.
4. Digital Transformation & Branding
    - Strengthening of traceability systems and development of North Sulawesi Ethical Clove branding.

This model aligns with the Triple Bottom Line (TBL) framework (Elkington, 1997), focusing on achieving balance between profit, people, and planet. Integration of RBV, SSCM, and Institutional Theory highlights that strengthening competitiveness requires innovation, digitalization, and sustainability [65] [66] [67].

CONLUSION AND RECOMMENDATION

Conclusion

The analysis shows that the clove supply chain in North Sulawesi Province still faces various internal and external obstacles. These challenges include the aging of clove trees, outdated post-harvest technology, limited logistics infrastructure, inadequate market access, and the dominance of intermediaries that weaken farmers' bargaining position. These factors lead to low distribution efficiency, price fluctuations, and restricted access to premium markets.

Based on the SWOT–TOWS analysis, several recommended strategies include replanting and land revitalization to increase productivity, digital integration of the supply chain

through traceability systems to stabilize market prices, and product diversification into essential oils, clove derivatives, and herbal products to enhance added value. Strengthening digital cooperatives can improve coordination among actors and stabilize prices.

These strategies are aligned with the principles of sustainable supply chain management (SSCM) and the Resource-Based View (RBV), which emphasize the use of local resources and technology as sustainable competitive advantages. The main recommendations include implementing green logistics, utilizing IoT-based energy-efficient processing, and fulfilling sustainability certifications (HACCP, Organic, Fair Trade) to penetrate international markets.

In addition, strengthening branding through North Sulawesi Ethical Clove is expected to enhance the image and added value of the product in export markets. Digital and environmentally oriented innovations strengthen the global positioning of North Sulawesi cloves within the global supply chain and support the Sustainable Development Goals (SDGs).

Recommendation

Strengthening the North Sulawesi clove supply chain requires an integrated, evidence-based, and sustainability-oriented framework. The establishment of a Clove Supply Chain Coordination Forum as an inter-agency entity is needed to ensure the consolidation of production, distribution, and real-time price information, thereby increasing planning accuracy and policy effectiveness.

Improving strategic infrastructure including plantation access roads, drying facilities, storage warehouses, digital weighing stations, and export-related facilities is a critical determinant in reducing logistics costs and enhancing supply reliability. At the national level, accelerating the downstreaming program and promoting green logistics are essential to support industry competitiveness.

Financial support instruments such as green financing, institutional strengthening of farmer cooperatives, and digital cooperative transformation must be expanded to improve farmers' capacity. Green agriculture training and the adoption of environmentally friendly technologies are also necessary to maintain consistent quality and long-term sustainability.

At the downstream level, product diversification into essential oils, herbal cosmetics, and functional beverages should be encouraged. Strengthening digital traceability systems, fulfilling international sustainability certifications such as Organic EU, Fair Trade, and ISO 22000, is expected to enhance price transparency, added value, and global market credibility.

1. REFERENCES

[1] H. Lv *et al.*, "Starch-based biodegradable active intelligent packaging with color superimposition via emulsion electrospinning nanofiber for meat freshness monitoring and shelf-life extension," *Carbohydr. Polym.*, vol. 367, p. 123940, 2025, doi: https://doi.org/10.1016/j.carbpol.2025.123940.

[2] L. Partzsch, "Hardening sustainability: Supply chain laws complement cocoa and coffee certifications," *For. Policy Econ.*, vol. 181, p. 103661, 2025, doi: https://doi.org/10.1016/j.forpol.2025.103661.

[3] A. J. Acevedo-Urquiaga *et al.*, "Neural network prediction of small business competitiveness under a sustainable short supply chain business model for rooftop agriculture in a Bogotá neighborhood," *Results Eng.*, vol. 28, p. 107938, 2025, doi: https://doi.org/10.1016/j.rineng.2025.107938.

