

การพัฒนากรอบการจัดการแบบบูรณาการสินค้าซีฟิชมาและแบบจำลองอ้างอิง
การดำเนินงานของซีฟฟลายเซนปลานิลในจังหวัดอุบลราชธานี
Development of an Integrated Lean–Six Sigma–SCOR Framework for Enhancing
Tilapia Supply Chain Performance in Ubon Ratchathani

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อวิเคราะห์โครงสร้างและประสิทธิภาพของซีฟฟลายเซนปลานิลในจังหวัดอุบลราชธานี และพัฒนากรอบการปรับปรุงแบบบูรณาการที่ผสานแบบจำลองอ้างอิงการดำเนินงานซีฟฟลายเซน แนวคิดลีน และกระบวนการของซีฟิชมา แม้ว่าพื้นที่จะมีผลผลิตปลานิลประมาณ 11,601 ตันต่อปี คิดเป็นมูลค่า 670.9 ล้านบาท แต่ระบบซีฟฟลายเซนยังคงเผชิญกับความไม่มีประสิทธิภาพเชิงโครงสร้าง การประสานงานที่อ่อนแอ และการกระจายมูลค่าที่ไม่เป็นธรรมระหว่างผู้มีส่วนได้ส่วนเสีย การวิจัยนี้ใช้การออกแบบเชิงคุณภาพแบบกรณีศึกษาเดียว โดยเก็บรวบรวมข้อมูลผ่านการสัมภาษณ์เชิงลึกและการสังเกตภาคสนามจากผู้ให้ข้อมูลจำนวน 20 ราย ครอบคลุม 4 กลุ่ม ได้แก่ ฟาร์มเพาะพันธุ์ ฟาร์มเลี้ยงแบบกระชัง ผู้ขนส่ง/ผู้ค้าส่ง และผู้ค้าปลีก จากนั้นใช้ SCOR ในการวิเคราะห์กระบวนการซีฟฟลายเซน ใช้แนวคิดลีนในการระบุความสูญเสีย และใช้ DMAIC เป็นกรอบในการวิเคราะห์ปัญหาและออกแบบแนวทางปรับปรุงอย่างเป็นระบบ ผลการศึกษาพบว่ากระบวนการวางแผนเป็นคอขวดสำคัญที่สุดของซีฟฟลายเซน เนื่องจากขาดการพยากรณ์ความต้องการและการแบ่งปันข้อมูล ส่งผลให้เกิดการจัดหาแบบตอบสนอง การผลิตไม่สอดคล้องกับความต้องการ และกระบวนการขนส่งที่กระจัดกระจาย การวิเคราะห์ด้วยแนวคิดลีนพบว่าความสูญเสียประเภทการขนส่งและการรอคอยเป็นปัญหาหลัก จากการประเมินตัวชี้วัดด้วยมาตรวัดแบบลิเคิร์ต 5 ระดับ พบว่าประสิทธิภาพด้านระยะเวลาการส่งมอบ (2/5) ต้นทุนการขนส่ง (2/5) และการประสานงานระหว่างผู้มีส่วนได้ส่วนเสีย (1/5) อยู่ในระดับต่ำ ขณะที่ความเชื่อถือได้ของการส่งมอบคำสั่งซื้ออยู่ในระดับปานกลาง (3/5) จากผลการศึกษาได้เสนอแนวทางปรับปรุงจำนวน 7 แนวทาง ครอบคลุมระยะสั้น กลาง และยาว ได้แก่ การสร้างกลไกแบ่งปันข้อมูลความต้องการ การรวมเส้นทางขนส่ง การรับรองมาตรฐานการปฏิบัติทางการเกษตรที่ดี การจัดตั้งสหกรณ์เกษตรกร และการพัฒนาแพลตฟอร์มดิจิทัลเพื่อเพิ่มประสิทธิภาพ ความโปร่งใส และการประสานงาน โดยแสดงให้เห็นว่ากรอบการทำงานแบบบูรณาการ SCOR–Lean–DMAIC สามารถใช้ในการวิเคราะห์และแก้ไขปัญหาเชิงโครงสร้างเชิงปฏิบัติการ และเชิงระบบของซีฟฟลายเซนเกษตรกรรมแบบรายย่อยได้อย่างเป็นระบบ

