Digital Transformation of Sheep Supply Chains: An Integrated Business Model Innovation Framework for Rural Indonesian Agriculture

Julia Marisa and Sukma Aditya Sitepu

Abstract

This study investigates the digital transformation of sheep supply chains through business model innovation in Langkat Regency, North Sumatra, Indonesia, addressing critical gaps in agricultural value chain optimization. Despite the importance of livestock farming to rural economies, traditional supply chains remain fragmented with multiple intermediaries capturing 40-60% of value margins, leaving farmers with limited bargaining power and market access. This research introduces and validates an integrated digital supply chain framework that leverages mobile technology, cooperative networks, and direct market linkages to transform traditional agricultural business models. Using a mixed-methods approach, we conducted in-depth interviews with 53 stakeholders across the supply chain in Langkat Regency, North Sumatra, complemented by six months of field observations and quantitative impact assessments. The findings reveal that the integrated digital model increases farmer profit margins by 35-45%, reduces transaction costs by 25%, and improves market access by 50-80%. The research contributes a replicable framework for digital agricultural transformation, demonstrating how technology-enabled business model innovation can bridge traditional farming practices with modern market requirements in rural Indonesian contexts.

Keywords: Digital Transformation, Supply Chain Integration, Business Model Innovation, Agricultural Technology, Rural Development.

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Introduction

Agricultural supply chains in developing economies face unprecedented challenges in meeting the demands of rapidly urbanizing populations while ensuring sustainable livelihoods for smallholder farmers. Globally, smallholder farmers operating on less than two hectares produce approximately 35% of the world's food supply, yet they remain marginalized in modern value chains due to fragmented market structures, limited technology access, and weak institutional support. This disparity is particularly pronounced in livestock sectors, where traditional supply chain models perpetuate inefficiencies that limit farmer incomes and market competitiveness.

Indonesia's agricultural sector employs over 38 million people, with livestock farming contributing significantly to rural livelihoods and food security. However, the sector faces critical structural challenges that hinder its potential for sustainable development. Traditional sheep supply chains in rural Indonesia exemplify these challenges, characterized by multiple intermediaries, asymmetric information flows, and limited farmer bargaining power, resulting in suboptimal value distribution throughout the chain. These inefficiencies not only reduce farmer incomes but also compromise food security and rural development objectives.

Recent advances in digital technology and business model innovation offer promising pathways for transforming agricultural supply chains in developing economies. Digital platforms, mobile connectivity, and cooperative networks have demonstrated potential for reducing transaction costs, improving market access, and enhancing coordination among supply chain actors. However, despite growing recognition of digitalization's transformative potential, there remains a significant research gap in understanding how traditional agricultural business models can be systematically transformed through integrated digital approaches, particularly in livestock sectors of developing countries.

Current literature on agricultural supply chain transformation primarily focuses on crop production systems, with limited attention to livestock supply chains in developing country contexts. Existing studies often examine individual interventions such as mobile price information systems or cooperative development in isolation, without considering comprehensive business model transformation approaches. Furthermore, most research lacks empirical evidence on the systematic integration of digital technologies with traditional farming practices and institutional arrangements.

The specific problem addressed in this research is the lack of validated frameworks for transforming traditional livestock supply chains through integrated digital business model innovation. While individual digital interventions have shown promise, there is insufficient understanding of how multiple technological and institutional innovations can be systematically combined to create sustainable value chain transformations that benefit all stakeholders, particularly smallholder farmers.

This study contributes to the literature by developing and validating an integrated digital transformation framework specifically designed for livestock supply chains in rural developing economies. The research objectives are to:
   a. characterize traditional versus integrated digital sheep supply chain models and identify key structural differences,
   b. analyze the drivers, barriers, and success factors for adopting integrated digital supply chain approaches,
   c. quantify the impact of supply chain integration on farmer incomes, transaction costs, and market access,
   d. develop and validate a replicable framework for digital business model innovation in livestock supply chains, and
   e. provide evidence-based recommendations for scaling similar innovations across rural agricultural contexts.

