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Optimizing Multimodal Transportation and the Role of Freight Forwarding in the Palm Oil (CPO) Supply Chain in Indonesia

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Abstract: This study aims to analyze the role of multimodal transportation and freight forwarding in optimizing the Crude Palm Oil (CPO) supply chain in Indonesia, including logistical challenges, transportation mode efficiency, and the impact of digital technology and government regulations. Employing a descriptive qualitative method with a systematic literature review, the research findings indicate that multimodal transportation and freight forwarding are crucial for logistics cost efficiency, despite facing implementation hurdles such as fragmentation and manual processes. The upstream CPO supply chain is fragmented with inadequate infrastructure, yet shorter distribution patterns and company-managed transportation prove more efficient. Technologies like the Internet of Things (IoT) and blockchain hold significant potential to enhance transparency and efficiency. In conclusion, optimizing the CPO supply chain necessitates infrastructure investment, farmer empowerment, regulatory refinement, and widespread adoption of digital technologies to achieve Indonesia's Logistics Vision 2025.

Keywords: CPO Supply Chain, Multimodal Transportation, Freight Forwarding, Logistics Efficiency, Digital Technology.

INTRODUCTION

The palm oil industry plays a strategic and vital role in the Indonesian economy. As the world's largest *producer of Crude Palm Oil* (CPO), Indonesia recorded significant production, reaching 46.99 million tons of palm oil in 2023, with most of it destined for export (Agricultural Data and Information Systems Center, 2024). This sector makes a significant contribution to Gross Domestic Product (GDP), non-oil and gas exports, and job creation for more than 16 million people, especially in rural areas (Nasution & Ningsih, 2025; Yassar et al., 2025). The majority of oil palm plantations are concentrated on the islands of Sumatra, Kalimantan, and Sulawesi (Aznur, T. Z., Hasibuan, M. F. A., Wahyuni, R., & Ginting, H. 2024; Yuanda et al., 2025).

Despite its tremendous economic potential, the palm oil industry in Indonesia is faced with complex logistical challenges. Indonesia's logistics index is still lagging behind other ASEAN countries, with logistics costs reaching 24% of *the Gross National Product* (GNP) (Wibowo & Chairuddin, 2017). The fundamental problems that contribute to these high costs and inefficiencies include government bureaucratic inefficiency, corrupt practices, and inadequate infrastructure availability, including the low quality of port infrastructure (Sitorus & Sony, 2016; Wibowo & Chairuddin, 2017). This suboptimal infrastructure condition directly extends the delivery time of goods and increases the overall operational costs of logistics (Sitorus & Sony, 2016).

In the geographical context of Indonesia as a vast archipelagic country, consisting of more than 13,000 islands, multimodal transportation is a key component in the logistics system (Kalangi et al., 2024). Multimodal transportation is defined as the movement of goods that uses at least two different modes of transportation (land, sea, air, rail) under a single contract and transportation document, from the point of origin to the final destination (Darmayanti et al., 2023; Kalangi et al., 2024; Sitorus & Sony, 2016). This system is essential to address the geographical challenges inherent in an archipelagic country like Indonesia. The role *of the Freight Forwarder* in this system is crucial, often referred to as the "architect" in the delivery of goods (Kalangi et al., 2024). *Freight forwarders* are responsible for taking care of all activities necessary for the delivery and receipt of goods, ranging from transportation procurement, warehousing services, cargo consolidation, to customs management (Kalangi et al., 2024). They function as consultants, proxies, coordinators, and supervisors of the entire shipping process, ensuring goods get to their destination safely and efficiently (Kalangi et al., 2024).

The legal framework governing multimodal transportation in Indonesia has been established through Government Regulation (PP) No. 8 of 2011 concerning Multimodal Transportation, which integrates the provisions of four Laws in the field of transportation (Darmayanti et al., 2023; Kalangi et al., 2024). Nonetheless, the implementation of intermodal transportation in Indonesia still faces significant obstacles, including fragmented responsibilities, lack of integrated single transportation documents, and manual processes that lead to delays (Darmayanti et al., 2023; Wibowo & Chairuddin, 2017). This shows that there is a gap between formal regulation and operational reality.

This report aims to analyze in depth the role of multimodal transportation and *freight forwarding* in optimizing the CPO supply chain in Indonesia. Specifically, this study will answer the following questions:

a. What is the role of multimodal transportation and *freight forwarding* in optimizing the CPO supply chain in Indonesia?
b. What are the main challenges faced in CPO logistics in Indonesia?
c. How is the efficiency of the current CPO transportation mode and its supporting infrastructure?
d. How can digital technology and government regulations affect the transparency and efficiency of the CPO supply chain?
e. What strategies can be recommended to improve the efficiency and sustainability of the CPO supply chain in Indonesia?

The supporting theories used in this analysis include the concept of *supply chain management* which discusses the flow of products, information, and finance (Munawarah et al., 2024; Primalasari et al., 2017), as well as logistics optimization theories that include analytical methods such as *Data Envelopment Analysis* (DEA) and *Linear Programming* for transportation efficiency (Yuanda et al., 2025; Aryawan, 2010). In addition, the concept of logistics cost efficiency and the role of digital technologies such as *the Internet of Things* (IoT) and *blockchain* in increasing transparency are also theoretical foundations (Nasution &

Ningsih, 2025; Wibowo & Chairuddin, 2017). Understanding the role of intermediaries such as middlemen and *ramps* in the supply chain structure is also based on the analysis of distribution patterns and marketing margins (Aznur et al., 2024).

METHOD

The research method used in this article is a qualitative descriptive approach with a focus on literature studies. This research is oriented towards an in-depth analysis of various aspects of supply chain management in agribusiness, especially as it relates to palm oil production in developing countries. The data was collected through a systematic literature search in various leading scientific databases, including the Web of Science and Google Scholar. Keywords used in the search process included "palm oil supply chain management" and "palm oil agribusiness". The literature analyzed includes relevant empirical studies and meta-analyses, with priority on publications published in the last five years, i.e. since 2020 (Nasution & Ningsih, 2025).

The research procedure involves careful review and observation of the journals that have been identified. Each article is analyzed to extract key information regarding challenges, opportunities, optimization strategies, and the role of digital technologies such as *the Internet of Things* (IoT) and *blockchain* in the palm oil supply chain. The collected data is then narratively rearranged to form a comprehensive argument and findings in this article. This approach allows for the synthesis of information from multiple sources to provide in-depth insights into optimizing palm oil supply chain management in developing countries, without conducting primary data collection directly on the ground.

RESULTS AND DISCUSSION

The Role of Multimodal Transportation and Freight Forwarding in CPO Supply Chain Optimization

Multimodal transportation and *freight forwarding* play a crucial role in optimizing the CPO supply chain in Indonesia. Multimodal transportation, defined as the use of at least two different modes of transportation under a single contract, is an important component of the national logistics system (Darmayanti et al., 2023; Kalangi et al., 2024; Sitorus & Sony, 2016). The goal is to realize *a one-stop service* with *a single seamless service* (S3) indicator, namely *a single operator*, *a single tariff*, and *a single document* (Sitorus & Sony, 2016).

Research shows that the Multimodal Transportation System has a close relationship with Logistics Cost Efficiency, with a correlation coefficient (r) of 0.89. The influence of multimodal systems on logistics cost efficiency according to respondents is 80%, indicating that an increase in the performance of multimodal systems by 1% can increase logistics cost efficiency by 1.12 times (Wibowo & Chairuddin, 2017). This is in line with the goals of Indonesia's Logistics Vision 2025 which seeks to reduce national logistics costs and increase competitiveness (Sitorus & Sony, 2016).

However, the implementation of multimodal transportation in Indonesia still faces obstacles. There are obstacles in the implementation of single responsibility and the use of one transportation document, as well as the document completion process that is still manual and time-consuming (Darmayanti et al., 2023; Wibowo & Chairuddin, 2017). The role *of freight forwarders* as shipping "architects" is crucial in overcoming this complexity, as they are responsible for taking care of all necessary activities, from transportation procurement, warehousing, to customs handling (Kalangi et al., 2024). They function as consultants, proxies, coordinators, and supervisors of the entire delivery process (Kalangi et al., 2024).

Main Challenges in CPO Logistics in Indonesia

CPO logistics in Indonesia faces various significant challenges that affect efficiency and competitiveness. One of the main obstacles is the limited fleet of trucks to transport the required volume of cargo, which leads to delivery delays and decreased productivity (Fitriani et al., 2023).