คำสำคัญ: ซีฟฟลายเซนปลานิล, แบบจำลองอ้างอิงการดำเนินงานซีฟฟลายเซน, สินค้าซีฟิชมา, กรอบการจัดการซีฟฟลายเซนแบบบูรณาการ, ซีฟฟลายเซนการเพาะเลี้ยงสัตว์น้ำ

Abstract

This study analyzes the structure and performance of the tilapia supply chain in Ubon Ratchathani, Thailand, and develops an integrated improvement framework combining the Supply Chain Operations Reference (SCOR) model, Lean principles, and the Six Sigma DMAIC methodology. Despite producing 11,601 tons annually with a value of 670.9 million baht, the provincial supply chain continues to face structural

inefficiencies, weak coordination, and unequal value distribution among stakeholders. A qualitative single-case study design was employed, with primary data collected through in-depth, semi-structured interviews and field observations involving 20 informants across four stakeholder groups: breeding farms, cage-based grow-out farms, transporters/wholesalers, and retailers. SCOR was used to map and evaluate supply chain processes, Lean analysis identified non-value-added activities, and DMAIC guided systematic problem analysis and improvement design. The results reveal that the Plan process is the most critical bottleneck across all actors due to the absence of demand forecasting and information sharing, leading to reactive sourcing, poorly timed production, and fragmented delivery processes. Lean analysis further identifies Transportation and Waiting as the dominant waste categories, driven by uncoordinated routing and repeated handling of live fish. Performance evaluation using a structured five-point Likert scoring procedure indicates low efficiency in delivery lead time (2/5), transportation cost efficiency (2/5), and stakeholder coordination (1/5), while order fulfillment reliability is moderate (3/5). Based on these findings, the study proposes seven improvement strategies across short-, medium-, and long-term horizons, including demand information-sharing mechanisms, route consolidation, Good Agricultural Practices (GAP) certification, farmer cooperative development, and a conceptual digital supply chain platform to enhance coordination, transparency, and efficiency. The study demonstrates how an integrated SCOR–Lean–DMAIC framework can systematically diagnose and address structural, operational, and systemic challenges in smallholder-based aquaculture supply chains.

Keywords: Tilapia supply chain, SCOR model, Lean Six Sigma, integrated supply chain framework, aquaculture supply chain

1. Introduction

Thailand's freshwater aquaculture sector produced approximately 466,953 tons in 2023, generating a market value of around 28,517 million baht. Among cultured species, Nile tilapia (*Oreochromis niloticus*) holds the highest economic value. In 2024, national tilapia production reached 275,958 tons, accounting for 27.63% of freshwater aquaculture output, with a farm-gate value of approximately 13,686 million baht. Ubon Ratchathani Province ranks 8th nationally, producing 11,601 tons valued at 670,867,000 baht across 17,420 farms. Despite this scale, economic benefits remain disproportionately captured by intermediaries rather than primary producers, reflecting broader patterns in Southeast Asian small-scale aquaculture systems (Department of Fisheries, 2024).

The tilapia supply chain in Ubon Ratchathani faces persistent structural and operational challenges. Farmers have low bargaining power due to information asymmetry and heavy dependence on transporter–wholesalers. Inter-stakeholder coordination is weak, and live fish transportation is inefficient. Mortality rates during transport can reach 10–18%, representing significant revenue losses under retail prices of 50–65 THB per kilogram (Colt & Fornshell, 2014). The absence of demand forecasting forces farmers to accept farm-gate prices significantly below downstream value, with margin gaps estimated at 30–50% in comparable aquaculture systems (Bjorndal et al., 2014; Kruijssen et al., 2020). These vulnerabilities are further compounded by limited access to financial services, price volatility, and slow adoption of production and information technologies (Gao & Wongleedee, 2025).

Existing research on aquaculture value chains in South and Southeast Asia has largely emphasized descriptive mapping of actors and relationships. Although recent studies increasingly address resilience and sustainability, systematic, process-oriented improvement frameworks remain limited (Mahmud et al., 2026).

Post-harvest losses in regional fish supply chains are estimated at approximately 25%, driven by inadequate handling, lack of cold chain infrastructure, and inefficient logistics (Kruijssen et al., 2020). Studies applying structured frameworks demonstrate their value in related contexts: SCOR analysis has identified planning failures as key sources of inefficiency in agri-food logistics (Mulyadi et al., 2025), while Lean Six Sigma applications consistently highlight Transportation and Waiting as dominant waste categories (Costa et al., 2018). In fisheries, VSM–DMAIC approaches have proven effective in identifying operational bottlenecks even in qualitative settings (Thamke, 2020), and Lean Six Sigma adoption has been linked to improved financial performance (Tortorella et al., 2020). These frameworks are inherently complementary: SCOR identifies where performance gaps occur, Lean explains what drives inefficiency, and DMAIC provides a structured pathway for improvement (Gomaa, 2025).