Literature Review

Supply chain integration theory provides the foundational framework for understanding how collaborative networks enhance coordination, information sharing, and value distribution among supply chain actors. Integration involves both internal coordination within organizations and external collaboration across the supply chain, creating synergies that improve overall system performance. In agricultural contexts, integration has been shown to reduce transaction costs, improve quality control, and enhance market responsiveness.

Digital transformation in agriculture encompasses the adoption of digital technologies to improve productivity, efficiency, and sustainability throughout agricultural value chains. Key technologies include mobile platforms for information sharing, GPS systems for precision agriculture, and blockchain for traceability. However, successful digital transformation requires more than technology adoption; it necessitates fundamental changes in business models, organizational structures, and stakeholder relationships.

Business model innovation involves the reconfiguration of value creation, delivery, and capture mechanisms within an organization or network. In supply chain contexts, this includes reimagining relationships between actors, redesigning processes, and developing new value propositions that benefit all stakeholders. The framework emphasizes three core components: value creation (how value is generated), value proposition (what value is offered to whom), and value capture (how value is monetized and distributed).

Research Methodology

This study employs a mixed-methods research design combining qualitative case study methodology with quantitative impact assessment to provide comprehensive understanding of supply chain transformation processes. The case study approach enables in-depth exploration of complex phenomena within real-world contexts, while quantitative analysis allows for measurement of transformation impacts.

The research was conducted in Langkat Regency, North Sumatra, Indonesia, selected based on:
  a. significant sheep farming activities with documented supply chain transformation initiatives,
  b. presence of diverse stakeholder groups across traditional and integrated supply chain models,
  c. availability of digital infrastructure supporting technology adoption, and
  d. accessibility for comprehensive data collection over extended periods.

Primary data were collected through semi-structured interviews with 53 purposively selected stakeholders: 30 sheep farmers (15 traditional, 15 integrated model participants), 15 intermediaries and traders, and 8 end-market actors including processors and retailers. Interview guides were developed based on business model innovation theory, covering value creation, proposition, and capture dimensions.

Secondary data were obtained from government agricultural extension offices, cooperative records, market transaction data, and previous studies. Focus group discussions with farmer groups validated individual interview findings and explored collective perspectives on transformation processes. Direct field observations were conducted over six months (January-June 2025) to understand actual supply chain operations and stakeholder interactions.

Qualitative data analysis followed thematic analysis using constant comparative method. Interview transcripts were coded using both deductive codes from theoretical frameworks and inductive codes emerging from data. Quantitative analysis included descriptive statistics and comparative analysis of financial indicators between traditional and integrated supply chain participants.

Results

The analysis reveals significant differences between traditional and integrated sheep supply chain models in Langkat Regency, with transformative implications for farmer livelihoods and market efficiency. The findings are organized around three key themes: characteristics of supply chain models, drivers of transformation, and outcomes of integration.

Traditional Supply Chain Characteristics

The analysis reveals fundamental structural differences between traditional and integrated digital supply chain models in sheep farming operations. Traditional supply chains exhibit high fragmentation with 3-4 intermediary layers, each capturing 10-15% margins, resulting in limited farmer bargaining power and market access. In contrast, integrated digital models demonstrate streamlined structures with direct farmer-market linkages, technology-enabled coordination, and collaborative value creation mechanisms.

