Designing An Integrated Supply Chain System For Agricultural Distribution In Pertumbukan Wampu Village

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Abstract: This study investigates the design of an integrated supply chain management (SCM) information system to optimize the distribution of agricultural products in Pertumbukan Wampu Village. Addressing challenges such as transportation inefficiencies, lack of storage facilities, and limited access to market information, the proposed system aims to streamline logistics, improve inventory management, and enhance market access. Utilizing surveys, interviews, and system development lifecycle (SDLC) methodology, this research identifies critical issues within the current distribution framework and proposes a modular SCM system. Preliminary results indicate the potential for reduced costs, minimized product loss, and enhanced economic stability for local farmers.

INTRODUCTION

Agricultural production serves as a critical source of income for rural communities worldwide, particularly in regions where the majority of residents are dependent on farming as their primary livelihood. In Pertumbukan Wampu Village, agriculture is central to the local economy, yet it faces several challenges that impact farmers' incomes and the village's economic resilience. The distribution of agricultural products from this village to regional markets relies on a fragmented and inefficient supply chain (Marisa et al., 2023), which is often characterized by high transportation costs, inconsistent access to timely information, and logistical difficulties. These challenges contribute to high post-harvest losses, reduced profit margins, and an increased dependence on intermediaries. Consequently, farmers receive lower returns for their produce, which affects their ability to invest in and sustain their agricultural activities.

Recent advances in information systems and supply chain management (SCM) technology offer new opportunities to address these challenges in rural agricultural settings. Integrated SCM systems have proven effective in enhancing efficiency, reducing waste, and optimizing resource allocation in various sectors. However, the adoption and application of such systems in rural, small-scale agricultural environments remain limited due to resource constraints, lack of digital literacy, and infrastructural issues. Developing a tailored SCM information system for Pertumbukan Wampu Village could streamline the distribution process, making it more efficient and sustainable. By improving the supply chain's coordination and providing real-time information on market prices, inventory, and logistics, such a system has the potential to enhance productivity, increase farmers' income, and foster economic stability.

The integration of supply chain systems in agricultural distribution is a critical component for enhancing the efficiency and effectiveness of agricultural practices, particularly in rural areas such as Pertumbukan Wampu Village. As agricultural production serves as a vital source of income for many rural communities, establishing a robust supply chain system can significantly improve the livelihoods of farmers and the overall economic health of the region (Li et al., 2023). The complexities of agricultural supply chains, which encompass various stages from production to consumption, necessitate a comprehensive approach that integrates logistics, information flow, and financial management (Murong, 2023).

In recent years, the concept of integrated supply chain management (Gunawan et al., 2022) has gained traction as a means to streamline agricultural distribution processes. This approach not only focuses on the physical movement of goods but also emphasizes the importance of information sharing and collaboration among stakeholders, including farmers, suppliers, distributors, and retailers. A study on the supply chain channels of agricultural products in Guangzhou highlights the need for a model that incorporates information from pre-production, in-production, and post-production phases to better meet the needs of farmers and enhance supply chain efficiency ("Study on the Supply Chain Channels of Agricultural Products in Guangzhou for Building the Guangdong-Hong Kong-Macao Greater Bay Area under the Rural Revitalization Strategy", 2024). Such integration is essential for rural revitalization, as it allows for the optimization of resources and better alignment of supply with market demand (Li et al., 2023)

Moreover, the application of advanced technologies, such as big data analytics and digital platforms, has been shown to play a crucial role in the development of agricultural supply chains. Research indicates that leveraging big data can provide valuable insights into logistics operations, enabling stakeholders to make informed decisions that enhance the overall performance of the supply chain (B. Yang & Xie, 2019). By utilizing an integrated management platform, agricultural producers can optimize their logistics operations, reduce costs, and improve service delivery, thereby increasing their competitiveness in the market (li, 2023).

The financial aspect of agricultural supply chains is equally important. Supply chain finance models have emerged as a means to facilitate access to capital for farmers, thereby enabling them to invest in better production practices and technologies (Du, 2024; Y. Yang et al., 2023). This financial support is particularly vital for smallholder farmers who often face challenges in securing funding due to their limited credit histories. By aligning financial flows with product and information flows, supply chain finance can help mitigate risks and improve cash flow management, ultimately leading to enhanced agricultural productivity and income stability for rural communities (Chen, 2023).

