Cendana International Conference on Social and Technology (CICoST)
CISoST - 2025
E-ISSN: 3047-2490
Oktober 2025
Page: 148 - 152

Design of a Marketing Information System for Smallholder Palm Oil Supply Chain in Langkat Regency with Prospective Artificial Intelligence Integration

Ritna Wahyuni[1*], Tifany Zia Aznur[2], M. Fariz Afif Hasibuan[3]
[1]Faculty of Science and Technology, Study Program of System and Technology Information , Institut Teknologi Sawit Indonesia , Medan, Indonesia
[2] Faculty of Science and Technology , Study Program of Agribussiness, Institut Teknologi Sawit Indonesia, Medan, Indonesia
[3]Faculty of Agriculture and Forestry, Study Program of Agribussiness, Satya Terra Bhinneka University, Medan, Indonesia
Email: [1*]ritnawahyuni@itsi.ac.id
(* : corresponding author)

Abstract
The palm oil supply chain in Indonesia faces persistent challenges, including price fluctuations, long distribution channels, and the weak bargaining position of smallholder farmers. This study analyzes the palm oil smallholder supply chain in Langkat Regency using the Food Supply Chain Network (FSCN) framework and designs a marketing information system prototype to improve transparency and efficiency. The proposed system allows farmers, traders, and palm oil mills (PKS) to access real-time price information and conduct transactions digitally, thereby reducing dependency on intermediaries and improving farmers' income share. Although the current study focuses on the development of an information system, it also highlights the potential integration of Artificial Intelligence (AI) technologies. AI can be applied in price prediction, demand forecasting, and logistics optimization, which will strengthen decision-making and enhance supply chain performance. The findings suggest that while the prototype provides an initial solution for improving transparency, the integration of AI in future development presents significant opportunities to address systemic inefficiencies. This study contributes to the discussion on the role of digital transformation and AI in agricultural supply chains, particularly in improving smallholder welfare and market competitiveness.

Keyword: Palm oil supply chain, Information system, FSCN, Artificial Intelligence, Price prediction

1. INTRODUCTION

The palm oil sector plays a strategic role in Indonesia's agricultural economy, particularly in provinces such as North Sumatra, where smallholder plantations contribute significantly to total production (Ellahi et al., 2024) . In Langkat Regency, smallholder palm oil farmers are key actors in regional economic activities. However, despite their contribution, the smallholder palm oil supply chain faces persistent structural and informational challenges, including price volatility at the farm level, long marketing channels, limited transparency, and asymmetric information between farmers and intermediaries (Ivanov, 2022) .

Previous empirical findings in Langkat indicate that the palm oil supply chain generally follows two dominant patterns: (1) Farmer → Middlemen → Ramp → Palm Oil Mill (PKS), and (2) Farmer → Middlemen → Palm Oil Mill. Similar multi-tier marketing structures have been observed in other palm oil producing regions in Indonesia (Jelliani & Maifianti, 2021). The existence of multiple intermediaries often affects marketing margins and farmer's share, reducing the bargaining power of smallholders (Barra et al., 2023) (Prasmatiwi et al., 2023) (Lioutas & Charatsari, 2020). Empirical studies on agricultural commodities also confirm that lower farmer's share is closely associated with long marketing chains and asymmetric pricing mechanisms (Sumarni, 2021) .These structural inefficiencies are closely related to fragmented information flows and the absence of an integrated marketing information system that supports coordinated decision-making among supply chain actors (Lioutas & Charatsari, 2020).

To understand these structural and performance issues, the study adopts the Food Supply Chain Network (FSCN) framework (Nugroho, 2021). FSCN enables systematic analysis of supply chain objectives, structure, management, resources, business processes, and performance indicators. Through this framework, critical bottlenecks in marketing margins, information distribution, and coordination mechanisms can be identified (Ivanov, 2022). However, supply chain analysis alone is insufficient to improve operational performance without translating the findings into a structured digital solution (Pradika Putri et al., 2020).

Therefore, this research integrates FSCN analysis with Soft System Methodology (SSM) to develop a conceptual model of a marketing information system tailored to smallholder palm oil supply chains. SSM is employed to identify stakeholders (CATWOE analysis), define root definitions, and construct a conceptual model that reflects real-world conditions derived from field observations, interviews, questionnaires, and focus group discussions. The research scope is limited to the design of a prototype-level system architecture, ensuring consistency with the research roadmap and Technology Readiness Level (TRL) targets (Baryannis et al., 2018).