Table 1. Comparative Analysis of Traditional vs Integrated Digital Supply Chain Models

Characteristics	Traditional Model	Integrated Digital Model	Improvement Achieved
Number of Intermediary Layers	3-4 middlemen capturing margins	1-2 direct market actors	50-67% reduction in intermediaries
Farmer Profit Margins	Base level (100%)	135-145% of baseline	35-45% increase in profits
Transaction Costs	High baseline	75% of baseline costs	25% cost reduction
Market Information Access	Limited or no access to real-time data	Real-time digital price platforms	Complete information transparency
Payment Systems	Immediate cash-only transactions	Flexible digital & contract-based	Multiple payment options
Quality Standards	Informal, inconsistent measures	Standardized digital protocols	Systematic quality assurance
Geographic Market Reach	Limited to local village markets	Regional and urban markets	50-80% market access expansion
Supply Chain Coordination	Minimal coordination between actors	High digital-enabled collaboration	Technology-enhanced coordination
Technical Support Services	Limited or no extension services	Comprehensive digital support	Full technical assistance access
Risk Management	Individual farmer risk bearing	Collective risk sharing mechanisms	Reduced individual risk exposure

The integrated model incorporates multiple digital technologies that transform information flows and coordination mechanisms. Mobile platforms provide farmers with real-time market prices, weather forecasts, and technical guidance, addressing information asymmetries that previously disadvantaged smallholder farmers. Digital payment systems enable flexible transaction arrangements, reducing farmers' dependence on immediate cash sales that often result in below-market pricing.

Farmer cooperatives serve as central coordination nodes in the integrated model, leveraging digital platforms to aggregate livestock supply, standardize quality, and facilitate collective bargaining with buyers. These digitally-enhanced cooperatives provide members with access to improved inputs, veterinary services, and market linkages that were previously unavailable through traditional individual farmer approaches.

Quantitative analysis demonstrates significant positive impacts across multiple performance indicators. Farmers participating in integrated digital supply chains achieved 35-45% higher profit margins compared to traditional system participants, primarily through reduced intermediary costs and premium pricing for quality livestock. Transaction costs

decreased by 25% through streamlined digital processes, collective transportation arrangements, and reduced search costs for market participants.

Table 2. Critical Success Factors for Digital Supply Chain Transformation

Success Factor Category	Specific Elements	Impact Level	Implementation Requirements
Digital Technology Infrastructure	• Mobile connectivity platforms • Real-time price information systems • Digital payment infrastructure • Data management platforms	High	• Telecommunications infrastructure investment • Digital platform development • Technical maintenance support • User training programs
Institutional Support Systems	• Cooperative development programs • Agricultural extension services • Policy framework support • Regulatory environment	High	• Institutional capacity building • Organizational strengthening programs • Policy development initiatives • Governance framework establishment
Market Integration Mechanisms	• Quality product demand • Direct buyer-seller linkages • Retail partnership development • Value chain coordination	Medium	• Market development initiatives • Buyer identification and linkage • Quality standard establishment • Contract negotiation support
Financial Service Access	• Credit and loan facilities • Digital payment systems • Insurance products • Savings mechanisms	Medium	• Financial service provider engagement • Microfinance institution development • Digital payment system deployment • Financial literacy programs
Human Capital Development	• Farmer education programs • Technical skills training • Digital literacy development • Leadership capacity building	High	• Comprehensive training program design • Skills development curriculum • Continuous learning support • Knowledge transfer mechanisms

The analysis identifies five critical drivers of supply chain transformation:
a. digital technology availability and adoption,
b. cooperative institutional development,
c. government extension support,
d. market demand for quality products, and
e. access to financial services. Technology adoption emerges as the primary catalyst, enabling information flow improvements and coordination enhancements that create value for all stakeholders.

