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Mapping and Evaluating the Pomelo Supply Chain: A SCOR-Based Case Study from South Sulawesi Province

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ABSTRACT

As the world's sixth-largest citrus producer, with pomelo as a strategically prioritized commodity, Indonesia faces critical supply chain inefficiencies where post-harvest losses in horticultural commodities can reach up to 40% in the absence of effective supply chain management, compounded by fragmented distribution networks. This study aims to analyze the configuration and evaluate the operational performance of the pomelo supply chain in its primary production center in Ma'rang Subdistrict, South Sulawesi. Employing a case study approach, this study collected data from 30 farmers (simple random sampling) and marketing actors (snowball sampling), analyzed using the Food Supply Chain Networks (FSCN) framework to map product, financial, and information flows, and the Supply Chain Operations Reference (SCOR) model metrics for reliability, responsiveness, flexibility, and asset management. The results reveal four distribution flows with high dependency on the Javanese market (65%). SCOR analysis identified dual structural constraints: demand fulfillment was consistently constrained at 53% across all channels due to stem borer pest attacks, while inter-island distribution exhibited below-parity performance characterized by extended lead times and elevated damage rates attributed to logistical complexity. These findings validate the integrated FSCN-SCOR framework as an effective diagnostic tool for identifying multidimensional supply chain vulnerabilities in smallholder agri-food systems, demonstrating that logistical complexity, rather than transaction volume, is the primary determinant of financial efficiency across supply chain actors. The study recommends prioritizing integrated pest management (IPM) programs and logistics optimization to enhance productivity and long-term competitiveness.

Keywords: *Agri-food Supply Chain, FSCN, Pomelo, SCOR Model, Supply Chain Performance.*

BACKGROUND

The horticultural sector serves as a primary driver of economic development and environmental sustainability globally. Within this sector, citrus stands as one of the world's most significant fruit crops, cultivated in over 140 countries (Food and Agriculture Organization of the United Nations, 2021). Indonesia plays a pivotal role in global citrus production, ranking sixth worldwide with an output of 2.92 million tons, contributing approximately 6.2% to global production (FAO, 2023). National citrus cultivation, dominated by pomelo (Citrus maxima) and sweet orange, encompasses 67.31 thousand hectares with a production volume of 2.68 million tons (Kementerian Pertanian, 2023).

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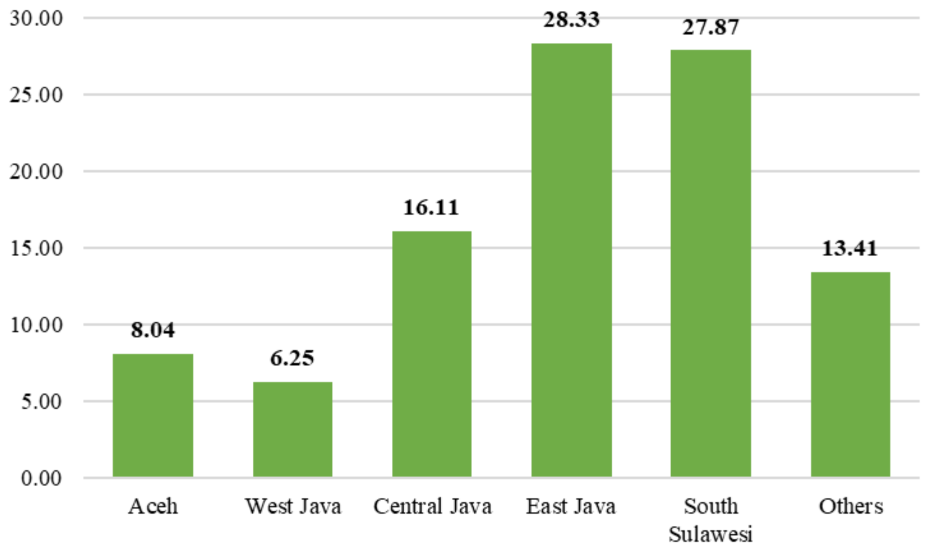

Figure 1. Average Percentage of Indonesian Pomelo Production by the Top 5 Provinces (2019-2023)
Source: Kementerian Pertanian (2024)