At the upstream level, small-scale farmers face the problem of limited access to funding to purchase quality production inputs, such as seeds and fertilizers, which has an impact on low productivity and dissatisfaction with the selling price of Fresh Fruit Bunches (FFB) (Nasution & Ningsih, 2025). The quality of FFB produced is often not optimal due to less efficient processing and the long distance between the land and the processing plant, which leads to lower selling prices (Arif et al., 2021; Nasution & Ningsih, 2025).

Transportation infrastructure is also a major obstacle, with about 61% of road infrastructure poor, causing high transportation costs and hindering farmers' access to markets (Nasution & Ningsih, 2025; Paonganan, 2020). In addition, the lack of coordination and synergy between various supply chain actors (farmers, collectors, factories, distributors) leads to inefficiencies in the management of product and information flows (Nasution & Ningsih, 2025).

The quality of port infrastructure in Indonesia in general is still low, ranking 104th out of 144 countries in the 2012-2013 period, and the absence of a national "hub port" is an obstacle in optimizing multimodal transportation (Sitorus & Sony, 2016). The limited capacity of ports for loading and unloading large ships (*post-panamax*) also has an impact on high transportation costs (Wibowo & Chairuddin, 2017).

Efficiency of CPO Transportation Modes and Supporting Infrastructure

The efficiency of CPO transportation varies greatly depending on the mode and distribution pattern used.

FFB Distribution Pattern and Efficiency

A study in Lalat Regency, North Sumatra, identified two patterns of smallholder palm oil supply chains (Aznur et al., 2024):

1. Supply Chain Pattern I: Middleman → Middleman Farmers → *Ramp* → Palm Oil Mills (PKS).
2. Supply Chain Pattern II: Middlemen → Middlemen → Palm Oil Mills (PKS).

The analysis shows that the Supply Chain Pattern II is more efficient because it has the lowest marketing margin and *the highest farmer's share* (Aznur et al., 2024). The selling price of FFB for farmers in Pattern I is Rp 2,168.87 per kg, while in Pattern II it is Rp 2,340.59 per kg (Aznur et al., 2024). Middlemen use *Carry and L300 pick-up cars (3-4 ton capacity), while* ramps *use* Dumptrucks *(8 ton capacity) (Aznur et al., 2024).*

FFB Transportation Performance (Private Company vs. Community Contractor)

Research in Asahan Regency, North Sumatra, compared the operational efficiency of FFB transport trucks managed by private companies and community contractors (Herviandinata et al., 2025). The results are presented in Table 1.

Table 1. Comparison of FFB Transportation Performance (Company vs. Community)

Treatment	Average Total Cycle Time (minutes)	Average Number of Janjang	Average FFB Weight (kg)	Productivity (tons/day)	Transport Cost (Rp/kg)
Company	74,7	317	5.611,9	19.641,05	15,8
Community	193,1	315	4.707,5	7.061,25	53,4

Source: Herviandinata et al., 2025

Table 1 shows that the transportation system managed by private companies is much more efficient. The company's transport cycle time is shorter (74.7 minutes) than that of community contractors (193.1 minutes), which is due to the consistent loading location and no sorting process at the mill (Herviandinata et al., 2025). The productivity of *dump trucks* of private companies is also higher (19,641.05 tons/day) than that of community contractors (7,061.25 tons/day). This difference in efficiency is reflected in the cost of transporting FFB per kg, where private companies only spend Rp 15.8/kg, while community contractors reach Rp 53.4/kg (Herviandinata et al., 2025).

CPO (Land and Sea Mode) Transportation System:
CPO transportation relies on tank trucks for land modes, with a general capacity of 5000 Liters, 10000 Liters, and 16000 Liters (Aryawan, 2010). The concept *of truck losing* (unloading/loading directly from/to a truck without warehouse storage) is often applied for cost efficiency, although it can prolong the docking time of ships at the port (Aryawan, 2010).
For marine modes, the main choice is tankers and barges (*tug-barges*) (Aryawan, 2010). An efficiency comparison between the two shows the *trade-off* between cost and risk:

a. **Tanker:** It has a large loading space, optimal load protection, high speed, and good stability. However, fuel consumption is greater, requires more crew, and overall operational costs are higher (Aryawan, 2010). It is recommended for delivery during bad weather periods because it is safer (Aryawan, 2010).
b. **Barges:** Less fuel consumption, minimal crew, can sail in shallow waters, and lower operating and initial investment costs. However, the cargo is not protected from the weather, lower speed, less stability, and prone to accidents in choppy waters (Aryawan, 2010).

Cost analysis shows that barges generally have lower costs than tankers for the same route. For example, for the Medan-Tanjung Priok route, the cost of using a tanker is Rp135,394,237,000, while by barge it is Rp79,038,624,000 (Aryawan, 2010).

CPO Loading and Unloading Process:
The process of loading oil palm meal onto barges often uses a *truck unloading system*, where the meal is transported from the warehouse to the dock using a truck, then transferred to a barge by *land crane* and nets. Load compaction with *a loader* is also carried out to maintain balance (Nasyukha et al., 2021). The main obstacles in this process are bad weather (rain) that stops loading, as well as equipment damage such as broken meshes or *jam crane* engines, which cause significant delays (Nasyukha et al., 2021). The unloading of liquid CPO from tankers can be carried out through *the Ship to Ship* (STS), *Conventional Mooring Buoy* (CBM), or *Single Point Mooring* (SPM) methods (Aryawan, 2010).

Main Port Infrastructure:
Ports serve as important "nodes" in multimodal transportation networks. The main destination ports in Java are Tanjung Priok, Tanjung Emas, and Tanjung Perak, while CPO's origin ports include Sampit, Belawan, and Makassar (Aryawan, 2010). However, the quality of Indonesia's port infrastructure is still poor, ranking 104th out of 144 countries in 2012-2013, with limited capacity for large ships and the absence of a national "hub port" (Sitorus & Sony, 2016).

Case Study of CPO Transportation Efficiency (PT. Raja Marga):
Case study on PT. The Raja Marga in Simeulue Regency exhibits common challenges such as delivery delays, potential product losses, and inventory imbalances (Yuanda et al., 2025). Through optimization using *Data Envelopment Analysis* (DEA) and *Linear Programming*

methods, the company is able to significantly reduce transportation expenses. The initial cost of IDR 2,218,360,000 can be optimized to IDR 2,073,350,978, with the Meulaboh route showing the highest efficiency (154.0%) compared to Calang (122.3%) and Labuan Haji (122.8%) (Yuanda et al., 2025).

The Role of Digital Technology and Government Regulation in Transparency and Efficiency

The application of digital technology and government regulatory frameworks has a major impact on the transparency and efficiency of the CPO supply chain.

Role of Digital Technology (Internet of Things and Blockchain):

Internet *of Things* (IoT) technology has been used in oil palm plantations to improve operational efficiency, such as the use of temperature and gas sensors to detect pests, diseases, and monitor soil maturity and fertility. In nurseries, IoT enables watering automation based on *real-time data* from soil moisture and temperature sensors (Al Maududy et al., 2021; Wati et al., 2022).

Blockchain technology offers transformative potential to improve data transparency and security in the CPO supply chain. By recording every transaction in *real-time* and decentralized, *blockchain allows traceability* of the origin of the product back to the source, which increases consumer confidence in the sustainability of the product. The principle of blockchain decentralization also protects data from manipulation, and integration with *smart contracts* can automate business processes such as payments to farmers based on digitally recorded crops (Iqbal et al., 2024). This technology directly addresses the problem of information asymmetry and lack of trust in the CPO supply chain (Nasution & Ningsih, 2025).

Impact of Government Regulations and Policies:

The government uses various policy instruments to balance economic and sustainability interests in the CPO sector. CPO export taxes are used to stabilize the price of cooking oil in the domestic market and ensure the availability of raw materials for the domestic industry, while increasing state revenue (Aryawan, 2010; Nasution & Ningsih, 2025).

CPO transportation activities are strictly regulated to ensure compliance with technical requirements and work safety. Loading and unloading facilities must be separate from public facilities and meet safety standards. Permits for processing, transportation by land, sea, and river, as well as storage of CPO are granted by the Minister of Industry or the Minister of Energy and Mineral Resources, often with a recommendation from the Minister of Energy and Mineral Resources (Aryawan, 2010).