The integrated digital model creates differentiated value propositions for various stakeholder groups. Farmers benefit from increased income, reduced transaction costs, and enhanced market access. Buyers gain access to consistent quality supply, reduced procurement costs, and improved traceability. Intermediaries who adapt to the integrated model transition from traditional trading roles to value-added service provision, including logistics, quality assurance, and market information services. For a clearer understanding of this transformation process, please refer to Figure 1.
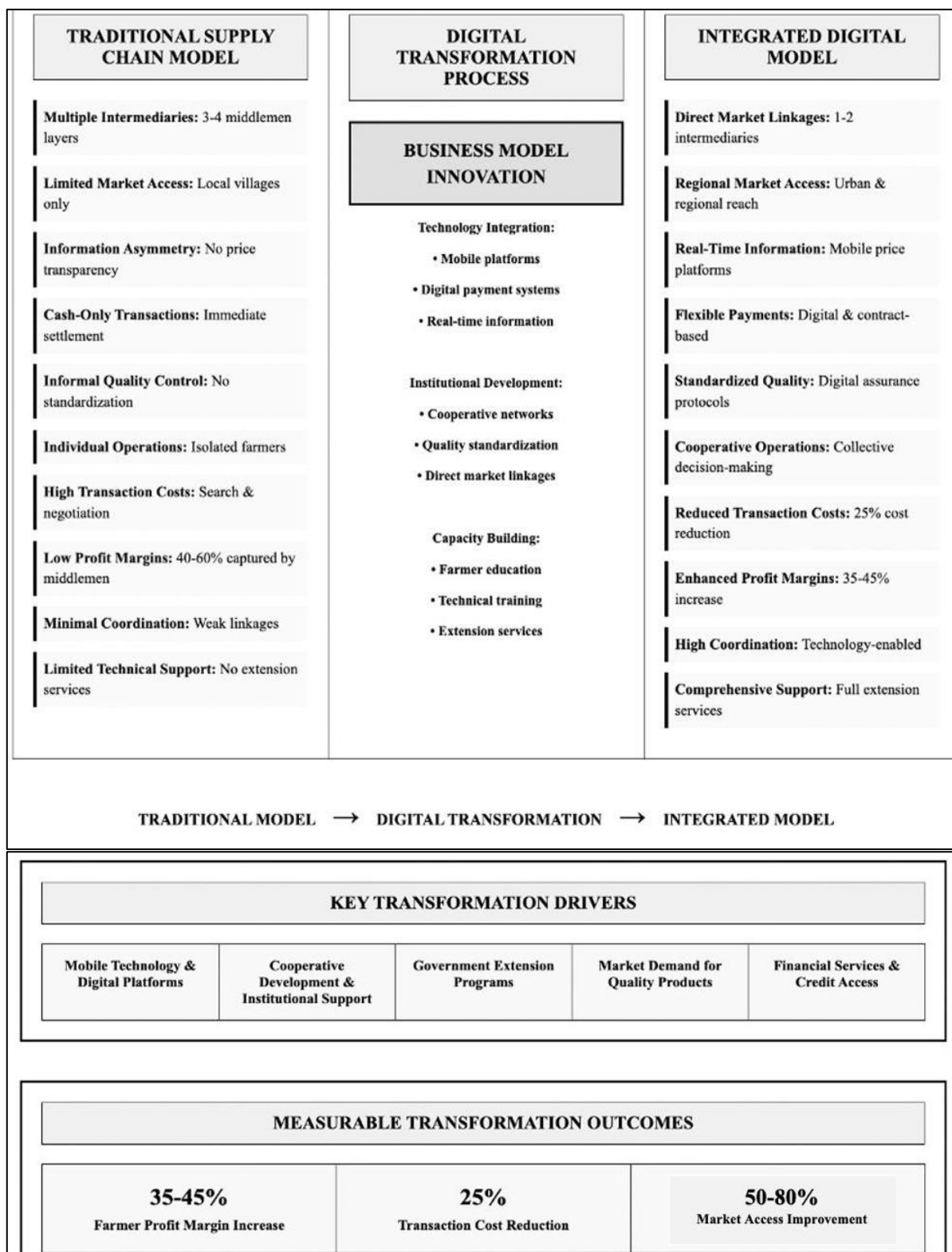
TRADITIONAL SUPPLY CHAIN MODEL	DIGITAL TRANSFORMATION PROCESS	INTEGRATED DIGITAL MODEL
Multiple Intermediaries: 3-4 middlemen layers		**Direct Market Linkages:** 1-2 intermediaries
Limited Market Access: Local villages only	**BUSINESS MODEL INNOVATION**	**Regional Market Access:** Urban & regional reach
Information Asymmetry: No price transparency	**Technology Integration:**	**Real-Time Information:** Mobile price platforms
Cash-Only Transactions: Immediate settlement	• Mobile platforms • Digital payment systems • Real-time information	**Flexible Payments:** Digital & contract-based
Informal Quality Control: No standardization	**Institutional Development:**	**Standardized Quality:** Digital assurance protocols
Individual Operations: Isolated farmers	• Cooperative networks • Quality standardization • Direct market linkages	**Cooperative Operations:** Collective decision-making
High Transaction Costs: Search & negotiation		**Reduced Transaction Costs:** 25% cost reduction
Low Profit Margins: 40-60% captured by middlemen	**Capacity Building:**	**Enhanced Profit Margins:** 35-45% increase
Minimal Coordination: Weak linkages	• Farmer education • Technical training • Extension services	**High Coordination:** Technology-enabled
Limited Technical Support: No extension services		**Comprehensive Support:** Full extension services