The strategic importance of pomelo is underscored by its designation as a priority commodity by the Directorate General of Horticulture (Decree of the Ministry of Agriculture No. 511/Kpts/PD.310/9/2006). As depicted in Figure 1, which illustrates the national distribution of pomelo production, South Sulawesi Province emerges as a primary production hub, contributing 27.87% to Indonesia's total output (Kementerian Pertanian, 2024). Within this province, Pangkep District is the dominant producer, accounting for 94.7% of regional production (DTPH-BUN Sulawesi Selatan, 2024). Ma'rang Subdistrict, a historical cultivation center in Pangkep, is particularly significant. However, as detailed in Table 1, which summarizes production trends from 2019 to 2023, the subdistrict experienced a significant 31.3% production decline in 2023. This decline is attributed to prolonged drought, pest infestations, and a high proportion of unproductive trees, highlighting the systemic vulnerabilities faced by producers.

Table 1. Pomelo Production by Subdistrict in Pangkep District

No.	Subdistrict	Years (Tons)				
		2019	2020	2021	2022	2023
1	Balocci	98.40	192.00	27.00	61.00	77.00
2	Minasatene	2.80	19.00	57.00	25.00	22.50
3	Tondong Tallasa	22.20	17.10	140.00	85.00	80.20
4	Pangkajene	36.80	35.00	20.00	20.00	28.00
5	Bungoro	7.00	7.30	150.00	35.00	13.54
6	Labakkang	4,841.20	4,485.00	6,110.00	4,410.00	3,760.00
7	Ma'rang	13,294.10	22,110.00	22,354.00	22,361.00	15,361.706
8	Segeri	803.00	1,130.00	660.00	178.00	19.60
9	Mandalle	5,570.80	225.00	44.00	31.00	10.05
	Total	24,703.00	28,220.00	29,562.00	27,197.00	19,372.596
	Growth (%)		14.20%	4.80%	-8%	-28.80%

Source: Dinas Pertanian Kab. Pangkep (2024)

The economic potential of pomelo in Ma'rang Subdistrict is substantial, with distribution networks extending to Java (65%), local markets in Makassar (25%), and Kalimantan (10%).

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However, this potential is constrained by critical supply chain vulnerabilities. The perishable nature of the commodity and its relatively short shelf life, combined with inadequate post-harvest handling, contribute to significant yield losses. Without effective supply chain management, post-harvest losses can reach up to 40% (Sanjaya & Perdana, 2019). Market uncertainty may further exacerbate excessive fluctuations in product stock, potentially resulting in supply shortages or surpluses.

The supply chain serves as a critical linkage mechanism connecting actors from production to distribution stages, thereby influencing product availability in the market (Asadikah & Sultan, 2023). Furthermore, supply chain management optimization can assist in managing frequent demand fluctuations, reducing the risk of stock shortages or surpluses (Monoarfa et al., 2022). The structure and mechanisms of agricultural supply chains not only highlight technical aspects but also encompass inherent challenges, including limited market access for farmers, non-transparent market information, and low technology adoption in distribution systems (Apriyani et al., 2023).

Research on horticultural commodity supply chains has expanded considerably over the past decade. In Indonesia, studies on horticultural supply chains predominantly address post-harvest issues, value-added distribution inequities, weak inter-actor coordination, and inefficiencies in product and information flows within fresh commodity distribution systems (Fauziana et al., 2023; Saptana et al., 2025; Azka et al., 2019; Haryono et al., 2024). With specific regard to pomelo, existing studies have addressed not only agronomic and productivity aspects but also marketing and farm income analyses. Nevertheless, studies that comprehensively analyze the supply chain from upstream to downstream remain relatively limited.

The application of standardized frameworks for evaluating the performance of local horticultural supply chains remains relatively scarce in the literature. More specifically, no study has comprehensively analyzed the structure and performance of the pomelo supply chain in South Sulawesi Province, despite the province being one of the primary national production centers and Pangkep District contributing approximately 94.7% of regional production. To address this gap, this study integrates the Food Supply Chain Networks (FSCN) framework to map actors and flows within the supply chain network with the Supply Chain Operations Reference (SCOR) model to evaluate performance based on five core processes: plan, source, make, deliver, and return (Supply Chain Council, 2006; Van Der Vorst, 2006). This integrated approach enables the systematic identification of structural bottlenecks alongside the measurement of operational efficiency.