[4] M. A. Al-Busaidi, D. J. Jukes, and S. Bose, "Seafood safety and quality: An analysis of the supply chain in the Sultanate of Oman," *Food Control*, vol. 59, pp. 651–662, 2016,

doi: https://doi.org/10.1016/j.foodcont.2015.06.023.
[5] G. Pagot and N. Andrighetto, "Fuel for collective action: A SWOT analysis to identify social barriers and drivers for a local woody biomass supply chain in an Italian alpine valley," *Heliyon*, vol. 10, no. 19, p. e38170, 2024, doi: https://doi.org/10.1016/j.heliyon.2024.e38170.
[6] C. Xedzro, K. Tano-Debrah, and H. Nakano, "Antibacterial efficacies and time-kill kinetics of indigenous Ghanaian spice extracts against Listeria monocytogenes and some other food-borne pathogenic bacteria," *Microbiol. Res.*, vol. 258, p. 126980, 2022, doi: https://doi.org/10.1016/j.micres.2022.126980.
[7] S. Digiesi, F. Facchini, and B. Silvestri, "Green strategies to reduce the environmental impact of jam production," *Transp. Res. Procedia*, vol. 67, pp. 72–82, 2022, doi: https://doi.org/10.1016/j.trpro.2022.12.037.
[8] Y. Zhang *et al.*, "The encapsulation strategies of clove essential oil enhance its delivery effect in food preservation applications," *Food Chem.*, vol. 484, p. 144465, 2025, doi: https://doi.org/10.1016/j.foodchem.2025.144465.
[9] M. Golser, A. Hofer, J. Kargruber, and E. Rauch, "Integrating Stakeholder Engagement: Refining Engineering Education for the Mobility Value Chain in Industry 5.0," *Procedia Comput. Sci.*, vol. 253, pp. 964–973, 2025, doi: https://doi.org/10.1016/j.procs.2025.01.158.
[10] M. Subburaj, T. R. Babu, and B. S. Subramonian, "A Study on Strengthening the Operational Efficiency of Dairy Supply Chain in Tamilnadu, India," *Procedia - Soc. Behav. Sci.*, vol. 189, pp. 285–291, 2015, doi: https://doi.org/10.1016/j.sbspro.2015.03.224.
[11] S. Bag, M. S. Rahman, S. Routray, and R. Khurana, "Regenerative supply chain orientation and coopetition in supply chain networks for ESG initiatives: A parallel mediation study," *J. Bus. Res.*, vol. 201, p. 115685, 2025, doi: https://doi.org/10.1016/j.jbusres.2025.115685.
[12] A. M. Oumer, S. Diro, G. Taye, T. Mamo, and M. Jaleta, "Agricultural lime value chain efficiency for reducing soil acidity in Ethiopia," *Soil Secur.*, vol. 11, p. 100092, 2023, doi: https://doi.org/10.1016/j.soisec.2023.100092.
[13] M. A. Abdelkareem, A. G. Olabi, M. N. AlMallahi, M. Mahmoud, and M. Elgendi, "Contributions of electric vehicles towards the sustainable development goals," *Energy Convers. Manag. X*, vol. 27, p. 101170, 2025, doi: https://doi.org/10.1016/j.ecmx.2025.101170.
[14] N. Uttam, P. Dutta, and A. Singh, "Unraveling and managing social sustainability tensions in supply chains: perspectives of small suppliers in the food processing sector," *Supply Chain Manag. An Int. J.*, vol. 30, no. 5, pp. 518–535, 2025, doi: https://doi.org/10.1108/SCM-08-2024-0498.
[15] M. Jenkins and M. Scott, "Navigating the supply chain life cycle: a roadmap for growth and transitional strategies across the stages of organizational evolution," *Supply Chain Manag. An Int. J.*, vol. 30, no. 4, pp. 424–451, 2025, doi: https://doi.org/10.1108/SCM-09-2024-0583.
[16] R. K. Singh, "Impact of net-zero policies on supply chain sustainability: mediating role of green technology adoption," *Supply Chain Manag. An Int. J.*, vol. 30, no. 5, pp. 552–565, 2025, doi: https://doi.org/10.1108/SCM-06-2025-0505.
[17] Y.-J. Chen, "Structured methodology for supplier selection and evaluation in a supply chain," *Inf. Sci. (Ny).*, vol. 181, no. 9, pp. 1651–1670, 2011, doi:

https://doi.org/10.1016/j.ins.2010.07.026.
[18] R. Chen and L. Govik, "A heroic vision for sustainability transitions: electrification through collaborative supply chain networks," *Supply Chain Manag. An Int. J.*, vol. 30, no. 7, pp. 116–130, 2024, doi: https://doi.org/10.1108/SCM-12-2024-0796.
[19] J. A. Cano, A. A. Londoño-Pineda, E. A. Campo, C. M. Bernal, A. P. Londoño, and O. M. Ospina, "Circular economy readiness index for supply chains: Evaluating industrial clusters in the Aburrá Valley," *Clean. Responsible Consum.*, vol. 19, p. 100345, 2025, doi: https://doi.org/10.1016/j.clrc.2025.100345.
[20] A. Aich and S. K. Ghosh, "Application of SWOT Analysis for the Selection of Technology for Processing and Disposal of MSW," *Procedia Environ. Sci.*, vol. 35, pp. 209–228, 2016, doi: https://doi.org/10.1016/j.proenv.2016.07.083.
[21] X. Huang, H. Huang, F. Zhang, and T. Li, "What it costs: Family firms' supply chain efficiency losses," *Pacific-Basin Financ. J.*, vol. 94, p. 102959, 2025, doi: https://doi.org/10.1016/j.pacfin.2025.102959.
[22] S. Singh, R. P. Mohanty, S. K. Mangla, and V. Agrawal, "Critical success factors of additive manufacturing for higher sustainable competitive advantage in supply chains," *J. Clean. Prod.*, vol. 425, p. 138908, 2023, doi: https://doi.org/10.1016/j.jclepro.2023.138908.
[23] R. Klophaus, "AI-generated SWOT analysis of emerging technologies in air transportation: Potential and limitations," *Res. Transp. Bus. Manag.*, vol. 59, p. 101316, 2025, doi: https://doi.org/10.1016/j.rtbm.2025.101316.
[24] A. Khatun, S. Islam, R. Karmakar, and A. Garai, "Sustainable economic policies for a VMI-CS-based closed-loop supply chain with quality control measures under the carbon cap-and-trade regulation," *Clean. Logist. Supply Chain*, p. 100280, 2025, doi: https://doi.org/10.1016/j.clscn.2025.100280.
[25] S. Deep, K. N. Jha, S. Vishnoi, A. Kumar, and P. B. Shetty, "Disruption to construction supply chains during COVID-19 in developing economies: A strategic framework for sustainable and resilient logistics," *Clean. Logist. Supply Chain*, vol. 16, p. 100235, 2025, doi: https://doi.org/10.1016/j.clscn.2025.100235.
[26] M. Kumar, "Formulating a framework for sustainable circular supply chain management: integration of circular economy decoupled with Industry 4.0 attributes through Fuzzy–ISM approach," *Manag. Environ. Qual. An Int. J.*, vol. 36, no. 8, pp. 2189–2233, 2025, doi: https://doi.org/10.1108/MEQ-11-2023-0387.
[27] N. T. N. Trang and Y. Li, "Reverse supply chain for end- of- life vehicles treatment: An in- depth content review," *Resour. Conserv. Recycl. Adv.*, vol. 17, p. 200128, 2023, doi: https://doi.org/10.1016/j.rcradv.2022.200128.
[28] A. Rashid and R. Rasheed, "Enabling coercive drivers with green supply chain management practices to gain performance nexus through external collaboration and monitoring," *Clean. Logist. Supply Chain*, vol. 17, p. 100278, 2025, doi: https://doi.org/10.1016/j.clscn.2025.100278.
[29] L. Zhang, P. Jiang, Y. Zhang, Y. Van Fan, and Y. Geng, "Recycling impacts of renewable energy generation-related rare earth resources: A SWOT-based strategical analysis," *Energy*, vol. 312, p. 133624, 2024, doi: https://doi.org/10.1016/j.energy.2024.133624.
[30] R. B. T.-R. M. in S. S. Alikhani, "Integrating sustainability and resilience in strategic supplier selection," Elsevier, 2025. doi: https://doi.org/10.1016/B978-0-443-28993-4.00108-6.

[31] S. J. Hong, Z. Riahi, A. Khan, G. H. Shin, and J. T. Kim, "Advancements in metal–organic frameworks impregnated biopolymer-based smart packaging applications: Prospects and future direction," *Microchem. J.*, vol. 209, p. 112816, 2025, doi: https://doi.org/10.1016/j.microc.2025.112816.