From a computer science perspective, the development of a marketing information system in agricultural supply chains represents a foundational step toward digital transformation. Information systems serve as structured platforms for data acquisition, storage, processing, and dissemination. In smallholder contexts,

E-ISSN: 3047-2490
Oktober 2025
Page: 148 - 152

reliable data management remains limited, making advanced analytics and intelligent optimization impractical without first establishing standardized digital infrastructure.

Recent developments in Artificial Intelligence (AI) demonstrate strong potential in supply chain forecasting, price prediction, and distribution optimization. Machine learning techniques have been widely applied in industrial supply chains to enhance predictive accuracy and reduce uncertainty. However, most AI-driven solutions assume the availability of clean, structured, and continuous datasets conditions that are rarely met in smallholder agricultural systems. This highlights a critical gap: before intelligent models can be implemented, an integrated information system must be established to ensure data reliability and interoperability (Ben-Daya et al., 2019).

Accordingly, this study focuses on the design of a marketing information system architecture derived from empirical FSCN findings and SSM-based stakeholder analysis. While AI implementation is not conducted in this research, the proposed system is intentionally designed with architectural compatibility for future AI integration, particularly for price forecasting and distribution optimization modules. This forward-compatible approach aligns with contemporary computer science research emphasizing scalable and modular system design (Ivanov, 2022).

The contribution of this study is twofold. First, it provides a structured and empirically grounded information system design for smallholder palm oil supply chains in Langkat Regency. Second, it bridges agricultural supply chain analysis with information system engineering by positioning the system as a foundational layer for future AI-enabled decision support systems. This approach ensures methodological consistency with the original research objectives while aligning with emerging discussions on intelligent supply chain systems.

2. RESEARCH METHOD

2.1 Research Framework

This research is structured within an integrated analytical–design framework combining Food Supply Chain Network (FSCN) analysis and Soft System Methodology (SSM) to produce a prototype-level marketing information system. The research framework consists of four main stages: (1) Supply Chain Diagnosis (FSCN Analysis); (2) Problem Structuring (SSM & CATWOE); (3) Conceptual System Modeling; (4) Prototype-Level System Architecture Design

The framework ensures that system development is grounded in empirical supply chain analysis rather than purely technical abstraction. Conceptually, the research flow can be described as:

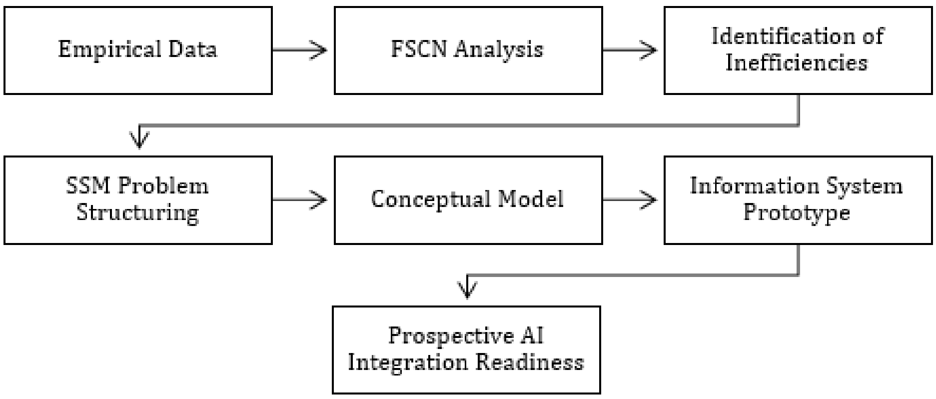

Figure 1. Research Flow

This structured approach aligns agricultural supply chain analysis with information system engineering principles.

2.2 Definition of Variables and Analytical Components

The study uses the following analytical variables derived from FSCN:

a. Supply Chain Structure: (1) Actors involved (farmers, middlemen, ramp, palm oil mills); (2) Distribution flow patterns
b. Supply Chain Performance: (1) Marketing margin; (2) Farmer's share
c. Supply Chain Management: (1) Information flow (2) Transaction mechanisms; (3) Coordination mechanisms
d. Resource and Business Process Components: (1) Production data; (2) Price information; (3) Quality grading; (4) Transaction records

These variables are analyzed to identify structural inefficiencies and information asymmetry within the smallholder palm oil supply chain.

2.3 Data and Sources

The study employs both primary and secondary data.