RESEARCH METHODS

This study employed a quantitative-descriptive research design to analyze the structure and evaluate the performance of the pomelo supply chain. The research location was purposively selected in Ma'rang Subdistrict, Pangkep District, South Sulawesi, Indonesia, based on its status as the primary pomelo production center, contributing approximately 79.29% of the district's total output, thereby providing a representative context for in-depth supply chain analysis.

The study population encompassed all pomelo farmers and marketing actors within the supply chain network of Ma'rang Subdistrict. A mixed sampling approach was implemented to ensure both representativeness and practicality. For the farmer population, probability sampling using a simple random sampling technique was applied, with a sample size of 30 farmers determined based on the Central Limit Theorem principle, which ensures normal distribution approximation for samples ≥30. For marketing actors, where population frames were unavailable, non-probability sampling using a snowball sampling technique was utilized to identify key informants through respondent referrals, yielding 7 regional wholesalers and 5 retailers as research informants.

Data collection employed method triangulation through structured interviews using questionnaires, direct field observations, and documentary analysis of official reports and relevant literature. Data analysis proceeded in two sequential stages corresponding to the research objectives.

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The initial stage involved a descriptive analysis of the supply chain structure using the Food Supply Chain Networks (FSCN) framework adapted from Van Der Vorst (2006), which examines three critical flows: product flow (physical movement of pomelo), financial flow (payment transactions), and information flow (market demand and price information exchange).

The subsequent stage measured operational performance using the Supply Chain Operations Reference (SCOR) model version 12.0 Level 1. The analysis followed a systematic procedure: identifying key performance indicators (KPIs) aligned with four performance attributes, namely Reliability, Responsiveness, Flexibility, and Asset Management; assigning weights based on benchmark values; calculating the overall supply chain performance; and drawing conclusions (Nurmahdy et al., 2020). The performance indicators employed in this study were adopted from previous literature (Arfian, 2022; Apriyani et al., 2018; Bolstorff & Rosenbaum, 2011) as follows:

1. Delivery Performance

   Delivery performance is the percentage of products delivered to the destination on time according to customer expectations, expressed as a percentage (%).

$$Delivery\ performance = \frac{Orders\ delivered\ on\ time}{Total\ orders\ delivered} \times 100\%$$

2. Standards Conformity

   Standards conformity reflects the ability of farmers or traders to fulfill customer orders in accordance with the quality standards expected by the customer, expressed as a percentage (%).

$$\text{Standards conformity } = \frac{Conforming\ deliveries}{Total\ orders\ delivered} \times 100\%$$

3. Fulfillment of Demand

   Fulfillment of demand is the percentage of product orders fulfilled in accordance with customer demand without requiring the customer to wait, expressed as a percentage (%).

$$Fulfillment\ of\ Demand = \frac{Demand\ fulfilled\ without\ waiting}{Total\ customer\ orders} \times 100\%$$

4. Flexibility

   Flexibility is the time required to respond to increases or decreases in demand without incurring penalty costs, expressed in days.

$$Flexibility = Source\ cycle + Pack\ cycle + Deliver\ cycle$$

5. Lead Time

   Lead time is the time elapsed from when a customer places a request until the product is received by the customer, expressed in days.

6. Demand Fulfillment Cycle

   The demand fulfillment cycle is the total time from when a customer places a request until the desired product is received, expressed in days.

$$Demand\ Fulfillment\ Cycle = Planning\ time + Packing\ time + Delivery\ time$$

7. Daily Supply

   Daily supply is the duration for which available product stock can meet customer needs without receiving additional supply, expressed in days. Average inventory and daily demand are measured in product units (pieces, kilograms, or tons) depending on the commodity type.

$$Daily\ Stock = \frac{Average\ inventory}{Average\ demand}$$

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8. Cash to Cash Cycle

The cash-to-cash cycle describes the flow of money between supply chain members, from the point at which a member pays the preceding member to the point at which payment is received from the subsequent member, expressed in days.

$$CTCC = Average\ inventory\ period + Days\ receivable\ from\ customers - Days\ payable\ to\ suppliers$$

The benchmark classification, as shown in Table 2, categorizes performance into three tiers: Superior (excellent performance), Advantage (good performance), and Parity (average or competitive performance). This comparative framework enables a systematic diagnostic assessment of supply chain strengths and operational weaknesses.