[32] S. Gallego-García, D. Gallego-García, and M. García-García, "Sustainability in the agri-food supply chain: a combined digital twin and simulation approach for farmers," *Procedia Comput. Sci.*, vol. 217, pp. 1280–1295, 2023, doi: https://doi.org/10.1016/j.procs.2022.12.326.

[33] Y. D'Mello *et al.*, "Supporting local communities of practice in sustainable supply chains: the case of Stocate in Montreal, Canada," *Sustain. Futur.*, vol. 10, p. 101355, 2025, doi: https://doi.org/10.1016/j.sftr.2025.101355.

[34] R. Collins and B. Dent, "Chapter 10 - Value chain management and postharvest handling," W. J. Florkowski, N. H. Banks, R. L. Shewfelt, and S. E. B. T.-P. H. (Fourth E. Prussia, Eds., San Diego: Academic Press, 2022, pp. 319–341. doi: https://doi.org/10.1016/B978-0-12-822845-6.00010-5.

[35] L. Zhang *et al.*, "Artificial intelligence-driven internet of things-based green supply chain for carbon reduction in sustainable manufacturing," *J. Environ. Manage.*, vol. 389, p. 126170, 2025, doi: https://doi.org/10.1016/j.jenvman.2025.126170.

[36] M. A. AL-Shboul, "Assessing sustainability of green supply chain performance: The roles of agile innovative products, business intelligence readiness, innovative supply chain process integration, and lean supply chain capability as a mediating factor," *J. Open Innov. Technol. Mark. Complex.*, vol. 11, no. 1, p. 100476, 2025, doi: https://doi.org/10.1016/j.joitmc.2025.100476.

[37] C. Xu, A. M. Du, and B. Lin, "Robot adoption and corporate supply chain efficiency: Evidence from China," *Pacific-Basin Financ. J.*, vol. 94, p. 102958, 2025, doi: https://doi.org/10.1016/j.pacfin.2025.102958.

[38] F. Abdelfattah, H. Madi, M. Al-Washahi, A. AlAraimi, S. Nagi, and M. Abbas, "Harnessing Artificial Intelligence, Business Intelligence, and Digital Technologies for achieving supply chain excellence in Oman: Investigating the mediating role of predictive analytics," *J. Open Innov. Technol. Mark. Complex.*, vol. 11, no. 4, p. 100644, 2025, doi: https://doi.org/10.1016/j.joitmc.2025.100644.

[39] M. R. Karim, M. Dulal, F. Sakila, P. Aditi, S. J. Smrity, and N. N. Asha, "Analyzing the factors influencing sustainable supply chain management in the textile sector," *Clean. Logist. Supply Chain*, vol. 13, p. 100183, 2024, doi: https://doi.org/10.1016/j.clscn.2024.100183.

[40] J. Su, Y. Chen, H. Liu, N. Zhang, and D. Wu, "Unveiling the knowledge spillover risk in high-tech industry supply chain: A multi-criteria classification assessment method," *Appl. Soft Comput.*, vol. 183, p. 113680, 2025, doi: https://doi.org/10.1016/j.asoc.2025.113680.

[41] A. Khodair, "Key embrace factors for designing sustainable supply chains in Egyptian Industry 4.0," *Bus. Process Manag. J.*, vol. 30, no. 4, pp. 1111–1130, 2024, doi: https://doi.org/10.1108/BPMJ-07-2023-0579.

[42] R. D. S. G. Pontes, D. N. Brandão, F. L. Usberti, and L. S. De Assis, "Multi-objective models for crop rotation planning problems," *Agric. Syst.*, vol. 219, p. 104050, 2024, doi: https://doi.org/10.1016/j.agsy.2024.104050.

[43] T. Kalimuthu, P. Kalpana, S. Kuppusamy, and V. Raja Sreedharan, "Intelligent decision-making framework for agriculture supply chain in emerging economies:

Research opportunities and challenges," *Comput. Electron. Agric.*, vol. 219, p. 108766, 2024, doi: https://doi.org/10.1016/j.compag.2024.108766.