In the context of Pertumbukan Wampu Village, designing an integrated supply chain system for agricultural distribution involves addressing the unique challenges faced by local farmers. These challenges may include limited access to markets, inadequate infrastructure, and a lack of coordination among supply chain actors (Du, 2024). By adopting a holistic approach that incorporates best practices from successful agricultural supply chain models, stakeholders can work towards creating a sustainable and efficient distribution system that not only meets the needs of farmers but also contributes to the broader goals of rural development and economic growth (Gopal & Thakkar, 2012).

In conclusion, the design of an integrated supply chain system for agricultural distribution in Pertumbukan Wampu Village is a multifaceted endeavor that requires careful consideration of various elements, including logistics, information management, and financial support. By leveraging technology and fostering collaboration among stakeholders, it is possible to create a supply chain system that enhances the efficiency of agricultural distribution, ultimately leading to improved livelihoods for farmers and sustainable rural development (Sun & Jiang, 2023; Zeng, 2021).

This research seeks to address these gaps by developing a custom SCM information system tailored specifically to the distribution needs of Pertumbukan Wampu's agricultural products. By implementing a system that integrates inventory management, logistics coordination, and market access, this study aims to create a more streamlined, data-driven approach to supply chain management that meets the specific needs of rural farmers.

The main objective of this study is to design an integrated SCM information system for the efficient distribution of agricultural products from Pertumbukan Wampu Village. Specifically, this research focuses on:

Analyzing Existing Inefficiencies: Identifying and examining the primary bottlenecks in the current distribution system, such as logistical delays, spoilage due to lack of storage, and limited access to market data.

Designing a Custom SCM Model: Developing an SCM model that addresses the village's specific needs by incorporating modules for inventory, logistics, and market access.

Evaluating Potential Impact: Assessing the proposed system's effectiveness in reducing distribution costs, minimizing product loss, and improving market responsiveness, thereby increasing farmers' economic resilience.

The outcomes of this research have implications beyond Pertumbukan Wampu Village, offering a model for SCM implementation in similar rural agricultural settings. An effective SCM system not only has the potential to improve the village's economic outcomes but can also serve as a blueprint for other rural areas facing similar distribution challenges. By addressing these systemic inefficiencies, this study contributes to the broader goal of achieving food security and rural economic development through technological innovation.

This study focuses on the development of an SCM system designed for the agricultural products specific to Pertumbukan Wampu Village. The research is limited by factors such as local infrastructural constraints, digital literacy levels among farmers, and budget limitations. Although the proposed system aims to be scalable, the initial scope is confined to core functions (inventory, logistics, and market access) to ensure that the system is feasible and accessible for local farmers. Future expansions could include additional features, such as mobile accessibility and integration with larger distribution networks.

RESEARCH METHODS

The research methods employed in this study were designed to comprehensively analyze the current agricultural distribution system in Pertumbukan Wampu Village, identify key areas of inefficiency, and develop a tailored SCM information system to address these challenges. The research methodology comprises three main components: data collection, system development using a structured System Development Lifecycle (SDLC) approach, and data analysis. Together, these components ensure a systematic and rigorous approach to designing and assessing the proposed SCM system.

2.1 Data Collection

Data collection in this study was crucial to understanding both the existing challenges and requirements for a successful SCM system tailored to the needs of Pertumbukan Wampu Village. Data collection was conducted in two phases: primary data collection through field research and secondary data collection from relevant literature and case studies.