Table 2. Performance Measurement Criteria and Benchmark Values for the Pomelo Supply Chain (Adapted from Food Scorecard).

SCM Attributes	Performance Attributes	Benchmark		
		Parity	Advantage	Superior
External Performance				
Reliability	Delivery Performance (%)	85.00 – 89.00	90.00 – 94.00	≥ 95.00
	Standards Conformity (%)	80.00 – 84.00	85.00 – 89.00	≥ 90.00
	Fulfillment of Demand (%)	94.00 – 95.00	96.00 – 97.00	≥ 98.00
Flexibility	Supply Chain Flexibility (days)	42.00 – 27.00	26.00 – 11.00	≤ 10.00
Responsiveness	Lead Time (days)	7.00 – 6.00	5.00 – 4.00	≤ 3.00
	Demand Fulfillment Cycle (days)	8.00 – 7.00	6.00 – 5.00	≤ 4.00
Internal Performance				
Asset	Daily Supply (days)	27.00 – 14.00	13.00 – 0.01	= 0.00
	Cash to Cash Cycle (days)	45.00 – 34.00	33.00 – 21.00	≤ 20.00

Source: Adapted from Arfian (2022); Apriyani et al. (2018); (Bolstorff & Rosenbaum, 2011).

RESULTS AND DISCUSSION

Structural Analysis of the Pomelo Supply Chain Using the FSCN Framework

This study applies the Food Supply Chain Networks (FSCN) framework developed by Van Der Vorst (2006) to structurally analyze the pomelo supply chain in Ma'rang Subdistrict, identifying a network comprising 42 key actors, including 30 farmers, 7 regional wholesalers, and 5 retailers. The supply chain structure encompasses primary members, namely farmers, regional wholesalers, and retailers, as well as secondary members including inter-island traders, inter-district traders, agricultural input providers, agricultural extension workers, and logistics service providers.

Despite serving extensive markets reaching Java and Kalimantan, the supply chain faces critical structural vulnerabilities characterized by declining productivity attributable to stem borer infestations and stem rot disease, which have been documented to reduce crop yields by up to 50% (Puspita et al., 2023). These production constraints, compounded by capital limitations and reliance on conventional technology among smallholder farmers, undermine the supply chain's capacity to

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meet downstream market demand, a bottleneck that will be examined further through product, financial, and information flow analyses in the subsequent sections.