Sustainability certifications such as *the Indonesian Sustainable Palm Oil* (ISPO) and *the Roundtable on Sustainable Palm Oil* (RSPO) are essential to increase the competitiveness of palm oil products in the international market. Certified products have a greater chance of being accepted in the global market, while products without certification are at risk of rejection. The certification process also increases farmers' knowledge of sustainable cultivation practices and productivity (Nasution & Ningsih, 2025). Regulatory support, incentives for environmentally friendly practices, strengthening supervisory policies, and strong infrastructure and institutional support are needed to encourage effective interaction between supply chain actors (Nasution & Ningsih, 2025).

Basic Concepts of Multimodal Transportation and Freight Forwarding

Multimodal transportation is defined as a system of transporting goods that uses at least two different modes of transportation, such as land, sea, air, or rail, but is based on a single contract as a multimodal transportation document (Darmayanti et al., 2023; Kalangi et al., 2024; Sitorus

& Sony, 2016). This process starts from one place of receipt of goods by a multimodal transportation business entity to the place determined for the delivery of goods to the recipient (Darmayanti et al., 2023; Sitorus & Sony, 2016).

The scope of activities in multimodal transportation is very wide and comprehensive. This includes the receipt of goods, storage, sorting, packing, marking, measuring, weighing, document management, issuance of transportation documents, calculation of transportation costs, claims, insurance for the delivery of goods, as well as settlement of bills and other costs until the goods are received by the right party (Kalangi et al., 2024; Sitorus & Sony, 2016).

Multimodal transportation has a strategic role as a key component in the logistics system. The movement of goods in this system is highly dependent on the nodes of the transportation network, such as ports that are the transfer points between sea and land modes (road or rail), or airports as the transfer points between air and land modes (Sitorus & Sony, 2016). Therefore, the overall performance and efficiency of the movement of goods flows is greatly influenced by the effectiveness of multimodal transportation. The main goal of multimodal transportation is to realize *one stop service* in freight transportation, with *a single seamless service* (S3) indicator that includes *a single operator*, *a single tariff*, and *a single document* for freight transportation (Sitorus & Sony, 2016).

Role and Scope of Freight Forwarding Activities

Freight Forwarding is a business that aims to represent the interests of the goods owner in taking care of all activities necessary for the delivery and receipt of goods through various modes of transportation, both land, sea, and air (Kalangi et al., 2024).

Freight forwarders can be classified into three categories based on their level of professionalism and operational reach (Kalangi et al., 2024):

1. **International Freight Forwarder (IFF) or Classification A**: This is a professional *forwarder* who carries out international *freight forwarding* activities (export/import). They have the right to issue or use *FIATA B/L (Bill of Lading),* have a strong international work network, adequate facilities and infrastructure, extensive experience, are able to offer competitive rates, and are responsible for compensation claims (Kalangi et al., 2024).
2. **Domestic/Regional Forwarder (Classification B):** The fundamental difference with IFF is that they are not yet entitled to issue *their own B/L* (*House B/L*) (Kalangi et al., 2024).
3. **Local Forwarder (Classification C):** This is the *forwarder* with the least classification, generally does not have an agent overseas, and often manages EMKL (Sea Cargo Expedition) services (Kalangi et al., 2024).

The scope of *Freight Forwarder's activities* is very broad, functioning as a consultant, proxy, coordinator, and supervisor in the shipping process (Kalangi et al., 2024):

Acting on behalf of the Exporter: *The Forwarder* will choose the most suitable route and mode of transportation, book *space* with the shipping company, and hand over the goods to the cargo owner (exporter). At the time of handover, the *forwarder* submits the *Forwarders Certificate of Receipt (CFR)* and *Forwarder Certificate of Transport (FTC)* documents to the exporter. They also study *the Letter of Credit (L/C)* to ensure its relevance to the delivery plan, carry out the packing of goods taking into account the natural conditions and regulations of the destination/transit country, carry out warehousing (if required), weigh, measure, and insure the goods if requested by the exporter. In addition, *the forwarder* takes care of export documents (such as *Goods Export Notice/PEB*), pays all transportation-related costs including *freight*, receives *a full set of Bill of Lading (B/L)* from the carrier, monitors the movement of goods during the journey, communicates with overseas *forwarding* agents for *clearance* preparationdocuments and cargo delivery, as well as taking care of recording damage or loss of goods in the claim process (Kalangi et al., 2024).

Acting on behalf of the Importer: The scope of activities includes receiving and checking import documents and other complementary documents, monitoring the movement of imported goods to determine the time of arrival, taking care of *the collection of Delivery Orders (D/O)* from shipping companies and paying import-related fees, creating and submitting documents to customs offices (including payment of import duties and taxes) or applying for temporary stockpiling outside the customs area, preparing temporary warehouses, taking care *of Job Slips* to port operators (Pelindo) for the legality of goods disbursements, and transporting and handing over goods to *consignees* (Kalangi et al., 2024).
In addition to the above roles, *freight forwarders* also play a role in:
a. Helping to promote Indonesia's export commodities abroad (Kalangi et al., 2024).
b. Helping the government simplify procedures and documents for shipping goods (Kalangi et al., 2024).
c. Supporting the development of national commercial fleets (Kalangi et al., 2024).
d. It functions as a *physical distribution* that includes various logistics activities such as transportation, management, warehousing, packing, naming, quality control, and customs management. The combination of all these activities can result in lower costs than if done separately (Kalangi et al., 2024).

Freight forwarders act as catalysts for fragmented supply chain integration. Indonesia's current logistics system is characterized by fragmented responsibilities across various transportation segments and a lack of integrated documentation. This creates complexity and inefficiency (Wibowo & Chairuddin, 2017). Multimodal transport, by definition, involves many modes and requires a seamless transition and integrated responsibilities. *Freight forwarders*, as described, perform a wide range of comprehensive services: from route selection and modes, handling physical cargo (packing, warehousing, weighing), managing all necessary documentation (B/L, D/O, customs), to coordination with various parties and settlement of claims (Kalangi et al., 2024). They basically provide a "single window" for the sender. In a logistics environment where integration is weak and responsibilities are scattered, *the ability of freight forwarders* to consolidate services, manage complex intermodal transfers, and handle all administrative burdens under one umbrella becomes critical. They act as *de facto* integrators, bridging the operational and documentation gap between different segments of the supply chain. This directly supports the aspiration of a "single seamless service" in multimodal transport, even when formal regulatory integration is still lacking. Therefore, the effectiveness of multimodal transportation in Indonesia, especially for high-volume commodities such as CPO, is highly dependent on the operational capabilities and legal recognition of *freight forwarders*. Strengthening their role, perhaps through a clearer regulatory framework that formally assigns them "sole responsibility" as Multimodal Transport Operators (MTOs), is essential to achieve greater efficiency and reduce logistics friction in national supply chains.

Legal Framework and Development of Multimodal Transportation and Freight Forwarding in Indonesia

The legal framework that regulates multimodal transportation in Indonesia has been established through Government Regulation (PP) No. 8 of 2011 concerning Multimodal Transportation. This PP functions as an implementing regulation that integrates the provisions of four laws in the field of transportation that have existed before, namely Law No. 23 of 2007 concerning Railways, Law No. 17 of 2008 concerning Shipping, Law No. 1 of 2009 concerning Aviation, and Law No. 22 of 2009 concerning Road Traffic and Transportation (Darmayanti et al., 2023; Kalangi et al., 2024). In addition, multimodal transportation activities can only be organized by multimodal transportation business entities, both national and foreign business entities, in accordance with Ministerial Regulation No. 8 of 2012 (Darmayanti et al., 2023).

The development of *the freight forwarding* industry in Indonesia has shown significant growth. In the mid-1970s, national *freight forwarding* companies began to emerge. At its peak, in 1980, the government granted operating licenses to 15 *freight forwarding* companies. In 1981, the Indonesian Freight Forwarder Association (INFFA) was founded and officially recognized as a member of FIATA (the Federation of International Freight Forwarders Association), a global organization that sets international trade standards (Kalangi et al., 2024). Then, on July 25, 1989, there was a merger of several related associations, such as INFA (Indonesia Freight Forwarder Association), GAVEKSI (Gabungan Veem dan Ekseksisi Seluruh Indonesia), and INFA (Indonesia Forwarder Association), into GAFEKSI (Gabungan Freight dan Ekseksisi Seluruh Indonesia). This organization continues to grow, and by 2011, GAFEKSI already had 1800 member companies spread throughout Indonesia (Kalangi et al., 2024).