However, prior studies typically apply these frameworks in isolation or at a single organizational level. SCOR alone lacks mechanisms for cross-actor coordination (Supply Chain Council, 2012; Mulyadi et al., 2025), Lean lacks system-wide mapping capabilities (Costa et al., 2018), and DMAIC lacks the diagnostic breadth needed for multi-tier supply chains (Gomaa, 2025). In the Ubon Ratchathani case, inefficiencies are simultaneously structural, operational, and systemic, requiring an integrated analytical approach that can address coordination failure, logistics inefficiency, and root-cause persistence across multiple stakeholders.

To address this gap, this study develops and applies an integrated Lean–Six Sigma–SCOR framework to analyze and improve the tilapia supply chain in Ubon Ratchathani. The study maps the supply chain using SCOR, identifies inefficiencies through Lean analysis, and applies DMAIC to examine root causes and propose targeted improvements. The DMAIC cycle is operationalized through the Define, Measure, Analyze, and Improve phases, while the Control phase is considered a future implementation stage. Theoretically, this study extends the application of integrated management frameworks to smallholder aquaculture in developing economies. Practically, the findings provide actionable insights for farmers, supply chain actors, and policymakers seeking to enhance efficiency, coordination, and competitiveness in the tilapia supply chain.

2. Materials and methods

2.1 Research Design

This study adopts a qualitative single-case study design combined with a framework development approach to analyze and improve the tilapia supply chain in Ubon Ratchathani, Thailand. The case is defined as a province-level supply chain encompassing four stakeholder tiers: breeding farms, cage - farming operations, transporters/wholesalers, and retailers. This design is appropriate for examining how and why structural and operational inefficiencies arise within a real-world context (Yin, 2018; Creswell, 2013). The study aims for analytic generalization by developing context-specific insights and a transferable improvement framework. Data were collected from multiple sources, including interviews, field observations, and secondary documents.

The analysis applies an integrated framework combining the SCOR model, Lean principles, and the Six Sigma DMAIC methodology to systematically evaluate performance, identify waste, and guide process improvement.

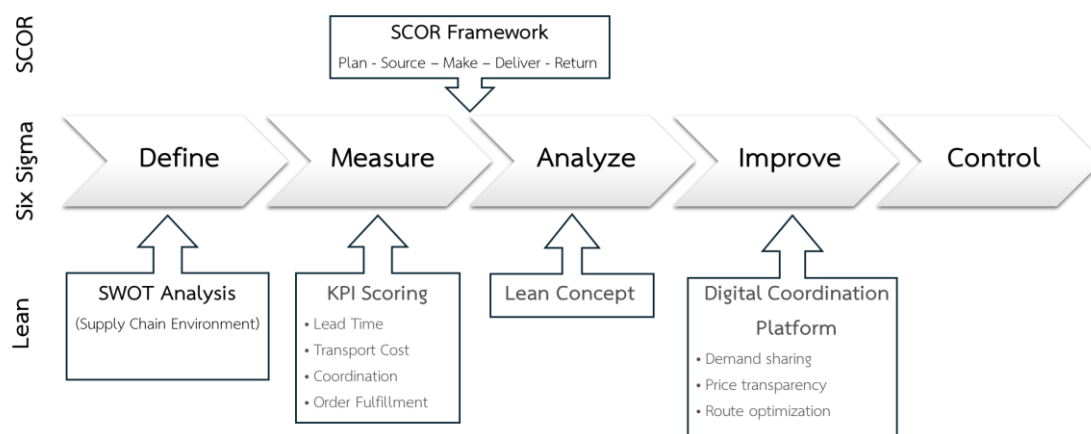


Figure 1. Integrated Lean–Six Sigma–SCOR framework for tilapia supply chain analysis and improvement

As illustrated in Figure 1, the integrated framework adapts the SCOR–Lean–DMAIC model of Nanthasamroeng et al. (2021) with four key extensions. First, SCOR mapping is applied across all stakeholder groups, breeding farms, cage farms, transporters/wholesalers, and retailers, to enable cross-actor performance diagnosis. Second, SWOT analysis is incorporated into the Define phase to capture contextual factors. Third, a five-point expert scoring approach is embedded in the Measure phase to establish KPI baselines for lead time, transportation cost, coordination efficiency, and order fulfillment reliability in a qualitative setting. Fourth, the Improve phase introduces a conceptual digital coordination platform to address planning inefficiencies, bargaining power imbalance, and transportation waste. These extensions constitute the study’s methodological contribution. Table 1 summarizes the alignment between SCOR and DMAIC.