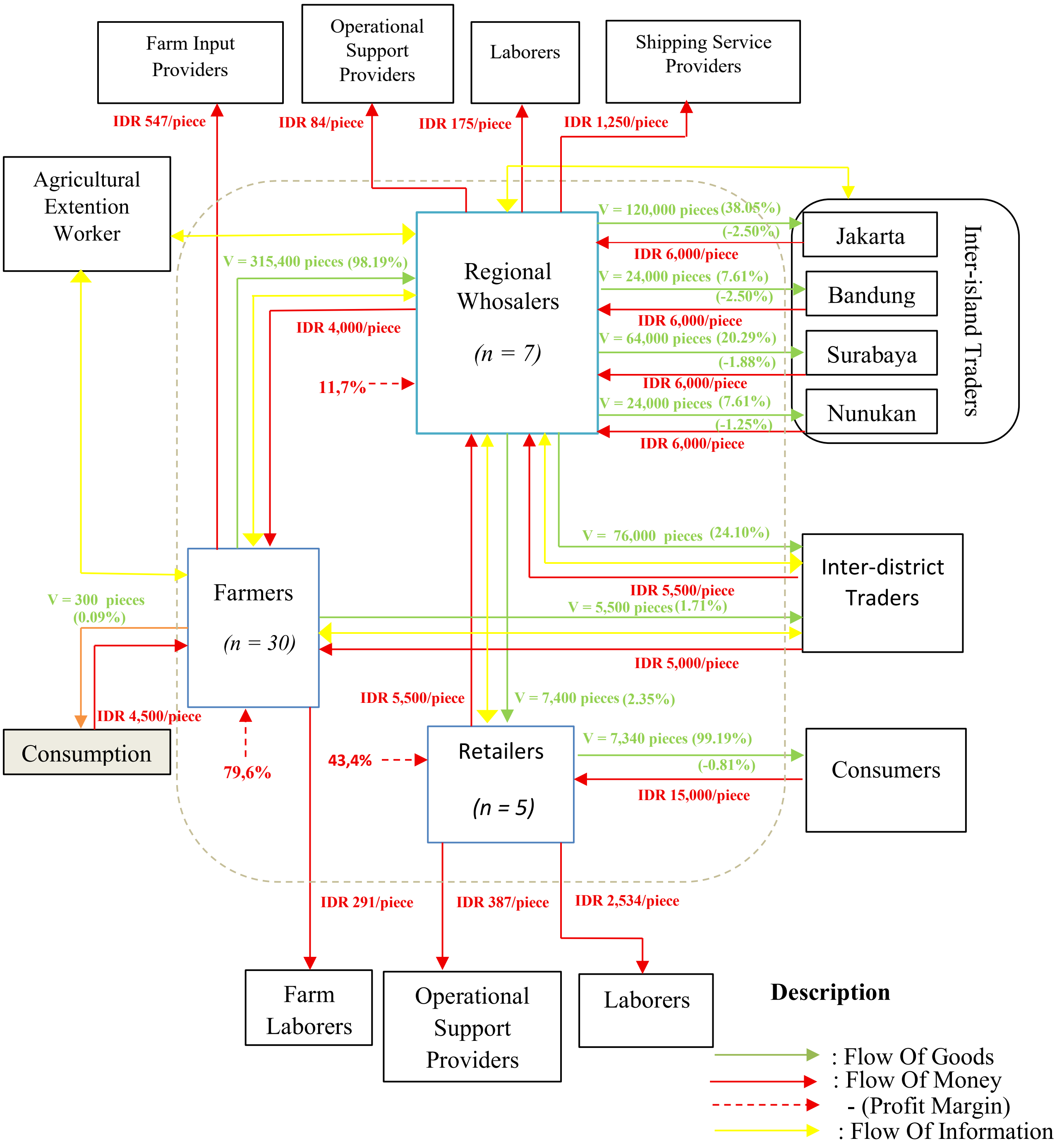

Figure 2. Pomelo Supply Chain Flow in Ma'rang Subdistrict, Pangkep District, 2025.
Source: Primary Data Processed, 2025

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Product Flow Analysis

The product flow originates from farmers, as illustrated in Figure 2. Of total pomelo production, 98.19% is distributed to regional wholesalers, 1.71% is sold to inter-district traders, and the remaining 0.09% is retained for personal consumption. The majority, 73.56% of total production, is distributed by regional wholesalers to inter-island markets. However, this distribution generates damage rates of up to 8.13%, with the highest damage occurring in shipments to Jakarta and Bandung due to extended shipping distances and prolonged transit times. Conversely, the lowest damage rates were recorded in shipments to Nunukan, attributable to shorter distances and the use of sack packaging. Where damage is significant, the resulting financial losses are borne by regional wholesalers as a recurring cost burden that suppresses their profitability, as elaborated further in the financial flow analysis. Unlike regional wholesalers, farmers are not financially affected by damage losses, as pomelo sales are conducted at the farm level prior to the distribution process. Furthermore, 24.10% of total sales are directed to inter-district traders. Retailers receive 2.35% of total supply from regional wholesalers, incurring a damage rate of 0.81%, which underscores the perishable nature of the commodity, a challenge also highlighted by Ali et al. (2025).

Delivery timeliness varies considerably. Transportation from farmers to regional wholesalers, who also conduct harvesting, requires an average of 10 hours with a capacity of 8,000 fruits per delivery, while direct procurement by inter-district traders takes 4-5 hours with a capacity of 500 fruits per delivery. The most significant challenge is inter-island distribution, where sea shipments require approximately seven days and carry a risk of damage to 100-500 fruits per delivery, attributable to the perishable nature of the commodity and limited cold chain services. This is consistent not only with international findings by Gidado et al. (2024) and Kaur & Watson (2024), but also with domestic evidence by Depari (2024), who highlights transportation-related damage as a critical vulnerability point in fresh produce supply chains in Indonesia. In contrast, deliveries to inter-district traders require 3-4 hours, while distribution to retailers takes approximately 30 minutes.