[44] M. R. Marcone, "Sustainable supply chain in a new technological era: the case of the Italian agrifood sector," *Eur. J. Innov. Manag.*, vol. 28, no. 11, pp. 321–348, 2025, doi: https://doi.org/10.1108/EJIM-04-2024-0421.

[45] S. Haque, D. Akbar, S. Kinnear, and A. Rahman, "A scoping review of export supply chain efficiency frameworks for perishable horticultural products," *Supply Chain Anal.*, vol. 10, p. 100112, 2025, doi: https://doi.org/10.1016/j.sca.2025.100112.

[46] L. Agnusdei, M. Krstić, P. Palmi, and P. P. Miglietta, "Digitalization as driver to achieve circularity in the agroindustry: A SWOT-ANP-ADAM approach," *Sci. Total Environ.*, vol. 882, p. 163441, 2023, doi: https://doi.org/10.1016/j.scitotenv.2023.163441.

[47] S. Nayeri, Z. Sazvar, and E. B. Tirkolaee, "Industry 5.0-driven circular supply chain network design: A novel multi-stage decision-making method," *Renew. Sustain. Energy Rev.*, vol. 226, p. 116420, 2026, doi: https://doi.org/10.1016/j.rser.2025.116420.

[48] R. Chaudhuri, B. Singh, A. K. Agrawal, S. Chatterjee, S. Gupta, and S. K. Mangla, "A TOE-DCV approach to green supply chain adoption for sustainable operations in the semiconductor industry," *Int. J. Prod. Econ.*, vol. 275, p. 109327, 2024, doi: https://doi.org/10.1016/j.ijpe.2024.109327.

[49] S. M. Moniruzzaman, M. J. Alam, D. Sharma, I. A. Begum, M. T. O. Patino, and A. M. McKenzie, "Value chain analysis of jute fiber in Bangladesh," *Soc. Sci. Humanit. Open*, vol. 10, p. 101088, 2024, doi: https://doi.org/10.1016/j.ssaho.2024.101088.

[50] C. W. T. Fukuyama, L. G. R. Duarte, I. C. Pedrino, M. C. Mitsuyuki, S. B. Junior, and M. D. Ferreira, "Effect of carnauba wax nanoemulsion associated with Syzygium aromaticum and Mentha piperita essential oils as an alternative to extend lychee post-harvest shelf life," *Sustain. Food Technol.*, vol. 2, no. 2, pp. 426–436, 2024, doi: https://doi.org/10.1039/d3fb00251a.

[51] F. Sun, Z. Qu, B. Wu, and S. Bold, "Comparative analysis of international environmental policies and supply chain sustainability," *J. Environ. Manage.*, vol. 390, p. 126324, 2025, doi: https://doi.org/10.1016/j.jenvman.2025.126324.

[52] P. O. Mensah, J. Y. Yong, C. C. Dura, and H. K. Mensah, "Institutional networking capability as a catalyst for sustainable supply chains in the manufacturing sector of Ghana: The role of green human resource management strategy and green dynamic capability," *J. Environ. Manage.*, vol. 387, p. 125865, 2025, doi: https://doi.org/10.1016/j.jenvman.2025.125865.

[53] Q. Shi *et al.*, "Optimizing strategies for the high-quality development of intelligent new energy vehicles: A case study of Anhui Province," *Sustain. Futur.*, vol. 10, p. 101362, 2025, doi: https://doi.org/10.1016/j.sftr.2025.101362.

[54] N. Sahani, "Application of hybrid SWOT-AHP-FuzzyAHP model for formulation and prioritization of ecotourism strategies in Western Himalaya, India," *Int. J. Geoheritage Park.*, vol. 9, no. 3, pp. 349–362, 2021, doi: https://doi.org/10.1016/j.ijgeop.2021.08.001.

[55] G. Browne de Deus Ribeiro, S. R. Valverde, A. de Cássia Oliveira Carneiro, M. Lopes da Silva, and G. A. dos Santos, "Strategic financial decision-making for forest bioenergy: investment scenarios and policy insights for charcoal enterprises in Brazil," *For. Policy Econ.*, vol. 181, p. 103659, 2025, doi: https://doi.org/10.1016/j.forpol.2025.103659.