Although the legal framework for multimodal transport already exists, there is a disparity between formal regulation and operational realities in multimodal implementation. The existence of a formal legal framework (Government Regulation No. 8 of 2011) shows the government's intention to promote integrated transportation. However, the implementation of intermodal transportation in Indonesia still faces significant obstacles, including fragmented responsibilities, lack of integrated single transportation documents, and manual processes that lead to delays (Darmayanti et al., 2023; Wibowo & Chairuddin, 2017). This shows that there is a gap in practical implementation. The existence of formal regulation does not automatically mean an efficient operational reality. The challenges highlighted (fragmented responsibilities, unintegrated documents) suggest that existing legal frameworks may not be strong enough or enforced to encourage the necessary integration and coordination between various stakeholders and modes. This creates an inconsistency in which the "architect" (*freight forwarder*) operates in a system that is not yet fully aligned with the ideal multimodal principles. To truly unlock the potential of multimodal transportation for CPO and other commodities, it is critical to bridge this gap. This involves not only refining regulations to ensure clearer single responsibility and requiring integrated documentation, but also investment in the digital infrastructure and human resources needed to support these changes. Without addressing this implementation deficit, the benefits of multimodal transportation will remain theoretical.

Palm Oil (CPO) Supply Chain in Indonesia: Streams and Actors

The palm oil supply chain in Indonesia involves several main actors who interact with each other, from upstream to downstream. Understanding the role of each actor is very important to analyze efficiency and optimization potential.

1. **Farmers**: Farmers are the starting point in the palm oil supply chain, responsible for the production of Fresh Fruit Bunches (FFB). They generally sell FFB twice a month (Aznur et al., 2024; Munawarah et al., 2024). Small-scale farmers, who often own less than 2 hectares of land, are highly dependent on collectors or middlemen (Aznur et al., 2024; Munawarah et al., 2024). This dependence is exacerbated by the urgent need for cash that is often needed even before harvest, as well as plantation locations that may not have adequate road access, making it difficult for smallholders to transport their crops directly to the Palm Oil Mills (PKS) (Aznur et al., 2024; Munawarah et al., 2024; Nasution & Ningsih, 2025).
2. **Merchant Collector (Middleman):** Middlemen act as crucial intermediaries in the supply chain. They are responsible for picking up crops from farmers' locations, conducting initial sorting, and then selling the collected FFB to ramps or directly to the

mills (Aznur et al., 2024; Munawarah et al., 2024). The role of middlemen also includes providing capital loans or down payments to farmers, which indirectly binds farmers to sell their FFB to the middlemen after harvest (Aznur et al., 2024; Munawarah et al., 2024). Middlemen often use *Carry and L300 pick-up cars with a capacity of 3-4 tons to transport FFB (Aznur et al., 2024).*

3. **Ramp/Platform**: *Ramp* is a wholesaler that has an official contract, such as *a delivery order* (DO) or Fruit Delivery Letter (SPB), with a PKS. They serve as a collection point and advanced sorting point for FFB before being sent to the PKS (Aznur et al., 2024; Munawarah et al., 2024). The advantage *of ramps* is their ability to provide direct cash payments to farmers or collecting agents, a feature that farmers urgently need to meet the need for quick liquidity after harvest (Aznur et al., 2024; Munawarah et al., 2024). FFB marketing activities from warehouses to mills are carried out using *dumptrucks* with a capacity of 8 tons, including transportation, sorting, and *grading* (Aznur et al., 2024).
4. **Palm Oil Mills (PKS):** PKS is the last link in the chain that receives FFB from farmers (either directly or through intermediaries) to be processed into crude palm oil (CPO) (Aznur et al., 2024; Munawarah et al., 2024). PKS acts as the end consumer while FFB, transforming it into a more valuable product. They also play an important role in maintaining competitive FFB purchase prices to ensure a consistent supply of raw materials for their production operations (Munawarah et al., 2024).

Fragmentation and power gaps in the upstream CPO supply chain are a deep problem. Small-scale farmers, despite being the main producer, often have limited land and urgent financial needs. This makes them financially vulnerable. They rely heavily on middlemen for cash payments and transportation, especially from remote areas (Aznur et al., 2024). This dependence creates a weak position for farmers. Middlemen and *ramps* have greater bargaining power and can affect prices and sorting criteria, which is often unfavorable for farmers (Aznur et al., 2024). This indicates an imbalanced market structure. The multi-layered structure in the upstream CPO (farmer-middleman-ramp-mill) supply chain is characterized by significant power asymmetry. Farmers are forced to accept the terms set by the intermediary due to their urgent financial needs and logistical constraints. This fragmentation not only reduces the share of the value of the final product that farmers receive, but also introduces additional handling measures and costs, which have the potential to impact FFB quality and overall supply chain efficiency. Optimizing the CPO supply chain requires a concerted effort to empower small-scale farmers. This can involve promoting direct contractual relationships with SMEs, supporting the formation and strengthening of farmer cooperatives to increase collective bargaining power, improving rural road infrastructure to reduce transportation dependency, and providing alternative financing options that are easily accessible. Addressing these fundamental issues is critical to creating a fairer, more efficient, and sustainable CPO supply chain.

Product, Information, and Financial Flows in the CPO Supply Chain

In the palm oil supply chain, there are three main streams that are interconnected and form the dynamics of the entire system:

1. **Product Flow**: This stream describes the physical movement of FFB from farmers to the processing point. FFB harvested by farmers moves to collectors (middlemen), then to *ramps* (if there is a distribution pattern), and finally arrives at the Palm Oil Mill (PKS) to be processed into CPO (Aznur et al., 2024; Munawarah et al., 2024; Primalasari et al., 2017). The quality of FFB received at PKS is very important and is checked based on the standards of the National Standardization Agency (BSN) in SNI-

01-2901-2006. These quality standards directly affect the price that farmers will receive (Munawarah et al., 2024).

2. **Information Flow**: The flow of information in the CPO supply chain is two-way. Information about market prices and delivery times generally comes from the mill or company and is distributed to middlemen or *ramps*, who then pass it on to farmers. Instead, information from farmers, such as the number of available products or harvest schedules, also flows back to the mills. This efficient exchange of information is essential to ensure the smooth supply of FFB (Aznur et al., 2024). Farmers are also increasingly proactive in seeking price information from external sources, such as the internet, and confirming it with middlemen to adjust their production to market needs and dynamics (Aznur et al., 2024; Munawarah et al., 2024).
3. **Financial** Flows: Financial flows generally move in one direction, from downstream to upstream. Payments come from the mill to middlemen or *ramps*, and then are forwarded to farmers. Payment from the PKS to the middleman or *ramp* often takes about 5 days due to the administrative and verification process at the head office. However, payments from middlemen or *ramps* to farmers are often made directly and in cash. However, these payments are often deducted from transportation costs or other costs. Some middlemen even provide capital or advances to farmers, effectively binding farmers to sell their crops to the middlemen (Aznur et al., 2024; Munawarah et al., 2024).

Information asymmetry and its impact on efficiency and fairness in the CPO supply chain are significant challenges. Information (prices, delivery times, quality standards) flows through a multi-stage chain involving SMEs, intermediaries, and farmers. Financial flows are mainly from the mills downwards, with intermediaries often providing immediate cash to farmers but also applying deductions (Aznur et al., 2024). Farmers are often "price payers" due to limited market information and urgent financial needs. The sequential nature of information and financial flows creates opportunities for information asymmetry. Intermediaries (middlemen, ramps) are in a position to have faster and more complete market information from the mills than individual farmers. The superiority of this information, coupled with their role in providing fast cash and transportation, allows them to exert a significant influence on prices and quality sorting, often to the detriment of farmers. Immediate cash payments, while seemingly beneficial, reinforce farmers' dependency and limit their ability to seek better prices or negotiate terms. To improve efficiency and fairness in the CPO supply chain, it is critical to democratize access to market information. Implementing a digital platform that provides farmers *with real-time* and transparent price data directly, along with the development of alternative microfinance options that are easily accessible, can significantly reduce information asymmetry and empower farmers to make more informed sales decisions. This will help reduce marketing margins and ensure a fairer distribution of value.

Domestic CPO Distribution Patterns (Case Study of Nagan Raya and Langkat)

The distribution pattern of CPO in Indonesia varies depending on the region and the structure of the local supply chain. Two relevant case studies are in Nagan Raya Regency, Aceh, and Langkat Regency, North Sumatra.

In Nagan Raya Regency, Aceh, research shows that there are three main streams that make up the palm oil supply chain: information flow, financial flow, and product flow. The main actors involved in these three streams are farmers, collectors, and palm oil mills (PKS) (Munawarah et al., 2024). This system describes the fundamental relationship between production, movement of goods, and financial transactions supported by the exchange of information.