E-ISSN: 3047-2490
Oktober 2025
Page: 148 - 152

Primary data: (1) Field observation; (2) In-depth interviews; (3) Questionnaires (73 purposively selected farmers); (4) Snowball sampling for intermediaries; (5) Focus Group Discussion (FGD)
Secondary data: (1) Statistical data from official institutions; (2) Regional production reports
Data were collected in Sei Bingai District, Langkat Regency.

2.4 Application of Food Supply Chain Network (FSCN)

FSCN analysis is applied to examine (Nugroho, 2021): (1) Supply chain objectives; (2) Structural configuration; (3) Management patterns; (4) Resource utilization; (5) Business processes; (6) Performance indicators (marketing margin & farmer's share). The analysis identifies bottlenecks in pricing mechanisms and distribution channels, serving as the empirical basis for system design.

2.5 Application of Soft System Methodology (SSM)

SSM is applied to translate identified problems into a system-based solution. The stages include: (1) Rich picture development; (2) Root definition formulation; (3) CATWOE analysis; (4) Conceptual modelling; (5) Logical system structuring. The outcome of this stage is a conceptual marketing information system aligned with stakeholder needs.

2.6 System Design and Validation

The marketing information system prototype is designed using object-oriented modeling principles. The system architecture consists of: (1) Data Input Layer (price, production, transaction data); (2) Data Processing Layer (aggregation and validation); (3) Information Output Layer (dashboard and reporting interface). Although full-scale implementation is beyond the scope of this study, the prototype model is validated conceptually through stakeholder feedback obtained during interviews and FGD sessions.
This validation ensures system feasibility and alignment with real-world supply chain conditions.

2.7 Prospective AI Integration Readiness

While AI implementation is not conducted, the system architecture is designed to ensure modular expansion capability. Structured data storage enables potential integration of: (1) Price prediction models; (2) Demand forecasting algorithms; (3) Logistics optimization modules. This forward-compatible architecture reflects a scalable digital transformation pathway.

3. RESULT AND DISCUSSION

3.1 Supply Chain Structure Analysis

The Food Supply Chain Network (FSCN) analysis conducted in Sei Bingai District, Langkat Regency, reveals that the smallholder palm oil supply chain is characterized by two dominant distribution structures:

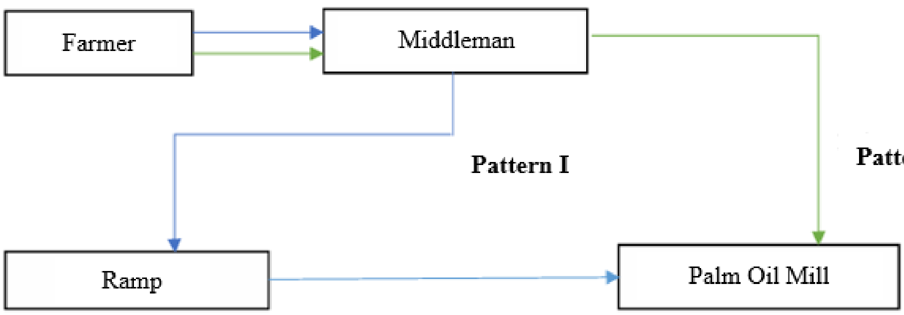

Figure 2. Supply Chain Oil Palm Patterns In Langkat

These structures indicate that smallholder farmers rarely engage in direct transactions with palm oil mills. Instead, collectors function as primary intermediaries who aggregate Fresh Fruit Bunches (FFB) from dispersed farmers before distributing them either to ramp stations or directly to mills.

From a structural perspective, the existence of multiple intermediaries significantly affects supply chain efficiency. Each intermediary introduces additional transaction layers, transportation costs, sorting processes, and profit margins (Baryannis et al., 2018). Consequently, marketing margins increase as products move downstream, while the farmer's share of the final mill price decreases.

Empirical findings from interviews and questionnaires involving 73 farmers confirm that pricing information is predominantly controlled by collectors. Farmers rely on daily price updates provided verbally or through informal communication channels. No standardized or digital mechanism exists to verify price accuracy. This creates a structural information asymmetry, where collectors possess greater bargaining power due to superior market information access.
In terms of FSCN components:

a. Supply Chain Objectives: Primarily profit-oriented at intermediary levels, with limited coordination mechanisms.
b. Structure: Linear and intermediary-dominated.
c. Management Pattern: Transaction-based, short-term, and informal.

E-ISSN: 3047-2490
Oktober 2025
Page: 148 - 152

d. Resources: Fragmented production and price data.
e. Business Processes: Manual recording and unstandardized grading.
f. Performance Indicators: Marketing margin variability and low farmer's share.