Table 1. Mapping of SCOR processes to DMAIC phases and Lean perspective in the integrated framework

SCOR process	Role in the tilapia supply chain (Ubon Ratchathani)	DMAIC in this study	Lean perspective (waste focus)	Key outputs in this study
Plan	Informal, experience-based planning at all actor levels with no demand forecasting or shared information platform; strong dependence on transporter–wholesalers for price and volume decisions.	Define–Measure–Analyze–Improve: Define planning as a system-level problem; Measure current planning practices and qualitative SCOR KPIs; Analyze root causes (information asymmetry, lack of shared platform); Improve via shared demand information mechanisms and standardized planning routines.	Waiting, overproduction, excess processing caused by missing demand signals and independent planning by each actor.	Identification of Plan as the primary bottleneck across all actors; proposal of weekly demand-sharing reports and coordinated planning mechanisms.

Table 1. Mapping of SCOR processes to DMAIC phases and Lean perspective in the integrated framework (Cont.)

SCOR process	Role in the tilapia supply chain (Ubon Ratchathani)	DMAIC in this study	Lean perspective (waste focus)	Key outputs in this study
Source	Decentralized input procurement (broodstock, feed, equipment) by individual farmers and breeders, limiting bargaining power and economies of scale.	Define–Measure–Analyze–Improve: Define sourcing fragmentation; Measure input channels and sourcing practices; Analyze effects on cost and supply security; Improve via cooperative or coordinated procurement options.	Inventory and transportation waste due to duplicated and uncoordinated purchasing.	Recognition of fragmented sourcing as a contributor to high input cost; suggestion of cooperative structures for input procurement.
Make	Breeding and grow-out operations at farms; biologically sound husbandry but exposed to climate variability and poorly synchronized with downstream demand.	Define–Measure–Analyze–Improve: Define production-stage issues (e.g., unsynchronized stocking/harvesting); Measure current Make processes against SCOR reliability and cost attributes; Analyze process variability and vulnerability; Improve via basic standardization and better scheduling.	Defects, over-processing, waiting (e.g., stress-induced mortality, non-standardized handling, idle capacity).	Clarification that Make is technically sound but its value is eroded by upstream Plan and downstream Deliver failures; identification of simple process-level improvements.
Deliver	Live-fish transportation and distribution dominated by transporter–wholesalers; fragmented routing, high transport cost, and high in-transit mortality.	Define–Measure–Analyze–Improve: Define Deliver as a critical bottleneck; Measure lead time, transportation cost, coordination efficiency, and order fulfillment reliability using SCOR metrics; Analyze causes using Lean waste mapping; Improve via route consolidation, coordinated scheduling, and a conceptual digital logistics platform.	Transportation and Waiting identified as dominant wastes (redundant trips, non-optimized routes, repeated handling of live fish).	Evidence of low responsiveness and cost performance; proposal of consolidated routing, digital coordination, and improved handling protocols.

Table 1. Mapping of SCOR processes to DMAIC phases and Lean perspective in the integrated framework (Cont.)

SCOR process	Role in the tilapia supply chain (Ubon Ratchathani)	DMAIC in this study	Lean perspective (waste focus)	Key outputs in this study
Return	No formal Return processes; unsold or rejected fish handled in ad hoc ways, if at all.	Define–Measure–Analyze (conceptual): Acknowledge the absence of structured Return processes; qualitatively consider their implications for waste and quality.	Potential defects and inventory waste associated with unmanaged returns.	Identification of Return as a prospective area for future system design and KPI development rather than a current focus of empirical implementation.

Note: The Control phase is included conceptually in the framework but is not empirically executed in the present study.