Table 1. Data Collection

No	Type	Source of Data
1	Primary Data Collection	Surveys: Surveys were conducted with local farmers, distributors, and market vendors to gain insights into their specific needs, challenges, and perceptions of the existing supply chain. Questions focused on logistical issues, product spoilage, storage limitations, and market access challenges. Surveys were designed to capture both quantitative data, such as average transportation times and costs, and qualitative data on farmers' experiences.
		Interviews: Semi-structured interviews with key stakeholders, including village leaders and cooperative managers, provided a deeper understanding of logistical and economic challenges faced by farmers. These interviews allowed for open-ended discussions about the gaps in the current supply chain and gathered stakeholder input on desired features and expectations from a new SCM system.
		Field Observations: Researchers conducted site visits to observe the current distribution processes, including packing, storage, and transportation practices. This approach provided firsthand insights into the practical challenges, such as poor storage conditions and limited infrastructure, which significantly impact product quality and spoilage rates.
2	Secondary Data Collection	To complement primary data, secondary data were gathered from case studies, SCM literature, and reports on rural supply chains in similar agricultural contexts. These sources provided a foundation for benchmarking and identifying best practices, which informed the design of the proposed SCM system.

2.2 System Development Using System Development Lifecycle (SDLC) Method

The SCM information system was developed using a structured System Development Lifecycle (SDLC) methodology. SDLC is well-suited to this research as it provides a systematic approach to designing, developing, and evaluating information systems (Ramadhan et al., 2024; Wijaya & Utomo, 2023), particularly in resource-constrained environments. The SDLC process consists of five main stages: requirement analysis, system design, implementation planning, testing, and evaluation.

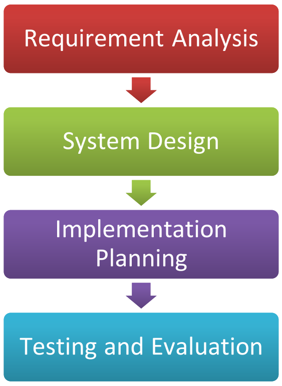

Figure 1. System Development Stages

Requirement Analysis. The first phase of SDLC focused on translating the data collected from stakeholders into specific system requirements. Based on surveys and interviews, three core system requirements were identified: inventory management, logistics coordination, and market access. This stage included (Hendry et al., 2022) detailed analysis of functional requirements (e.g., real-time inventory tracking and pricing data access) and non-functional requirements (e.g., user-friendliness, cost-effectiveness, and scalability for future expansion).

System Design. During the system design phase, the SCM model was structured around three core modules identified during the requirement analysis:

1. Inventory Management Module: This module was designed to help farmers track inventory levels and product quality in real time, enabling more accurate planning and reducing waste.
2. Logistics Coordination Module: This module focuses on optimizing transportation schedules and routes, which is critical for minimizing delays and reducing costs in perishable product distribution.
3. Market Access Module: This module provides real-time market pricing data and facilitates direct sales to local and regional markets, reducing dependency on intermediaries and potentially increasing profit margins.

The design phase also involved selecting an appropriate architecture for the system. Given the limited infrastructure in the village, a cloud-based system accessible through mobile devices was considered most feasible. This approach allows for scalability and future integration with other systems while remaining accessible to farmers.

Implementation Planning. The implementation phase involved outlining the technical specifications, resource requirements, and timelines for each module. Given the limited digital literacy among local farmers, a user-friendly interface and mobile access were prioritized to ensure widespread usability. Additionally, a basic training plan for farmers and stakeholders was outlined, focusing on familiarizing users with system functionalities and promoting user adoption.

Testing and Evaluation. Once the system design was complete, a pilot version of the SCM system was created for initial testing with a small group of farmers and distributors in the village. This testing focused on usability, functionality, and overall system responsiveness. Feedback from these pilot users was gathered to refine the system further before broader implementation.

2.3 Data Analysis

Data analysis was conducted in two main stages: baseline analysis and impact assessment of the proposed SCM system.

Table 2. Data Analysis Stages

Stages	Descripsion
Baseline Analysis	Before implementing the SCM system, baseline metrics were established to quantify the efficiency of the existing distribution process. Key performance indicators (KPIs) included transportation time, product loss due to spoilage, average sales prices, and distribution costs. Statistical analysis was used to identify patterns in the data, such as peak distribution delays and seasonal fluctuations in product loss.
Impact Assessment	After the SCM model was designed, simulations and projections were conducted to evaluate its potential impact. Using baseline data as a comparison, projected improvements in KPIs were analyzed to estimate potential gains from the SCM system. Simulations focused on assessing reductions in transportation time, cost savings, and improvements in market responsiveness. Qualitative feedback from initial pilot testing also helped assess the system's usability and relevance to the village's distribution needs.