Financial Flow Architecture

The financial flow across the pomelo supply chain in Ma'rang Subdistrict moves unidirectionally from consumers to farmers, as illustrated in Figure 2. Payment transactions are conducted in cash for all local actors, while inter-island traders exclusively use bank transfers, with settlement occurring within one day for local transactions and three days upon arrival for inter-island shipments.

At the farmer level, financial outflows commence with production input expenditures, while inflows are generated through pomelo sales to regional wholesalers and inter-district traders, with a small portion retained for personal consumption. The relatively high profit margin of 79.6% reflects a low cost structure typical of smallholder farming, characterized by family-based labor, privately owned land, and reliance on conventional technology, rather than strong market positioning (Pariasa & Hardana, 2024).

At the wholesaler level, financial outflows are dominated by pomelo procurement and inter-island shipping costs, representing 78% of non-procurement operational expenditure, while inflows derive from sales across inter-island and local markets. Damage incurred during inter-island shipments generated economic losses borne by regional wholesalers, evidencing the financial vulnerability inherent in long-distance distribution of perishable commodities (Ali et al., 2025; Mohan et al., 2023). Consequently, despite handling the largest financial volume in the supply chain, regional wholesalers recorded the lowest profit margin at 11.7%.

At the retail level, financial outflows are limited to pomelo procurement and minor operational costs, while inflows derive entirely from direct consumer sales. Despite negligible damage losses, retailers maintained the second highest profit margin at 43.4%, reflecting the financial advantage of

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short-distance distribution and direct consumer access (Iacovone & McKenzie, 2022; Septian & Nasrul, 2021).

Information Flow Dynamics

Information flow operates through telephone communication and face-to-face meetings among supply chain actors, as illustrated in Figure 2. Farmers notify traders of harvest readiness but assume a passive role in price negotiation, while regional wholesalers act as price determinants, a power asymmetry that has been widely documented in smallholder horticultural supply chains (Kumar et al., 2025). This asymmetry fails to provide sufficient incentives for farmers to address productivity constraints, ultimately undermining the overall demand fulfillment capacity of the supply chain.

At the wholesaler level, coordination of quantities and delivery schedules with inter-island traders, who frequently dictate market prices and quality standards, generates complexity that affects supply chain responsiveness and lead time performance, particularly in long-distance distribution channels. Agricultural extension workers provide technical cultivation guidance but have a limited role in market linkage, while the entry of pomelo from neighboring districts further compounds market uncertainty (Pratiwi et al., 2025). Collectively, these information asymmetries constitute a structural constraint on supply chain performance, which will be further quantified in the subsequent SCOR-based analysis.

Performance Analysis of Pomelo Supply Chain Flows Using the SCOR Model

Performance measurement across four identified flows revealed a critical trade-off between market reach and operational efficiency.

Supply Chain Flow I: Farmers → Regional Wholesalers → Inter-island Traders

The following are the results of supply chain performance measurements using the SCOR model in the first supply chain flow.

Table 3. First Stream Supply Chain Performance Calculation Results

SCM Attributes	Performance Attributes	Farmers to regional wholesalers	Categories	Regional wholesalers to inter-island traders	Categories
External Performance					
Reliability	Delivery Performance (%)	100.00	Superior	100.00	Superior
	Standards Conformity (%)	99.00	Superior	97.00	Superior
	Fulfillment of Demand (%)	53.00	Below Parity	60.00	Below Parity
Flexibility	Supply Chain Flexibility (days)	2.00	Superior	11.00	Advantage
	Lead Time (days)	2.00	Superior	10.00	Below Parity
Responsiveness	Demand Fulfillment Cycle (days)	2.00	Superior	10.00	Below Parity
Internal Performance					
Asset	Daily Supply (days)	0.52	Advantage	0.55	Advantage
	Cash to Cash Cycle (days)	1.52	Superior	3.55	Superior

Source: Primary Data Processed, 2025

This flow demonstrated the most constrained performance. Demand fulfillment was critically low (53% and 60%), falling below the parity standard. The lead time (10 days) and order fulfillment cycle (11 days) were sub-optimal due to complex maritime logistics, increasing product damage risk as highlighted by Haque et al. (2025).