Meanwhile, in Langkat Regency, North Sumatra, the analysis identified two different patterns of smallholder palm oil supply chain flows (Aznur et al., 2024):

1. **Supply Chain Pattern I**: Middleman → Middleman Farmers → *Ramp* → Palm Oil Mills (PKS). In this pattern, FFB from farmers passes through two intermediaries (middlemen and *ramps*) before reaching the PKS (Aznur et al., 2024).
2. **Supply Chain Pattern II:** Middleman → Middleman Farmers → Oil Palm Mills (PKS). This pattern is shorter, with FFB from farmers only passing through one intermediary (middleman) before going directly to the PKS (Aznur et al., 2024).

Analysis of marketing margin and *farmers' share* (the share received by farmers of the final price) shows that the Supply Chain Pattern II is more efficient than the Supply Chain Pattern I. The higher efficiency in Pattern II is due to lower marketing margins and *higher farmers' share* (Aznur et al., 2024). The selling price of FFB for farmers in supply chain I is IDR 2,168.87 per kg, while in supply chain II is IDR 2,340.59 per kg (Aznur et al., 2024).

Shorter distribution channels increase efficiency and *farmer's share*. The Langkat study explicitly identified two supply chain patterns, with Pattern II (farmers → middlemen → mills) more efficient than Pattern I (farmers → middlemen → *ramp* → mills). The higher efficiency in Pattern II is directly associated with having the "lowest margin and *highest farmer's share* " (Aznur et al., 2024). Any additional intermediaries (such as "*Ramp*" in Pattern I) in the supply chain introduce additional costs (e.g., handling, storage, transportation, and profit margins for those intermediaries). These additional costs are ultimately borne by the consumer (higher price) or, more commonly in the agricultural supply chain, by the main producer (lower price received). Shorter chains reduce these cumulative costs and allow a larger proportion of the final selling price to reach the farmer. These findings provide a clear strategic direction for optimizing the CPO supply chain: efforts should be made to streamline distribution channels by minimizing the number of intermediaries where possible. This could involve promoting a direct procurement model by PKS from farmer groups or cooperatives, or strengthening the capacity of middlemen to bypass *the ramp*, thereby increasing farmers' incomes and overall supply chain cost-effectiveness.

Analysis of CPO Transportation Modes and Supporting Infrastructure

CPO Transportation System: Land and Sea Modes

CPO transportation in Indonesia relies on a combination of land and sea modes to connect production areas with processing centers and markets.

Land Mode: Tanker trucks are the main means for transporting CPO from ports to cooking oil factories or final destinations (Aryawan, 2010). Tank trucks are available in various capacities, generally 5000 Liters, 10000 Liters, and 16000 Liters (Aryawan, 2010). The limited availability of a truck fleet is a major obstacle in cargo delivery, causing delivery delays and reducing the productivity of logistics companies (Fitriani et al., 2023). The concept of *truck losing*, which is the unloading or loading directly from/to the truck without going through storage in the warehouse, is often applied for cost efficiency (Aryawan, 2010). However, this practice can prolong the docking time of ships at the port, which has the potential to incur additional costs related to *berth time* (Aryawan, 2010).

Sea Mode: For the distribution of CPO between islands in Indonesia, the main choice is tankers and *tug-barges* (Aryawan, 2010).

a. **Tankers**: These ships are specifically designed to transport oil or its derivative products, including liquid CPO (Aryawan, 2010). The advantages of tankers include large cargo space, optimal cargo protection from weather factors because they are in the *cargohold*, high speed, and good ship stability (Aryawan, 2010). However, tankers have some disadvantages, such as greater fuel consumption (due to high speeds), the need for more crew or crew members, much higher port costs (related to *the ship's Gross Tonnage*), and greater overall operational costs (Aryawan, 2010).

b. **Barge (*Tug-Barge*):** It is a wide-body, flat-bottomed floating device that is pulled or pushed by a tugboat (Aryawan, 2010). The advantages of barges include less fuel consumption (due to low speeds), minimal crew numbers, the ability to sail in shallow or tidal waters (rivers), lower operating costs and initial investments, and low water load (Aryawan, 2010). However, barges have disadvantages such as unprotected cargo from outside conditions (rain, heat), lower speed, less stability, less carrying capacity per unit, and susceptibility to accidents in choppy waters (Aryawan, 2010).

There is a *trade-off* between cost and risk in choosing a marine mode for CPO. Barges offer much lower operational and initial investment costs than tankers (Aryawan, 2010). This makes it economically attractive. However, barges are highly susceptible to adverse weather conditions (rain, waves), have lower speeds, and less stability, which can lead to delays, product exposure, and a higher risk of accidents (Aryawan, 2010). On the other hand, tankers are stronger and safer, but more expensive (Aryawan, 2010). The choice between tankers and barges for CPO transportation is a classic optimization problem that involves important considerations between minimizing direct transportation costs and mitigating various operational risks (e.g., CPO damage due to exposure, delays affecting supply chain rhythms, increased insurance premiums due to higher risks). Decisions that are based solely on cost can lead to increased indirect costs from product loss, delivery delays, or safety incidents. The selection of the optimal mode for CPO transportation should not only be based on the lowest direct costs, but should include a comprehensive risk assessment. This means that sophisticated decision models are needed that take into account weather variability, CPO quality degradation rates, insurance costs, and the urgency of on-time delivery. In addition, it suggests that governments or industry bodies may need to invest in infrastructure (e.g., closed loading facilities, improved navigation aids) or provide incentives to make safer and more reliable modes more economically feasible, especially for high-value or time-sensitive CPO shipments.

Comparison of Efficiency of Sea Transportation Modes for CPO

CPO distribution optimization often uses analytical methods such as penalty and *simplex methods* to identify distribution patterns with the lowest transportation costs (Aryawan, 2010). Based on this analysis, the optimal route for domestic CPO distribution in Indonesia has been identified, including routes from Medan to Tanjung Priok, Sampit to Tanjung Priok, Makassar to Tanjung Priok, Sampit to Tanjung Emas, and Sampit to Tanjung Perak (Aryawan, 2010).

The results of the comparative analysis of efficiency between sea transportation modes show that barges generally have lower costs than tankers for the same route (Aryawan, 2010). For example, for the Medan-Tanjung Priok route, the cost of using a tanker is Rp135,394,237,000, while by barge it is Rp79,038,624,000 (Aryawan, 2010). However, although barges are more cost-effective, it is recommended to use tankers during periods of inclement weather (e.g., Period III shipping) due to the higher safety and reliability factors offered by tankers (Aryawan, 2010).

Optimizing domestic CPO transportation costs has strategic implications for national competitiveness. The study identified the optimal CPO distribution route and noted that barges are generally cheaper than tankers, although tankers are safer in bad weather (Aryawan, 2010). Indonesia's overall logistics costs are high, which negatively impacts the competitiveness of products (Wibowo & Chairuddin, 2017). By identifying and implementing the most cost-effective modes and routes of transportation for CPO, the overall logistics costs for this critical commodity can be significantly reduced. The direct cost savings at this stage of transportation contribute to the reduction of the final price of CPO derivative products, making them more competitive in both domestic and international markets. The strategic choice between cost (barge) and reliability/safety (tanker) needs to be carefully balanced to avoid the hidden costs of product delays or loss. Therefore, a well-optimized CPO transportation network is a real mechanism to increase Indonesia's national competitiveness, in direct line with the goals of Indonesia's Logistics Vision 2025 (Sitorus & Sony, 2016). This suggests that policy interventions can focus on providing infrastructure that supports the most cost-effective modes (e.g., improved river navigation for barges) while also reducing their risks (e.g., weather forecasting, emergency response), or providing incentives for safer use of modes during high-risk periods.

CPO Loading and Unloading Process

The CPO loading and unloading process, both in solid (meal) and liquid form, has its own characteristics and obstacles.

Loading: For loads such as oil palm meal, the process of loading to barges often uses *a truck losing* system. In this system, palm oil meal is transported directly from the owner's warehouse to the dock using trucks, then transferred into barges gradually using loading and unloading equipment such as land *cranes* and nets. The oil palm meal from the truck is poured into the tarpaulin-based meshes, then transferred into the barge by *crane*. Each truck transports about 8 tons of palm oil meal (Nasyukha et al., 2021). During the loading process, cargo compaction inside the barge using *the Loader tool* is also carried out to maintain the balance of the ship, considering the large volume of cargo (Nasyukha et al., 2021).