The absence of transparent pricing systems reinforces dependency relationships. Farmers prioritize immediate cash transactions over price negotiation, further weakening their bargaining position.
Thus, the structural configuration itself becomes a primary bottleneck in achieving supply chain efficiency and equitable value distribution.

3.2 Identified Information Gaps and Systemic Bottlenecks

The diagnostic phase identifies four critical information gaps:

a. Lack of real-time price dissemination, Price updates are informal and often delayed. No unified platform exists for disseminating verified price information to all actors simultaneously.
b. Absence of centralized transaction records, Transaction documentation is manual and actor-specific. Farmers rarely maintain written sales records. This limits historical price analysis and income monitoring.
c. Limited transparency in quality grading, Grading criteria are inconsistently applied. Farmers have minimal visibility regarding weight deductions and quality classifications.
d. No integrated data repository among actors, Production data, distribution data, and pricing information are stored separately by different actors, preventing aggregated analysis.

These issues confirm the need for a structured marketing information system (Puryantoro et al., 2019) (Nugroho, 2021) .

3.3 Conceptual System Design

Based on SSM analysis, stakeholder mapping identifies: (1) Customers: Smallholder farmers; (2) Actors: Farmers, middlemen, administrator, mills; (3) Transformation: From fragmented information flow to integrated digital system; (4) Worldview: Transparent information improves supply chain fairness; (5) Owners: Local institutions or cooperatives; (6) Environmental Constraints: Limited digital literacy and infrastructure. The system ensures standardized data flow and centralized storage (Baryannis et al., 2018).

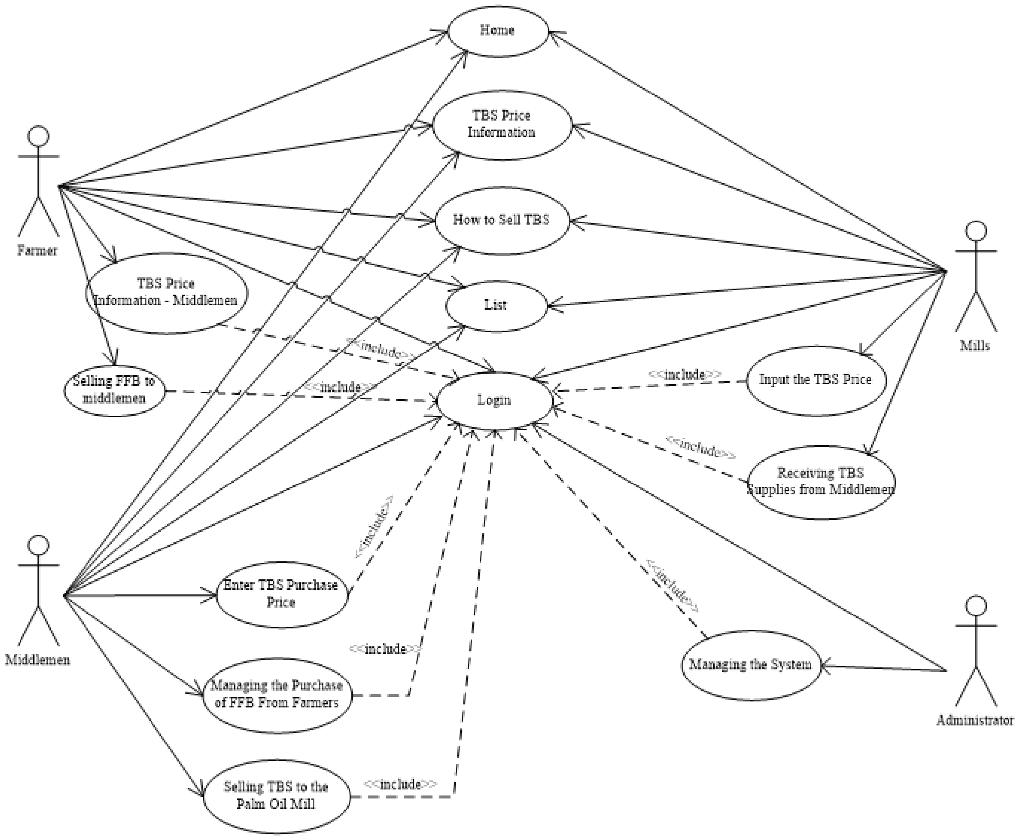

Figure 3. Marketing Information System Use Case Diagram

3.4 Prospective AI Integration (Conceptual Discussion)

Although Artificial Intelligence is not implemented in this study, the system is designed to support future integration. Structured datasets could enable: (1) Machine learning-based price forecasting; (2) Demand trend modeling; (3) Distribution route optimization; (4) Anomaly detection in transaction records. The modular design ensures that predictive models can be added without restructuring the core database architecture. This forward-compatible approach reflects scalable system engineering principles and aligns with emerging intelligent supply chain systems.