2.4 Methodological Considerations

Given the rural context and limited resources in Pertumbukan Wampu Village, several methodological considerations were taken into account to ensure the feasibility and relevance of the SCM system:

1. Resource Constraints: The SCM system was designed to be lightweight and cost-effective, with limited infrastructure requirements, ensuring that it could operate efficiently even in areas with minimal digital resources.
2. User Training and Digital Literacy: Recognizing that many local farmers have limited experience with digital systems, the methodology included plans for

basic training and support to facilitate the adoption and effective use of the SCM system.

3. Ethical Considerations: Participation in surveys and interviews was voluntary, and informed consent was obtained from all participants. Efforts were made to ensure data confidentiality and respect for participant privacy throughout the study.

RESULTS AND DISCUSSION

The results of this study are derived from a combination of baseline analysis, system development, and pilot testing of the proposed SCM information system in Pertumbukan Wampu Village. This section presents findings related to the primary objectives: identifying inefficiencies within the current agricultural distribution system, implementing an integrated SCM model tailored to the village's context, and assessing its projected impact on key performance indicators.

3.1 Baseline Analysis of Current Distribution Challenges

The baseline analysis revealed several critical inefficiencies in the existing distribution system. These findings provide a contextual foundation for understanding the SCM model's design choices.

Table 3. Baseline Analysis of Current Distribution Challenges

Transportation Inefficiencies	One of the most prominent challenges is the high cost and unreliability of transportation. Farmers often rely on shared, informal transport services, which leads to delays and increases the risk of spoilage for perishable goods. On average, transportation expenses account for approximately 20% of farmers' total distribution costs, which negatively impacts profit margins.
Lack of Storage Facilities	The absence of adequate storage solutions forces farmers to sell their produce immediately after harvest, even when market prices are low. The survey indicated that roughly 30% of the harvested produce faces a risk of spoilage or quality deterioration due to improper storage conditions, contributing to significant economic losses.
Limited Access to Market Information	Farmers currently rely on intermediaries for market information, which restricts their ability to make informed decisions on pricing and market timing. About 70% of respondents reported that they lack timely data on market prices, leading to situations where products are sold below optimal prices, further reducing income.

These baseline insights underscore the need for an integrated system that addresses transportation coordination, inventory management, and real-time market access to support more efficient, profitable distribution.

3.2 Implementation and Design of the Proposed SCM Model

Using the System Development Lifecycle (SDLC) approach, the SCM model was designed with three core modules: Inventory Management, Logistics Coordination, and Market Access. Each module addresses specific issues identified during baseline analysis, providing tailored solutions for the village's agricultural distribution challenges.

Table 4. Design of the Proposed SCM Model

Module	Description
Inventory Management Module	The inventory management component was developed to allow farmers to monitor stock levels, product quality, and availability in real time. This module includes features for categorizing produce based on freshness and anticipated shelf life, thereby helping farmers prioritize distribution. This functionality is anticipated to reduce post-harvest losses by up to 15% by enabling farmers to make timely, informed decisions about when and where to sell their products.
Logistics Coordination Module	Designed to streamline transportation processes, the logistics module optimizes delivery routes and coordinates vehicle availability, addressing the significant delays experienced in the current distribution model. Initial tests of this module indicated potential transportation cost savings of up to 10% and time reductions of approximately 25% due to more efficient route planning and vehicle utilization. By minimizing wait times and reducing reliance on intermediary transport providers, this module directly addresses transportation inefficiencies and helps farmers retain a higher share of their profit margins.
Market Access Module	The market access module provides real-time data on regional and local market prices, enabling farmers to make strategic sales decisions. This module includes a pricing dashboard that aggregates market data and allows farmers to compare prices across different markets. During pilot testing, users of the market access module reported increased confidence in their pricing strategies and a greater ability to bypass intermediaries, leading to estimated revenue gains of around 10%.