2.2 Data Collection

Primary data were collected through in-depth, semi-structured interviews with key stakeholders across four tiers of the tilapia supply chain: breeding farms, grow-out farms, transport operators/wholesalers, and retailers. Participants were selected using purposive and snowball sampling based on their operational roles. Purposive criteria were defined separately for each stakeholder group to ensure sufficient operational experience. Tilapia breeding farms were eligible if they had operated continuously for at least three years and actively supplied juvenile fish to cage farms within Ubon Ratchathani Province. Cage- farming operations required a minimum of three years of grow-out experience along the Mun River and at least one floating cage unit. Fish transport operators/wholesalers were included if they had at least three years of experience purchasing and distributing live tilapia within the province and operated at least one dedicated live-fish transport vehicle. Retailers were selected based on a minimum of two years of selling live or fresh tilapia at a fixed market location. Across all groups, willingness, and ability to describe operational processes, cost structures, and coordination practices in detail were additional inclusion criteria. Snowball sampling was applied in midstream and downstream tiers to identify further informants through practitioner referrals.

Table 2. Informant Profile by Supply Chain Tier

Stakeholder Group	Supply Chain Tier	Number of Informants	Sampling Method	Average Interview Duration
Tilapia breeding farms	Upstream	5	Purposive	45–90 min
Cage farming operations	Midstream	6	Purposive + Snowball	45–90 min
Fish transporters / wholesalers	Midstream–Downstream	4	Snowball	45–90 min
Retailers	Downstream	5	Snowball	45–90 min
Total		20		

As shown in Table 2, total of 20 informants across four stakeholder tiers aligns with a purposive, depth-oriented sampling strategy appropriate for qualitative single-case study research (Creswell, 2013). Data collection continued until thematic saturation was reached, with no substantively new themes emerging from additional interviews. Given the relatively small and geographically concentrated population of tilapia supply chain operators in the Mun River basin, the sample is considered representative of key operational perspectives. The study aims for transferability rather than statistical generalizability, consistent with case study methodology (Yin, 2018).

Interviews were conducted at participants’ operating locations, lasting approximately 45–90 minutes, using a semi-structured guide covering operational processes, logistics activities, cost structures, information flow, and coordination. All interviews were conducted in Thai and subsequently transcribed and translated. Non-participant observation and secondary data from fisheries statistics and related reports were used to support the analysis. Triangulation across multiple data sources enhanced the credibility of the findings, and all participants provided informed consent and were assured of confidentiality.

2.3 Analytical Framework

The analytical framework integrates three complementary components in a sequential structure. First, the SCOR model is used to map and evaluate supply chain processes across the Plan, Source, Make, Deliver, and Return domains, with performance assessed in terms of reliability, responsiveness, and cost efficiency. Second, Lean principles are applied to identify non-value-added activities, particularly in transportation, waiting, over-processing, and excess inventory, using value stream concepts. Third, the Six Sigma DMAIC methodology serves as the overarching problem-solving framework, guiding the study through the Define, Measure, Analyze, Improve, and Control phases to systematically analyze inefficiencies and develop improvement strategies.

Although Six Sigma is conventionally associated with quantitative defect reduction and statistical process control, its application here is interpreted in a qualitative dimension. Variation reduction is operationalized as the identification and mitigation of recurring process inconsistencies across supply chain actors. Three forms of qualitative variation are examined: price volatility resulting from transporter-dominated price setting; inconsistent product quality and handling due to the absence of live-fish handling standards; and coordination variability arising from the lack of shared planning routines

and information platforms. The DMAIC cycle is used to identify these variation sources (Define–Analyze), assess their severity through expert-scored KPI evaluations (Measure), and design targeted interventions to reduce their occurrence and impact (Improve), with Control treated as a prospective implementation stage.

2.4 Performance Measurement

Supply chain performance was evaluated using four key performance indicators (KPIs) derived from SCOR attributes and operational considerations: lead time, transportation cost, coordination efficiency, and order -fulfillment reliability. KPI assessment followed a structured two-round expert scoring procedure using a five-point Likert scale (1 = very poor, 5 = excellent). In the first round, informants from the four supply chain tiers independently rated current-state performance on each KPI based on their operational experience, and scores were aggregated using arithmetic means, with numerical values and corresponding descriptive levels (High, Moderate, Low) reported side by side in Table 6 to support transparency and enable future pre/post comparison. In the second round, aggregated scores were presented to a panel of five academic and industry experts; where panel assessments differed from informant means by more than one scale point, scores were revised through structured discussion until consensus was reached, and the final KPI values in Table 6 represent these consensus-validated ratings. A comparative assessment was also conducted between current-state performance and projected performance under the proposed improvement framework using the same scoring procedure applied to stakeholder-informed estimates of expected improvement.