Tanker Dismantling: For liquid CPO, the unloading process from tankers can be carried out through several methods:

a. **STS (*Ship to Ship*):** The process of transferring cargo between ships at sea.
b. **CBM (*Conventional Mooring Buoy*):** Dismantling through a pipeline on the seabed to an onshore storage tank using *a conventional mooring* buoy.
c. **SPM (*Single Point Mooring*): A facility for** loading and unloading via pipelines on the seabed to/from an onshore tank, where the tanker is moored on a single *buoy* and can rotate 360 degrees (Aryawan, 2010).

Loading/Unloading Constraints

The loading process, especially for oil palm meal on barges, can experience significant obstacles that cause delays. For example, bad weather such as rain can stop all loading activities (Nasyukha et al., 2021). In addition, damage to loading and unloading, such as breaking meshes or *jamming crane* engines, can also lead to operational shutdowns and drastically extend loading times, far beyond the planned schedule (Nasyukha et al., 2021).

The technology gap and its impact on the operational efficiency of CPO ports are very significant. Loading CPO (or its derivatives such as palm oil meal) often involves manual or semi-manual processes (*cranes*, nets) and is susceptible to weather and equipment damage (Nasyukha et al., 2021). These methods cause significant delays and inefficiencies. The quality of Indonesia's port infrastructure is generally low (Sitorus & Sony, 2016). Reliance on conventional cargo handling equipment, which is sensitive to weather and prone to breakdowns at ports, directly contributes to the inefficiencies observed in the CPO supply chain. This points to a broader problem of a lack of investment in modern port technology and maintenance, which is a critical obstacle in the overall logistics system. The manual nature of some processes means higher labor costs and slower *throughput* compared to automated systems. To improve the efficiency and reliability of CPO logistics, especially at crucial port interfaces, there is a need for investment in advanced, automated, and weatherproof cargo handling equipment (e.g., dedicated CPO pumping systems, closed loading/unloading facilities). In addition, the implementation of robust maintenance programs and the potential for digitization of port operations (e.g., for *real-time* monitoring of equipment status) will significantly reduce delays and increase *throughput*, in line with the national logistics vision.

Main Port Infrastructure in Indonesia for CPO

Ports play a crucial role as "nodes" or *nodes* in multimodal transportation networks, facilitating the transfer of goods between sea and land modes (Sitorus & Sony, 2016). For CPO distribution, several ports in Indonesia have a strategic role:

a. **Main Destination Ports in Java**: Tanjung Priok (Jakarta), Tanjung Emas (Semarang), and Tanjung Perak (Surabaya) are the main ports on the island of Java that are the destination for domestic CPO distribution from production areas (Aryawan, 2010).
b. **CPO's Ports of Origin**: Sampit (Kalimantan), Belawan (Sumatra), and Makassar (Sulawesi) are important ports in CPO-producing areas that are the starting point for shipments (Aryawan, 2010).

However, the quality of port infrastructure in Indonesia in general is still considered poor. In 2012-2013, Indonesia's port infrastructure was ranked 104th out of 144 countries reviewed (Sitorus & Sony, 2016). This shows that there are significant limitations in capacity and facilities. The limited capacity of ports for loading and unloading large ships (*post-panamax*) is an obstacle, which has an impact on Indonesia's transportation ability for foreign transportation and indirectly causes transportation costs to be relatively high (Wibowo & Chairuddin, 2017). In addition, Indonesia also does not have a national "hub port" that can optimize the role of multimodal transportation (Sitorus & Sony, 2016).

Port infrastructure as the main "bottleneck" of national logistics is very clear. Ports serve as critical "nodes" or "nodes" in multimodal transportation networks, facilitating the transfer of goods between sea and land modes (Sitorus & Sony, 2016). These ports are essential for the distribution of CPO between islands. Ports in Indonesia generally have low infrastructure quality and limited capacity, especially for large ships (Sitorus & Sony, 2016). This shows the existence of physical limitations and operational inefficiencies. Shortages at these ports directly lead to longer transit times, increased costs, and decreased overall efficiency throughout the supply chain. This indicates the presence of systemic barriers. The poor conditions and limited capacity of the port infrastructure effectively act as major obstacles, undermining the potential benefits of multimodal transport. Even if land-based collection and sea-based long-distance transportation are optimized, delays and inefficiencies at transfer points at ports can negate these advantages, creating bottlenecks for the entire logistics system. This problem does not only occur in CPO but has an impact on all commodities passing through these ports. Therefore, targeted and substantial investment in port infrastructure modernization is a prerequisite for achieving significant improvements in CPO logistics and overall national supply chain efficiency. This includes deepening of grooves, expansion of dock capacity, procurement of advanced cargo handling equipment, and improved land connectivity (e.g., rail lines to ports). Such improvements are fundamental to realizing the vision of "locally integrated, globally connected" of Indonesia's logistics system (Sitorus & Sony, 2016).

Case Study of CPO Transportation Efficiency (PT. Raja Clan in Simeulue)

Case study on PT. Raja Marga in Simeulue Regency provides a concrete overview of the challenges and potential for optimization in CPO transportation. PT. Raja Marga distributes CPO using a combination of land (CPO transport trucks) and sea (ships) to its facilities in Nagan Raya (Yuanda et al., 2025).

The company faces several common problems in its supply chain, including shipping delays, potential product losses, and inventory imbalances (Yuanda et al., 2025). To overcome this, the research was conducted using Data Envelopment Analysis (DEA) and Linear Programming methods to analyze and optimize transportation efficiency (Yuanda et al., 2025).

The results of the analysis showed varying levels of efficiency between CPO distribution routes: Calang reached 122.3%, Meulaboh 154.0%, and Labuan Haji 122.8%. The Meulaboh route shows the highest level of efficiency among the three (Yuanda et al., 2025). Furthermore, through the proposed optimization, the company is able to significantly reduce transportation expenses. The initial cost of IDR 2,218,360,000 can be optimized to IDR 2,073,350,978, a substantial savings achieved through adjusting the number and capacity of trucks used (Yuanda et al., 2025).

The potential for micro-optimization in facing macro logistics challenges is enormous. PT. Raja Marga, as a sole proprietorship, faces common CPO transportation challenges such as delays and product loss (Yuanda et al., 2025). This is a micro-level issue in the broader logistics landscape. Despite these challenges, the application of analytical methods (DEA, *Linear Programming*) at the enterprise level can identify specific operational adjustments (e.g., optimizing the type and number of trucks) that result in substantial cost savings (Yuanda et al., 2025). This shows the effectiveness of internal optimization. This case illustrates that even when macro-level issues such as national infrastructure shortages or fragmented regulations remain, individual actors in the supply chain are powerless. Data-driven strategic optimization at the enterprise or route level can result in significant efficiency improvements and cost reductions. These local successes, if replicated across industries, can collectively contribute to a more efficient national logistics system. This highlights the importance of promoting analytical tools and best practices at the operational level within CPO companies. Encouraging such micro-optimization, perhaps through industry associations or government support programs, can create a cumulative positive impact on overall logistics performance, even as larger systemic reforms are being pursued. It demonstrates a two-pronged approach: top-down development of policies and infrastructure, combined with bottom-up operational excellence.

Challenges and Strategies for CPO Supply Chain Optimization

Key Challenges in the CPO Supply Chain

Palm oil supply chains in developing countries, particularly Indonesia, face a complex set of challenges that affect their efficiency, sustainability and competitiveness:

1. **Access to Funding and Farmer Resources**: Small-scale farmers often struggle to access adequate funding to purchase high-quality production inputs, such as superior seeds and fertilizers. Capital constraints and low accessibility to these resources result in low productivity and in turn, dissatisfaction with the selling price of FFB offered by palm oil collectors and mills (Nasution & Ningsih, 2025; R1).
2. **FFB Quality and Processing**: The quality of FFB produced by smallholder farmers is often not optimal. This is due to inefficient processing practices at the farmer level and the long distance between the location of the land and the processing plant. The decline in FFB quality has a direct impact on lower selling prices, which ultimately reduces farmers' income (Arif et al., 2021; Nasution & Ningsih, 2025).
3. **Transportation Infrastructure**: Inadequate road infrastructure conditions are the main obstacles in the transportation of FFB to the factory. With an estimated 61% of road infrastructure poor, transportation costs are high, and farmers' access to markets is significantly hampered (Nasution & Ningsih, 2025; Paonganan, 2020).
4. **Coordination and Synergies in the Supply Chain**: The lack of coordination and synergy between various actors in the supply chain, such as farmers, collectors, mills, and distributors, leads to inefficiencies in the management of product and information flows. This hinders the optimization of the entire process (Nasution & Ningsih, 2025).
5. **Compliance with Sustainability Standards**: Despite efforts to implement sustainability standards such as ISPO (Indonesian Sustainable Palm Oil) and RSPO (Roundtable on Sustainable Palm Oil), many smallholders face difficulties in meeting these requirements. This inability can limit their access to international markets that are increasingly demanding sustainable products (Nasution & Ningsih, 2025).