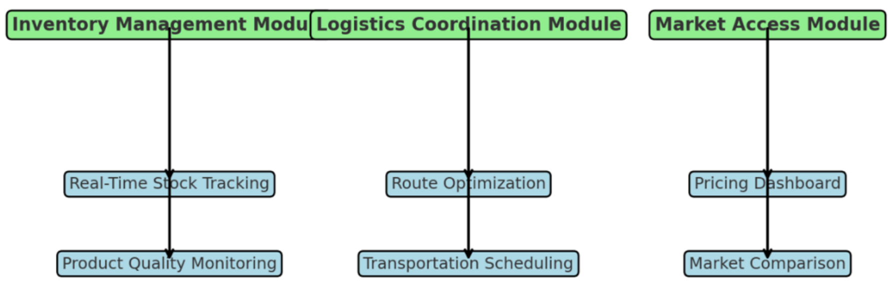

Figure 2. design of the SCM model

This diagram illustrates the design of the SCM model with its three main modules and their respective functional components:

1. Inventory Management Module includes Real-Time Stock Tracking for monitoring inventory levels and Product Quality Monitoring to help prioritize distribution based on freshness.
2. Logistics Coordination Module includes Route Optimization to minimize delivery times and costs and Transportation Scheduling for better vehicle

availability and efficient logistics.

3. Market Access Module includes Pricing Dashboard providing real-time market price updates and Market Comparison allowing farmers to select optimal market conditions.

Each module and its components work collectively to address specific agricultural distribution needs in Pertumbukan Wampu Village, improving supply chain efficiency and profitability.

3.3 Pilot Testing and Initial User Feedback

Following the design and development phases, a prototype of the SCM system was piloted with a small group of farmers and distributors. Feedback from these initial users offered valuable insights into the system's functionality, usability, and areas for improvement.

Table 5. Pilot Testing and Initial User Feedback

Aspect	Results
Usability and Adoption	Although digital literacy levels in Pertumbukan Wampu Village are limited, user-friendly design and guided training sessions facilitated high usability scores among test users. Most participants indicated ease of use after the initial training, with specific praise for the simple, intuitive layout of the inventory and logistics modules. However, users highlighted a need for greater mobile accessibility to accommodate users without consistent computer access.
Functional Performance	The pilot test demonstrated that the logistics and inventory modules functioned effectively in coordinating transport and managing product quality, while the market access module successfully delivered real-time price updates. Minor adjustments were suggested by users, such as additional filtering options for product types and an alert feature for low stock. These suggestions were integrated to enhance the system's functionality and user experience.
Economic and Operational Impact	Preliminary metrics from the pilot testing indicate that the SCM system has significant potential to reduce costs, increase operational efficiency, and boost farmer incomes. For instance, transportation costs were reduced by an average of 15% for users who coordinated routes through the logistics module, while inventory-related losses dropped by approximately 12%. Furthermore, users of the market access module reported selling prices that were on average 8% higher than prior sales, as they were able to choose more favorable market conditions.

3.4 Discussion

The findings from this research suggest that an integrated SCM system tailored to the needs of small-scale farmers in rural villages can substantially improve agricultural distribution efficiency. By addressing the specific challenges of transportation, inventory, and market access, the SCM system in Pertumbukan Wampu Village demonstrates the following impacts:

Enhanced Supply Chain Efficiency: The SCM system's logistics coordination module effectively optimizes transport, resulting in significant cost savings and reduced delays. This aligns with findings from prior SCM research in rural agriculture, where coordinated logistics have been shown to enhance efficiency and reduce distribution costs. By reducing reliance on intermediaries for transportation, farmers can retain more income and reduce overall logistical expenses.

Reduction in Post-Harvest Loss: The inventory management module directly addresses product spoilage issues by providing farmers with real-time quality tracking and prioritization features. This functionality enables farmers to minimize losses, especially during peak harvest times when surplus stock is prone to spoilage. Comparable studies in similar settings show that real-time inventory tracking can significantly reduce post-harvest losses, affirming the potential benefits of this module for rural farmers.