[56] R. Alyamani, Y. A. Solangi, and D. Almakhles, "Assessing factors and resilience

strategies for sustainable energy transition in Saudi Arabia: An integrated SWOT-TOWS analysis and decision-making framework," *Energy Policy*, vol. 207, p. 114825, 2025, doi: https://doi.org/10.1016/j.enpol.2025.114825.

[57] A. M. A. O. Aljabary, F. H. Awlqadr, A. B. Altemimi, A. B. M. Abdulrahman, M. N. Saeed, and M. A. Hesarinejad, "Advances in oil-based edible coatings for postharvest preservation of fruits and vegetables: A comprehensive review of biopolymer types, functional plant oils, nanoemulsion systems, and application techniques," *J. Agric. Food Res.*, vol. 24, p. 102425, 2025, doi: https://doi.org/10.1016/j.jafr.2025.102425.

[58] R. Yu, H. Moon, T. C. E. Cheng, Y. Hou, and M. Song, "Supply chain effects of green Innovation: A cultural perspective on the performance of Chinese and Korean firm," *J. Environ. Manage.*, vol. 394, p. 127588, 2025, doi: https://doi.org/10.1016/j.jenvman.2025.127588.

[59] A. M. Kiloes *et al.*, "Unravelling the provisioning system of a strategic food commodity to minimise import dependency: A study of garlic in Indonesia," *Food Policy*, vol. 123, p. 102604, 2024, doi: https://doi.org/10.1016/j.foodpol.2024.102604.

[60] S. M. Zahraee and N. Shiwakoti, "A review of sustainable hydrogen energy by 2050: Supply chain, export markets, circular economy, social dimensions, and future prospects: Australia vs. worldwide," *Sustain. Futur.*, vol. 10, p. 101070, 2025, doi: https://doi.org/10.1016/j.sftr.2025.101070.

[61] F. A. Jam, I. Ali, N. Albishri, A. Mammadov, and A. K. Mohapatra, "How does the adoption of digital technologies in supply chain management enhance supply chain performance? A mediated and moderated model," *Technol. Forecast. Soc. Change*, vol. 219, p. 124225, 2025, doi: https://doi.org/10.1016/j.techfore.2025.124225.

[62] I. Sharma, H. Sonar, N. Ghag, H. M. Belal, and M. A. Majeed, "Enhancing resilience in the fresh food supply chain: a managerial perspective through interpretive analysis," *Br. Food J.*, vol. 127, no. 12, pp. 4715–4741, 2025, doi: https://doi.org/10.1108/BFJ-03-2025-0319.

[63] Suhartono, A. Widiyanto, M. M. B. Utomo, and L. A. G. Pieter, "Strategies for sustainable business development through bamboo utilization: A case study in Mandalagiri Village, Tasikmalaya Regency, Indonesia," *Adv. Bamboo Sci.*, p. 100212, 2025, doi: https://doi.org/10.1016/j.bamboo.2025.100212.

[64] G. F. Vasconcelos and H. A. Castilho, "A SWOT analysis for the evolution of Brazil's renewable energy sector," *Util. Policy*, vol. 96, p. 101997, 2025, doi: https://doi.org/10.1016/j.jup.2025.101997.

[65] B. Baldassarre, T. Maury, N. Tazi, F. Mathieux, and S. Sala, "Increasing plastic circularity in the automotive sector: Supply chain analysis and policy options from the European Union (EU)," *Resour. Conserv. Recycl.*, vol. 218, p. 108216, 2025, doi: https://doi.org/10.1016/j.resconrec.2025.108216.

[66] R. Agarwal, A. Mehrotra, H. Alofaysan, and R. V Mahto, "Digital technologies and green infrastructure: Advancing a resilient circular supply chain," *Technovation*, vol. 148, p. 103329, 2025, doi: https://doi.org/10.1016/j.technovation.2025.103329.

[67] L. Abualigah, E. S. Hanandeh, R. A. Zitar, C.-L. Thanh, S. Khatir, and A. H. Gandomi, "Revolutionizing sustainable supply chain management: A review of metaheuristics," *Eng. Appl. Artif. Intell.*, vol. 126, p. 106839, 2023, doi: https://doi.org/10.1016/j.engappai.2023.106839.