6. **Market Risks and Price Fluctuations**: Fluctuations in global palm oil prices can significantly impact farmers' incomes and overall supply chain stability. This price uncertainty makes production planning more complex and risky (Nasution & Ningsih, 2025).
7. **Collector Involvement**: Collectors often have greater bargaining power than small farmers. They tend to set prices that are unfavorable for farmers, which ultimately creates dissatisfaction among farmers with the prevailing price system (Nasution & Ningsih, 2025).

These challenges form a vicious circle of inefficiency and socio-economic disparities upstream of the CPO supply chain. Farmers, as major producers, face a range of challenges: limited access to funding for inputs, which results in lower quality of FFB (Nasution & Ningsih, 2025); poor rural infrastructure leads to high transportation costs (Nasution & Ningsih, 2025); and weak bargaining power against intermediaries who offer low prices and quick cash (Nasution & Ningsih, 2025). These individual challenges are interrelated. For example, a lack of funds hinders investment in quality inputs, leading to lower quality FFB, which in turn results in lower prices. High transportation costs are further eroding already thin margins. The dependence on intermediaries for cash immediately strengthened the weak bargaining position of farmers. This creates a mutually reinforcing cycle of low productivity, low income, and constant dependence for small-scale farmers. Structural inefficiencies in upstream supply chains are not isolated problems, but symptom of deeper socio-economic vulnerabilities that trap farmers in a cycle of marginalization, hindering the optimization of the supply chain as a whole. A partial approach to addressing these challenges will not be enough. A holistic strategy that integrates financial inclusion (e.g., microcredit, direct payment schemes), infrastructure development (e.g., connecting roads, local collection centres), capacity building (e.g., training of sustainable practices, quality management), and market reforms (e.g., strengthening farmer cooperatives, promotion of direct contracts with SMEs) is needed. Such an integrated approach is critical to breaking the cycle of inefficiencies and ensuring the long-term sustainability and fairness of the CPO supply chain.

The Role of Digital Technology (Internet of Things and Blockchain) in Increasing Transparency and Efficiency

The application of digital technologies, particularly the *Internet of Things* (IoT) and *blockchain*, offers transformative potential to improve transparency and efficiency in the palm oil supply chain. The complex CPO supply chain involves many parties, from farmers to consumers, and faces increasing demands for data transparency and security (Iqbal et al., 2024; Nasution & Ningsih, 2025).

Internet of Things (IoT): IoT technology has been widely used in oil palm plantations to improve operational efficiency and productivity. For example, temperature and gas sensors can be used to detect the presence of pests and diseases in oil palm plants, as well as to monitor soil maturity and fertility levels (Al Maududy et al., 2021). In nurseries, IoT also enables automation of the watering process based on *real-time data* from soil moisture and temperature sensors, ensuring optimal conditions for seedling growth (Wati et al., 2022).

Blockchain: Blockchain technology has great potential to revolutionize data transparency and security in the supply chain. By recording every transaction in *real-time* and decentralized, *blockchain allows traceability* of the origin of the product back to its source. This ability increases consumer confidence in the sustainability of palm oil products. The principle of blockchain decentralization also protects data from manipulation or cyberattacks through strong cryptographic mechanisms. In addition, *blockchain* enables integration with *smart contracts* for the automation of business processes, such as payments to farmers based on digitally recorded crops, reducing the need for manual intervention and speeding up transactions (Iqbal et al., 2024).

This technology serves as a driver of supply chain transformation from fragmentation to integration and trust. The CPO supply chain is complex, involves many actors, and faces challenges related to transparency, data security, and coordination (Nasution & Ningsih, 2025). IoT provides detailed *real-time* data from the physical environment (farm conditions, product status), while *blockchain* offers an immutable, transparent, and decentralized ledger for recording transactions and product origins (Iqbal et al., 2024). This digital technology directly addresses the core problems of information asymmetry and lack of trust in the CPO supply chain. IoT can provide objective, verifiable data on agricultural practices and product quality, while *blockchain* can ensure that this data, along with transactional information, is securely recorded and accessible to all authorized participants. This eliminates the need for intermediaries to manually verify information, reduces the chance of manipulation, and builds trust among stakeholders, from farmers to end consumers. The adoption of IoT and *blockchain* is not only an incremental improvement but a transformative step for the CPO supply chain. It enables a shift from fragmented and opaque operations to an integrated, transparent, and trustworthy ecosystem. This is critical to meet the growing global demand for sustainable and ethically sourced palm oil, improve supply chain resilience, and ultimately enhance the competitiveness of Indonesia's CPO in the international market.

The Impact of Government Regulations and Policies on the CPO Supply Chain

Government regulations and policies have a significant impact on the efficiency, sustainability, and competitiveness of the CPO supply chain in Indonesia. These policies are designed to balance a wide range of interests, from domestic economic stability to compliance with global standards.

Domestic Trade Policy: The government uses CPO export tax instruments as a tool to inhibit excessive exports, with the main objective of stabilizing the price of cooking oil in the domestic market and ensuring the availability of sufficient raw materials for the domestic industry (Aryawan, 2010). In addition, this policy also serves to increase state and regional revenues (Aryawan, 2010; Nasution & Ningsih, 2025).

CPO Transportation Arrangements: CPO transportation activities, both by land and sea, are strictly regulated to ensure compliance with technical and occupational safety requirements set by the relevant departments (Aryawan, 2010). It is also important that loading and unloading facilities for CPO must be separate from public facilities and meet applicable safety standards, considering the nature of this commodity (Aryawan, 2010). Permits for CPO processing, land, sea, and river transportation, and storage, are granted by the Minister of Industry or the Minister of Energy and Mineral Resources, often with a recommendation from the Minister of Energy and Mineral Resources (Aryawan, 2010).

Sustainability Certification (ISPO and RSPO): Certifications such as Indonesian Sustainable Palm Oil (ISPO) and the Roundtable on Sustainable Palm Oil (RSPO) are becoming very important to increase the competitiveness of palm oil products in the international market (Nasution & Ningsih, 2025). Products that have been certified have a greater chance of being accepted in the global market, while products without certification are at risk of rejection (Nasution & Ningsih, 2025). In addition, the certification process also contributes to increasing farmers' knowledge of sustainable cultivation practices and ultimately increasing productivity (Nasution & Ningsih, 2025).

Regulatory and Infrastructure Support: The government provides regulatory support, including incentives for environmentally friendly agricultural practices and strengthening of surveillance policies (e.g., to reduce the practice of forest burning). Support for adequate infrastructure and strong institutions, as well as good coordination between relevant parties, is also needed to encourage effective interaction between supply chain actors (Nasution & Ningsih, 2025).

Regulations serve as a balance between economic interests and sustainability in the CPO sector. Government policies aim to achieve various objectives: stabilizing domestic CPO prices/supply, generating export revenues, and promoting sustainable practices. Instruments such as export taxes are used for economic stabilization (Aryawan, 2010), while certifications such as ISPO/RSPO are for sustainability and market access (Nasution & Ningsih, 2025). Government regulation is not a single policy, but an ongoing effort to balance potentially conflicting goals. For example, export taxes may secure domestic supplies but can reduce export competitiveness or farmers' incomes if not managed carefully. Similarly, while sustainability certification is critical for global market access, its implementation can be challenging and costly for small-scale farmers, requiring government support to ensure compliance without undue burden. The effectiveness of these policies depends on their ability to create a synergistic environment in which economic growth and environmental responsibility reinforce each other. Effective government intervention in the CPO supply chain requires a nuanced and adaptive policy framework. This means constantly evaluating the impact of economic policies on sustainability goals and vice versa. It also implies the need for targeted support mechanisms (e.g., financial assistance, technical assistance) for small-scale farmers to comply with sustainability standards, ensuring that regulatory burdens do not inadvertently push them out of formal supply chains or into unsustainable practices. This integrated policy approach is critical to achieving long-term stability and global competitiveness.