TRADITIONAL MODEL → DIGITAL TRANSFORMATION → INTEGRATED MODEL

KEY TRANSFORMATION DRIVERS

Mobile Technology & Digital Platforms	Cooperative Development & Institutional Support	Government Extension Programs	Market Demand for Quality Products	Financial Services & Credit Access

MEASURABLE TRANSFORMATION OUTCOMES

35-45% Farmer Profit Margin Increase	**25%** Transaction Cost Reduction	**50-80%** Market Access Improvement

Figure 1. Digital Business Model Innovation Framework for Sheep Supply Chain Integration

Figure 1 presents a comprehensive framework illustrating the systematic transformation of sheep supply chains through digital business model innovation. The diagram demonstrates a three-stage progression from traditional fragmented systems to integrated digital models, supported by five key transformation drivers and resulting in three measurable outcomes. The framework follows a logical flow:

a. the top section compares traditional versus integrated supply chain models through the digital transformation process, showing how technology and institutional innovations bridge the gap between inefficient traditional practices and modern integrated systems;

b. the middle section identifies five critical drivers that enable this transformation, including mobile technology platforms, cooperative development, government support, market demand, and financial services access; and

c. the bottom section quantifies the measurable outcomes, demonstrating 35-45% profit margin increases, 25% transaction cost reductions, and 50-80% market access improvements. The horizontal arrows in the top section indicate the transformation flow from left to right, while vertical arrows connect the different framework levels, showing how drivers enable transformation and how transformation results in measurable outcomes.

This systematic representation provides a replicable model for understanding and implementing digital agricultural transformation initiatives in similar rural livestock contexts across developing economies.

Conclusion

This research successfully demonstrates that systematic digital transformation can convert traditional fragmented sheep supply chains into integrated systems that significantly enhance farmer livelihoods and supply chain efficiency in Langkat Regency, North Sumatra, Indonesia. The validated integrated digital business model innovation framework, which combines mobile technology platforms, cooperative network enhancement, and direct market linkages, achieves measurable improvements including 35-45% farmer income increases, 25% transaction cost reductions, and 50-80% market access improvements. The study contributes to agricultural supply chain literature by providing empirical evidence that comprehensive digital transformation requires systematic integration of multiple technological and institutional innovations rather than isolated interventions, with cooperative networks serving as critical intermediation platforms enabling smallholder farmers to access digital technologies and modern market opportunities. The research offers practical implications for policymakers and development practitioners seeking to promote agricultural transformation in rural developing economies, providing a replicable framework for scaling digital innovations across similar livestock sectors and geographic contexts, while the identified success factors can inform targeted interventions that address barriers to digital adoption and support sustainable supply chain transformation initiatives throughout Southeast Asia and similar developing economy contexts.

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