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Supply Chain Flow II: Farmers → Regional Wholesalers → Inter-district Traders

The following are the results of supply chain performance measurements using the SCOR model on the second supply chain flows.

Table 4. Second Stream Supply Chain Performance Calculation Results

Chain II					
SCM Attributes	Performance Attributes	Farmers to regional wholesalers	Categories	Regional wholesalers to inter-district traders	Categories
External Performance					
Reliability	Delivery Performance (%)	100.00	Superior	100.00	Superior
	Standards Conformity (%)	99.00	Superior	100.00	Superior
	Fulfillment of Demand (%)	53.00	Below Parity	100.00	Superior
Flexibility	Supply Chain Flexibility (days)	2.00	Superior	3.00	Superior
	Lead Time (days)	2.00	Superior	2.00	Superior
Responsiveness	Demand Fulfillment Cycle (days)	2.00	Superior	2.00	Superior
Internal Performance					
Asset	Daily Supply (days)	0.52	Advantage	1.00	Advantage
	Cash to Cash Cycle (days)	1.52	Superior	3.00	Superior

Source: Primary Data Processed, 2025

Performance improved significantly. The second segment achieved 100% demand fulfillment (superior category). Despite the upstream constraint of 53% demand fulfillment due to productivity issues, operational metrics like lead time and flexibility showed enhanced performance due to simpler logistics.

Supply Chain Flow III: Farmers → Regional Wholesalers → Retailers

The following are the results of supply chain performance measurements using the SCOR model on the third supply chain flow.

Table 5. Third Stream Supply Chain Performance Calculation Results

Chain III							
SCM Attributes	Performance Attributes	Farmers to regional wholesalers	Categories	Regional wholesalers to retailers	Categories	Retailers to consumers	Categories
External Performance							
Reliability	Delivery Performance (%)	100.00	Superior	100.00	Superior	100.00	Superior
	Standards Conformity (%)	99.00	Superior	100.00	Superior	100.00	Superior
	Fulfillment of Demand (%)	53.00	Below Parity	100.00	Superior	100.00	Superior
Flexibility	Supply Chain Flexibility (days)	2.00	Superior	2.00	Superior	1.00	Superior
	Lead Time (days)	2.00	Superior	1.00	Superior	1.00	Superior
Responsiveness	Demand Fulfillment Cycle (days)	2.00	Superior	1.00	Superior	1.00	Superior

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SCM Attributes	Performance Attributes	Farmers to regional wholesalers	Categories	Regional wholesalers to retailers	Categories	Retailers to consumers	Categories
Internal Performance							
Asset	Daily Supply (days)	0.52	Advantage	0.73	Advantage	1.00	Advantage
	Cash to Cash Cycle (days)	1.52	Superior	1.73	Superior	1.00	Superior

Source: Primary Data Processed, 2025

This flow exhibited the most efficient performance within the local distribution ecosystem. The final segment achieved 100% superior demand fulfillment. Operational dimensions exhibited enhanced performance due to reduced distribution distances, confirming findings by Raftowicz et al. (2024) that shorter chains are more efficient.

Supply Chain Flow IV: Farmers → Inter-district Traders

The following are the results of supply chain performance measurements using the SCOR model on the fourth supply chain flow.

Table 6. Fourth Stream Supply Chain Performance Calculation Results

Chain IV			
SCM Attributes	Performance Attributes	Farmers to inter-district traders	Categories
External Performance			
Reliability	Delivery Performance (%)	100.00	Superior
	Standards Conformity (%)	99.00	Superior
	Fulfillment of Demand (%)	83.00	Below Parity
Flexibility	Supply Chain Flexibility (days)	2.00	Superior
	Lead Time (days)	2.00	Superior
Responsiveness	Demand Fulfillment Cycle (days)	2.00	Superior
Internal Performance			
Asset	Daily Supply (days)	0.83	Advantage
	Cash to Cash Cycle (days)	1.83	Superior

Source: Primary Data Processed, 2025

This streamlined flow showed optimal operational efficiency across delivery and responsiveness metrics. However, it confirmed the production bottleneck, as demand fulfillment remained at 83%. This aligns with Septian & Nasrul (2021), who found minimized chains enhance efficiency but cannot resolve upstream constraints.