Indonesia's Logistics Vision 2025 and Its Implications

Goals and Strategy of Indonesia's Logistics Vision 2025

Indonesia's Logistics Vision 2025 is an ambitious national strategic framework, aiming to transform Indonesia's logistics sector to be more efficient and competitive at the global level. This vision states: "By 2025, Indonesia's Logistics Sector, which is domestically integrated between islands and internationally connected to the world's major economies efficiently and effectively, will enhance national competitiveness to succeed in the era of global supply chain competition" (Sitorus & Sony, 2016).

To achieve this vision, the strategy involves the development of an integrated logistics network, known as "Nodes & Arcs" and "Gateways". "Nodes" refer to important nodes such as ports, terminals, and warehouses, while "Arcs" refer to connecting nodes such as roads, highways, railways, and shipping lanes. "Gateways" serve as gateways for international connections, including ports, customs, and trade/industrial facilities (Sitorus & Sony, 2016).
The specific objectives of Indonesia's Logistics Vision 2025 include:

a. **Domestic Distribution System Improvement**: Improve and integrate the domestic distribution system so that every economic node across regions is effectively connected, creating an integrated domestic logistics between islands (Sitorus & Sony, 2016).
b. **Export Support**: Facilitate the flow of goods from production centers to ports and connect them to international networks, thus supporting increased exports (Sitorus & Sony, 2016).
c. **Infrastructure Development Priorities**: Directing infrastructure development based on transportation modes and geographical considerations that are expected to have the greatest economic impact in the long term (Sitorus & Sony, 2016).

d. **Policy Synchronization**: Provide clear direction to each department, logistics service provider, and logistics service provider, to ensure policy synchronization in building a national logistics system (Sitorus & Sony, 2016).
e. **Efficiency and Competitiveness**: Reduce national logistics costs, increase the speed of movement of goods throughout Indonesia, and ultimately increase national competitiveness in the global market (Sitorus & Sony, 2016).

This 2025 vision serves as a holistic framework for the transformation of national logistics. Vision 2025 articulates a comprehensive goal: "domestically integrated throughout the archipelago and internationally connected" (Sitorus & Sony, 2016). This implies addressing geographical and systemic fragmentation. The strategy involves the development of "Nodes & Arcs" and "Gateways" networks, explicitly connecting physical infrastructure with connectivity goals (Sitorus & Sony, 2016). This vision aims to reduce logistics costs, increase speed, and increase national competitiveness (Sitorus & Sony, 2016). This vision is not just an aspiration, but provides a holistic strategic framework that recognizes the multi-dimensional nature of Indonesia's logistics challenges. It recognizes that isolated improvements (e.g., simply building new roads) are not enough; Instead, a systemic approach that integrates various aspects is needed.

CONCLUSION

A comprehensive analysis of the optimization of multimodal transportation and the role *of freight forwarding* in the palm oil (CPO) supply chain in Indonesia confirms the sector's vital position in the national economy, while highlighting significant logistical challenges. As the world's largest CPO producer, supply chain efficiency is crucial for Indonesia's competitiveness.

The CPO supply chain at the upstream level is still highly fragmented, especially among small-scale farmers. Farmers' dependence on intermediaries such as middlemen and *ramps* is caused by limited access to funding, suboptimal quality *of Fresh Fruit Bunches* (FFB), and poor road infrastructure, which ultimately creates information asymmetry and unbalanced bargaining power (Nasution & Ningsih, 2025; Aznur et al., 2024). Shorter distribution patterns have proven to be more efficient, reducing intermediary margins and increasing farmers' income (Aznur et al., 2024). National logistics challenges are exacerbated by low logistics indexes, high costs, and long delivery times, largely due to bureaucratic inefficiencies, corruption, and inadequate infrastructure, including poor port quality (Wibowo & Chairuddin, 2017; Sitorus & Sony, 2016). This shows the need for interventions in the field of industrial engineering to optimize the structure of supply chains and rural infrastructure.

The efficiency of CPO transportation modes and their supporting infrastructure shows complexity. Although shorter distribution patterns improve efficiency, poor port infrastructure and limited capacity are major obstacles, leading to delays and increased costs (Sitorus & Sony, 2016; Nasyukha et al., 2021). The choice between tankers and barges for sea transportation involves a *trade-off* between cost and risk, where barges are more cost-effective but vulnerable to weather, while tankers are safer but more expensive (Aryawan, 2010). This underscores the need for sophisticated decision models in logistics systems engineering, which integrates cost-benefit analysis with comprehensive risk assessments to achieve optimal resource allocation and operational resilience.

Although a legal framework for multimodal transportation already exists (Government Regulation No. 8 of 2011), its implementation still faces obstacles such as fragmented responsibilities and time-consuming manual processes (Darmayanti et al., 2023; Wibowo & Chairuddin, 2017). In this context, *freight forwarders* play an important role as integrators, bridging operational and documentation complexities (Kalangi et al., 2024). The transformative potential of digital technologies such as *the Internet of Things* (IoT) for *real-*

time monitoring and *blockchain* for product transparency and traceability is enormous (Iqbal et al., 2024; Al Maududy et al., 2021). The strategic adoption of this technology represents a significant advancement in industrial science and engineering, enabling stronger data management, process automation, and improved supply chain integrity, thereby driving greater trust and efficiency across the CPO value chain.

To address these challenges and realize Indonesia's ambitious Logistics Vision 2025, which aims for a domestically integrated and internationally connected logistics sector (Sitorus & Sony, 2016), a holistic strategic approach is needed. This includes targeted investments in port infrastructure modernization and rural road network improvements, as well as the empowerment of small-scale farmers through a direct procurement model and increased access to resources. In addition, strengthening the legal framework for multimodal transportation operators and promoting the widespread adoption of digital technology are crucial. These recommendations collectively make substantial contributions to the field of industrial engineering by advocating for systemic improvements in logistics planning, operational efficiency, and supply chain resilience. By integrating advanced analytical methods, technological innovations, and adaptive policy frameworks, Indonesia can achieve significant reductions in logistics costs, increase product competitiveness, and ensure the long-term sustainability and long-term fairness of the vital CPO industry.

Recommendations

Based on the above conclusions, several strategic recommendations are proposed to optimize multimodal transportation and the role of *freight forwarding* in the CPO supply chain in Indonesia:

1. **Infrastructure Strengthening and Port Modernization**:
   a. Prioritize investment in CPO port infrastructure modernization, including deepening of grooves, expansion of dock capacity, and procurement of sophisticated, automated, and weatherproof loading and unloading equipment.
   b. Improve land-to-port connectivity (e.g., rail lines) to reduce congestion and speed up the flow of goods.
   c. Consider building a national "hub port" to optimize the role of multimodal transportation.
2. **Farmer Empowerment and Upstream Supply Chain Rationalization**:
   a. Encourage a direct procurement model between PKS and farmer groups or cooperatives to reduce the number of intermediaries and increase *farmers' share*.
   b. Increase farmers' access to funding, quality seeds, and sustainable cultivation practices through government programs or private partnerships.
   c. Invest in improving rural road infrastructure to reduce transportation costs from the plantation to the collection point.
3. **Optimizing the selection of risk-based transportation modes**:
   a. Develop more sophisticated decision models for the selection of marine transportation modes that consider not only direct costs but also risk factors such as weather conditions, potential product damage, and urgency of delivery.
   b. Consider incentives or subsidies for safer and more reliable use of modes during high-risk periods.
4. **Improvement of the Regulatory Framework and the Role *of Freight Forwarders***:
   a. Revise and strengthen multimodal transport regulations to ensure clearer single responsibilities for Multimodal Transport Operators (MTOs) and encourage the use of integrated single transport documents.
   b. Provide stronger legal recognition and support for *freight forwarders* as key facilitators in multimodal logistics systems.

5. **Massive Adoption of Digital Technology**:
   a. Encourage and facilitate the adoption of IoT technology in plantations for *real-time monitoring* and FFB quality management.
   b. Applying *blockchain* to improve the transparency and traceability of CPO products from farms to end consumers, as well as to automate payments to farmers through *smart contracts*.
   c. Invest in digital infrastructure that supports data integration across the supply chain.
6. **Integrated and Adaptive Government Policies**:
   a. Formulate policies that holistically balance economic objectives (domestic price stability, export earnings) with sustainability objectives (certification, green practices).
   b. Provide targeted technical and financial support to small-scale farmers to comply with sustainability standards such as ISPO and RSPO, ensuring they remain part of the formal supply chain.

By comprehensively implementing these recommendations, Indonesia can significantly improve the efficiency and competitiveness of its CPO supply chain, in line with Indonesia's Logistics Vision 2025 goal of becoming a domestically integrated and globally connected country in the world supply chain market.

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