2.5 SWOT-Based Contextual Analysis

To complement the process-level diagnosis and support problem prioritization in the Define phase of the DMAIC cycle, a SWOT analysis was incorporated into the analytical framework. Macro-level opportunities and threats were identified by synthesizing evidence from in-depth interviews, non-participant observations, and secondary data on production, market trends, and policy conditions for freshwater aquaculture in Ubon Ratchathani. Interview transcripts were reviewed to extract statements on external drivers (market demand, policy support, climate variability, competitive pressure), which were coded and grouped into opportunity and threat factors through iterative researcher consensus. The resulting SWOT matrix (Table 3) highlights four key opportunities, fast biological growth of tilapia, relatively low feed cost, strong domestic demand, and supportive government policy, and four key threats, high export taxes and costs, climate variability and flooding, intense inter-regional price competition, and structurally low bargaining power of cage -farm operators. These factors did not serve as performance indicators but framed the interpretation of SCOR and Lean findings and guided the design of improvement strategies.

Table 3 Opportunities and Threats in Tilapia Supply Chain of Ubon Ratchathani

Dimension	Factor	Implication for Supply Chain
Opportunity	Fast biological growth rate of tilapia	Short production cycles; potential for high throughput if coordination improves
	Relatively low feed cost compared to other aquaculture species	Moderate cost base; margin improvement possible through supply chain efficiency gains
	Strong and growing consumer demand for tilapia in Thai cuisine	Stable downstream demand; market pull exists for improved supply reliability
	Government policy support for freshwater aquaculture	Access to extension services, subsidized broodstock from Inland Fisheries Center
Threat	High export taxes and associated export costs	Limits international market development; traps supply chain in domestic low-margin markets
	Climate variability and seasonal flooding	Disrupts cage operations on the Mun River; increases production uncertainty
	Intense price competition from other tilapia producing regions	Downward pressure on farm-gate prices; exacerbates farmers' low bargaining power
	Low bargaining power of cage farm operators	Structural dependency on wholesalers; suppresses farm profitability and reinvestment capacity

2.6 Research Procedure

The research procedure is structured around the DMAIC methodology, with the Define, Measure, Analyze, and Improve phases executed and the Control phase specified conceptually as a later implementation stage. In the Define phase, key supply chain problems were identified using stakeholder interviews, SIPOC analysis, and process mapping. In the Measure phase, the current-state supply chain was mapped with the SCOR framework and baseline performance was assessed against defined KPIs, supported by value stream visualization. In the Analyze phase, root causes were examined using Fishbone diagrams and the 5-Why technique, with Lean waste categories mapped to identify critical inefficiencies. In the Improve phase, an integrated improvement framework was developed, including process redesign and a conceptual digital coordination platform, with feasibility assessed through stakeholder consultation. The Control phase is outlined conceptually, proposing KPI tracking and role assignment as guidance for future implementation rather than empirically tested interventions.

2.7 Conceptual Evaluation of the Proposed Model

The proposed integrated framework was evaluated through a two-stage expert validation process to assess operational feasibility and the credibility of the KPI scoring procedure. In both stages, a structured five-point Likert scale was used so that expert judgments could be linked directly to the KPI scores reported in Table 6.

In Stage 1, five supply chain practitioners were purposively selected: two cage farm operators with at least five years of commercial tilapia farming experience, one fish transport operator/wholesaler active on the Mun River basin route, and two retail vendors handling live freshwater fish. They reviewed the proposed improvement strategies and assessed their feasibility using a five-point checklist covering implementability under current resource constraints, expected impact on operational efficiency, and barriers to adoption. Practitioners also rated current-state and projected post-improvement performance for the four KPIs: lead time, transportation cost, coordination efficiency, and order fulfillment reliability.

These individual ratings were averaged to form initial KPI scores and improvement estimates.