The study therefore contributes not only to agricultural supply chain analysis but also to information system engineering by positioning digital infrastructure as a prerequisite for intelligent decision support systems (Ben-Daya et al., 2019).

4. CONCLUTION

This study analyzes the smallholder palm oil supply chain in Langkat Regency using the Food Supply Chain Network framework and translates empirical findings into a marketing information system prototype through Soft System Methodology. The results show that structural inefficiencies and information asymmetry significantly affect marketing performance. To address these issues, a structured marketing information system architecture is proposed. The system design emphasizes data standardization, transparency, and stakeholder integration. While Artificial Intelligence is not implemented in this research, the proposed architecture ensures readiness for future AI-based price forecasting and distribution optimization modules. By establishing a reliable digital information foundation, smallholder supply chains can gradually transition toward intelligent and data-driven management systems. This research contributes to the integration of agricultural supply chain analysis and information system engineering, providing a scalable pathway toward AI-enabled supply chain transformation. This study offers methodological contributions by integrating the Food Supply Chain Network (FSCN) framework with Soft System Methodology (SSM) to bridge empirical supply chain diagnosis and information system design in a smallholder agricultural context. From a policy perspective, the proposed digital marketing information system provides a practical foundation for local governments, cooperatives, and agribusiness stakeholders to enhance pricing transparency and strengthen farmer bargaining positions. Future research may focus on implementing the system at a broader scale, conducting pilot testing, and integrating machine learning algorithms for real-time price forecasting and logistics optimization to evaluate measurable performance improvements.

REFERENCES

Barra, F. Al, Mustaniroh, S. A., & Deoranto, P. (2023). Evaluasi kinerja rantai pasok kelapa sawit di kabupaten kampar. *Jurnal Ekonomi Pertanian Dan Agribisnis (JEPA)*, *7*, 1440–1449.

Baryannis, G., Validi, S., Dani, S., & Antoniou, G. (2018). *Supply Chain Risk Management and Artificial Intelligence : State of the Art and Future Research Directions*.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: a literature review. *International Journal of Production Research*, *57*(15–16), 4719–4742.

Ellahi, R. M., Wood, L. C., & A., B. A. E.-D. (2024). *Blockchain-Driven Food Supply Chains: A Systematic Review for Unexplored Opportunities*. 2–30.

Ivanov, D. (2022). Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Annals of Operations Research*, *319*(1), 1411–1431.

Jelliani, J., & Maifianti, K. S. (2021). Analisis perilaku pasar tandan buah segar (tbs) kelapa sawit perkebunan rakyat di kecamatan darul makmur kabupaten nagan raya. *Jurnal Bisnis Tani*, *6*(2), 83–97.

Lioutas, E. D., & Charatsari, C. (2020). Smart farming and short food supply chains: Are they compatible? *Land Use Policy*, *94*, 104541.

Nugroho, W. W. (2021). Analisis Rantai Pasok Kentang di Kecamatan Ngablak Kabupaten Magelang dengan Metode Analisis FSCN (Food Supply Chain Network). *Agrista*, *9*(3).

Pradika Putri, F., Marimin, M., & Yuliasih, I. (2020). *Peningkatan Efektivitas Dan Efisiensi Manajemen Rantai Pasok Agroindustri Buah: Tinjauan Literatur Dan Riset Selanjutnya*.

Prasmatiwi, F. E., Ismono, R. H., Lestari, D. A. H., Evizal, R., & Fitriani, F. (2023). Kinerja Usahatani dan Rantai Pasok Kelapa Sawit Rakyat Pola Mandiri Di Kabupaten Tulang Bawang Provinsi Lampung. *Jurnal Penelitian Pertanian Terapan*, *23*(1), 151–162.

Puryantoro, P., Hani, E. S., & Bekti, S. (2019). *Manajemen Rantai Pasokan Strategi Peningkatan Daya Saing Mangga*.

Sumarni, B. (2021). Analisis farmer's share komoditas bawang merah. *Jurnal Agercolere*, *3*(2), 53–58.