Performance analysis across the four identified distribution channels reveals a critical trade-off between market access and operational efficiency. Inter-island distribution exhibited the most vulnerable performance, with extended lead times and elevated damage rates attributable to maritime logistical complexity and the absence of cold chain infrastructure, consistent with Kaur & Watson (2024). Conversely, local distribution channels demonstrated markedly superior performance, corroborating Raftowicz et al. (2024) on the efficiency advantages of shortened supply chains for perishable commodities. Critically, demand fulfillment remained consistently constrained at 53% across all channels, identifying production-level constraints – specifically stem borer infestations and stem rot disease, as the primary root cause of supply chain underperformance, independent of distribution channel complexity.

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Theoretical and Practical Implications

This study identifies a dual challenge in the pomelo supply chain: a primary constraint characterized by low demand fulfillment (53%) rooted in production-level limitations, and secondary inefficiencies in distribution that intensify with increasing supply chain complexity. This is consistent with the conceptual foundation established by Van Der Vorst (2006), who posits that supply chain business activities are a series of systematically organized activities that generate outputs in the form of physical products, services, and information directed toward specific market segments or consumers. These findings corroborate Apriyani et al. (2023) and Dzulfikri et al. (2024), who similarly identified upstream production constraints – rather than distribution failures – as the primary driver of performance gaps in smallholder agricultural supply chains in Indonesia. At the international level, Haque et al. (2025) further corroborate that logistical complexity remains the dominant efficiency constraint in export-oriented horticultural supply chains.

Beyond confirming existing findings, this study contributes new insights by integrating the FSCN and SCOR frameworks: logistical complexity, rather than transaction volume or revenue scale, is the primary determinant of financial efficiency, as evidenced by profit margins of 79.6% for farmers, 11.7% for wholesalers, and 43.4% for retailers. This extends Nurmahdy et al. (2020) and Raftowicz et al. (2024) by quantifying the financial costs of longer distribution chains through per-actor profitability analysis. The persistent price asymmetry documented by Kumar et al. (2025) and Herzberg et al. (2022) is corroborated through information flow analysis, while Chand et al. (2021) and Iacovone & McKenzie (2022) substantiate that shortened distribution channels yield higher financial returns at the retail level. Overall, these findings imply that interventions should prioritize integrated pest management, followed by logistics optimization for inter-island distribution, to enhance the overall resilience and competitiveness of the supply chain.

CONCLUSION AND SUGGESTION

This study identifies two structural constraints limiting the performance of the pomelo supply chain in Ma'rang Subdistrict: phytosanitary barriers on the production side and logistical complexity on the distribution side. The integration of the FSCN-SCOR framework demonstrates that logistical complexity, rather than transaction volume or value, is the primary determinant of financial efficiency across supply chain actors, while information asymmetry weakens farmers' bargaining position and overall demand fulfillment capacity. The principal academic contribution of this study lies in demonstrating that the integrated FSCN-SCOR framework is capable of simultaneously diagnosing multidimensional supply chain vulnerabilities, something that neither framework can achieve independently.

To strengthen the resilience and competitiveness of the pomelo supply chain, targeted policy interventions and institutional support are essential. Implementation of Integrated Pest Management (IPM) protocols is the primary priority, supported by agricultural extension workers and government facilitation in providing effective pesticides, technical training, and plant rejuvenation programs. At the distribution level, the use of high-capacity truck transportation (±13,000 fruits/trip) and protective packaging such as PE foam net or bubble wrap are recommended to reduce lead times and minimize damage in long-distance distribution. Further research is needed to explore environmentally friendly pest control methods, integrated logistics optimization, and to test the generalizability of the FSCN-SCOR framework for other horticultural commodities with similar inter-island distribution characteristics.

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