In Stage 2, three experts (two academics in supply chain or agricultural logistics and one industry consultant with food or aquaculture experience) evaluated the framework using a rubric covering: logical consistency of the SCOR–Lean–DMAIC sequence, methodological completeness, alignment between root causes and interventions, and transferability to comparable smallholder aquaculture contexts. Each criterion was rated on a five-point scale, with qualitative comments requested for ratings below 4. The expert panel also reviewed Stage-1 KPI scores. When any expert's view differed from practitioners' means by more than one scale point, discrepancies were discussed until a consensus value was reached. The final KPI scores in Table 6 reflect these consensus-validated ratings and the feedback incorporated into the refined framework.

3. Results

3.1 Current Structure of the Tilapia Supply Chain

The tilapia supply chain in Ubon Ratchathani consists of four main stakeholder groups across upstream, midstream, and downstream stages, as illustrated in Figure 2. The upstream stage is led by breeding farms that source broodstock, procure feed from commercial suppliers, and utilize basic transport equipment to distribute tilapia fry to farmers. These inputs form the foundation for subsequent production activities. The midstream stage comprises both subsistence and commercial farmers. Subsistence farmers typically raise fish in ponds or rice paddies for household consumption, while commercial operators, particularly cage-based farms along major water bodies, rear fish to market size for sale. This stage represents the primary production segment of the supply chain. The downstream stage is dominated by fish transporters who also function as wholesalers. These actors collect fish directly from farms, determine purchase prices, and distribute products to retailers and food service operators. This structure results in strong farmer dependency on wholesalers, who act as the primary interface between production and market distribution.

In addition to the structural configuration, three key flows characterize the supply chain. Product flow moves downstream from breeding farms to farmers, then to transporters, retailers, and ultimately consumers. Financial flow operates in the reverse direction, with transporters–wholesalers capturing a significant share of the margin at the midstream–downstream interface. Information flow, however, is highly centralized at the transporter level, with limited upstream sharing of demand and price data, resulting in information asymmetry that disadvantages farmers.

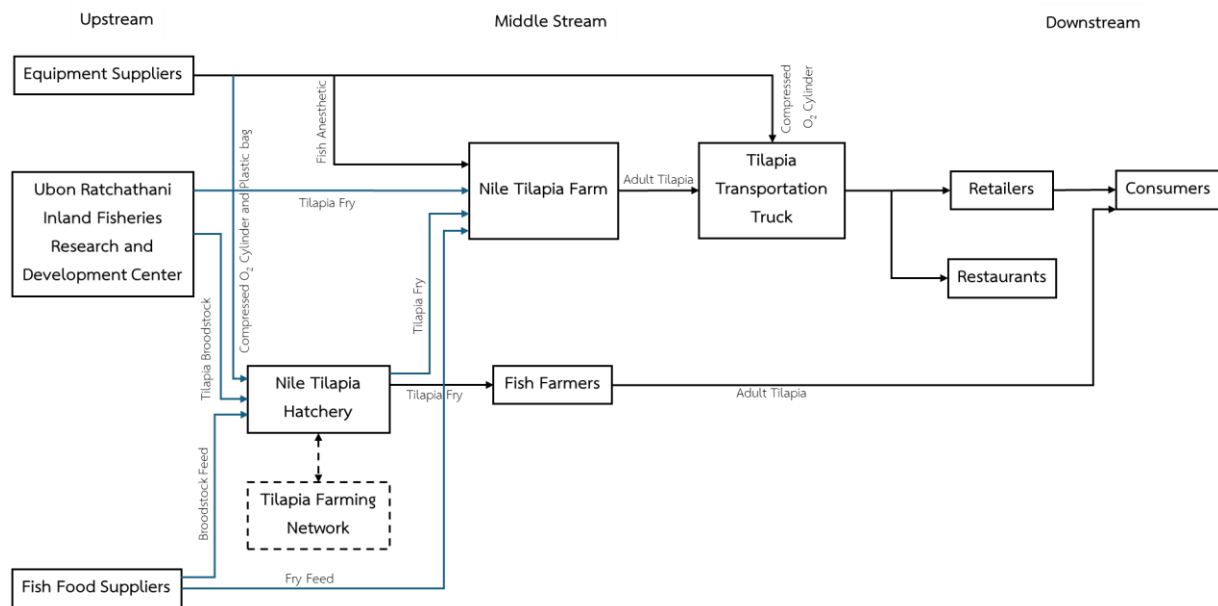


Figure 2. Current structure of the tilapia supply chain in Ubon Ratchathani

3.2 SCOR-Based Process Analysis by Supply Chain Actor

Supply chain processes were analyzed using the SCOR model framework, applied independently to each of the four key actors: (1) tilapia breeding farms, (2) cage farming operations, (3) fish transporters/wholesalers, and (4) retailers. The analysis focused on the Plan, Source, Make, and Deliver processes for each actor and examined how weaknesses in these processes contribute to overall supply chain underperformance. Table 4 summarizes the main issues identified across all segments, organized by SCOR process category.