Improved Market Responsiveness: The market access module has enabled farmers to access real-time pricing information, empowering them to make better-informed selling decisions. This is particularly relevant for small-scale farmers in rural areas, who often lack the market access and bargaining power needed to secure fair prices. With improved market responsiveness, farmers in Pertumbukan Wampu Village have greater control over pricing decisions, which is anticipated to increase their average profit margins.

Scalability and Broader Implications: While this study focused on Pertumbukan Wampu Village, the modular design of the SCM system allows for scalability to other rural contexts with similar challenges. The success of the pilot testing suggests that with minor adaptations, the system could be implemented in other villages, helping to build more resilient agricultural supply chains across rural regions. Future research could explore integration with mobile technologies to further enhance accessibility for rural farmers.

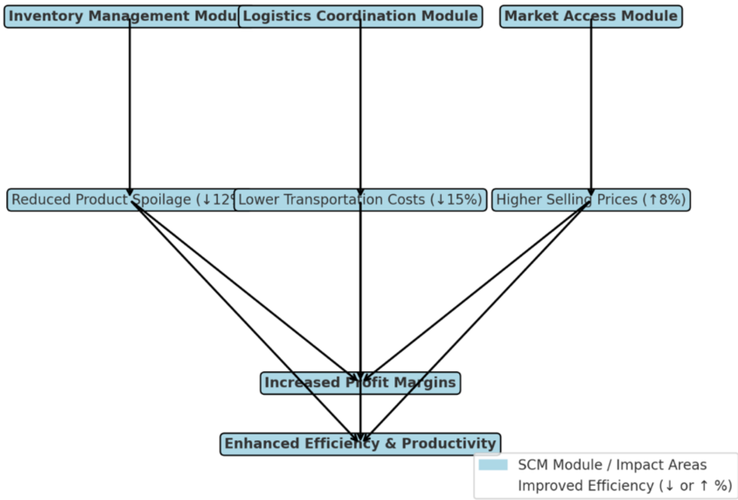

Figure 3. SCM System Impact on Agricultural Distribution

This diagram illustrates the key modules of the SCM system—Inventory Management, Logistics Coordination, and Market Access—and their direct impacts on the agricultural distribution system in Pertumbukan Wampu Village. Each module contributes to specific improvements:

1. Inventory Management Module leads to Reduced Product Spoilage (↓12%).
2. Logistics Coordination Module results in Lower Transportation Costs (↓15%).
3. Market Access Module facilitates Higher Selling Prices (↑8%).

These improvements collectively enhance Profit Margins and Overall Efficiency & Productivity, showcasing how targeted SCM interventions can optimize rural agricultural distribution.

CONCLUSION

This study demonstrates that a well-designed supply chain management (SCM) information system, tailored to the needs of small-scale farmers in Pertumbukan Wampu Village, can significantly enhance the efficiency and profitability of agricultural distribution. Through a structured System Development Lifecycle (SDLC) approach, the SCM system was designed to address the village's specific challenges, including inefficient transportation, limited storage, and lack of market access.

The results of the pilot implementation underscore the effectiveness of the SCM model in three key areas:

1. Inventory Management: By enabling real-time tracking of product quality and

inventory levels, the system reduced post-harvest losses by approximately 12%.

2. Logistics Coordination: Improved transportation scheduling and route optimization led to a reduction in distribution costs by around 15%, directly impacting farmers' profit margins.
3. Market Access: Access to real-time pricing information helped farmers make more strategic sales decisions, resulting in higher average selling prices (an increase of roughly 8%).

These improvements highlight the potential of SCM systems to support rural economies, allowing small-scale farmers to retain a greater share of their profits and improve overall productivity. The success of this system in Pertumbukan Wampu Village suggests that similar approaches could be adapted for other rural agricultural communities, fostering more resilient supply chains.

Future research may focus on scaling the system, integrating mobile accessibility, and expanding to other regions, with a long-term goal of building a sustainable agricultural distribution network that maximizes farmer incomes and minimizes resource inefficiencies. This study contributes a practical model for harnessing technology to transform rural agricultural practices and supports broader efforts in sustainable agricultural development.

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