Table 4. Summary of key issues by supply chain segment and SCOR process

Supply chain segment	SCOR process	Main issues identified	Performance implication
Upstream – Tilapia breeding farms	Plan	Informal, experience-based planning of juvenile output; no demand forecasting or structured communication with cage farms.	Systematic mismatches between fry supply and downstream demand; risk of chronic over- or under-supply.
	Source	Inputs (broodstock, feed, equipment) procured individually from limited suppliers.	Weak bargaining power; limited economies of scale and higher unit input costs.
	Make	Biologically sound breeding cycle but exposed to climate variability and poorly synchronized with cage-farm stocking schedules.	Production variability and timing mismatches that propagate downstream.
	Deliver	Basic live-fish delivery to cage farms using simple equipment; no coordinated scheduling.	Localized transport inefficiencies and stress-induced fry losses.

Table 4. Summary of key issues by supply chain segment and SCOR process (Cont.)

Supply chain segment	SCOR process	Main issues identified	Performance implication
Midstream – Cage farming operations	Plan	Stocking and harvesting based on personal experience; no access to formal demand data from downstream buyers.	Reactive production planning, recurrent supply–demand imbalances, and dependence on transporter-wholesalers.
	Source	Juveniles sourced exclusively from breeding farms; feed from a small number of commercial distributors.	Limited supplier choice and weak price-negotiating position for key inputs.
	Make	Technically sound grow-out operations along the Mun River but not synchronized with market demand and vulnerable to climate variation.	Biological performance is undermined by planning failures; heightened exposure to price volatility.
	Deliver	Farmers sell only at farm-gate to transporter-wholesalers, who set both price and quantity.	Very low bargaining power; farm-gate prices substantially below consumer-end value.
Midstream– Downstream – Fish transporters / wholesalers	Plan	Route planning based on informal knowledge; no integrated routing or demand aggregation system.	Fragmented trips, excess fuel consumption, and extended delivery lead times.
	Source	Product sourced directly from cage farms at prices determined unilaterally by transporters.	Structural monopsony power and persistent margin capture at the midstream–downstream interface.
	Make (Handle)	Live-fish handling during loading and in-vehicle holding with limited standardization and constrained tank capacity.	Elevated stress and mortality risk; inconsistent product condition on arrival.
	Deliver	Fragmented distribution to retailers and restaurants; no cold chain and no route optimization.	High transportation cost and prolonged lead times; mortality and shrinkage that can reach 10–18% in extreme cases.

Table 4. Summary of key issues by supply chain segment and SCOR process (Cont.)

Supply chain segment	SCOR process	Main issues identified	Performance implication
Downstream – Retailers	Plan	Purchase volumes based on daily experience and intuition; no formal demand forecasting or sales recording.	Demand variability not captured systematically, reinforcing upstream planning uncertainty.
	Source	Exclusive sourcing from transporter-wholesalers through a single procurement channel.	Limited ability to compare prices or secure alternative supply; dependency on transporter pricing.
	Make (Process)	Live-to-fresh conversion and display without standardized handling or temperature control.	Handling losses and shrinkage of approximately 10–18% of daily throughput under typical conditions.
	Deliver	Direct sale to end consumers and restaurants with no formal order management or feedback system.	Absence of structured demand information flowing upstream; missed opportunity for coordinated planning and performance feedback.

Across all four actors, the Plan process was consistently the weakest link, with no actor operating a structured demand forecasting or information-sharing mechanism. When the Plan is dysfunctional, Source becomes reactive, Make becomes poorly timed, and Deliver becomes fragmented, a cascading failure pattern that is most acutely expressed in the Deliver process of the transporter-wholesaler tier, where fragmented routing, the absence of cold chain, and unilateral price-setting converge to suppress both operational efficiency and farmers' bargaining power.

3.3 Problem Identification: Lean Waste Analysis

Applying a Lean perspective to the cross-actor SCOR process findings, five categories of operational problems were identified, each corresponding to specific non-value-added activities (waste types) as defined in the TIMWOOD framework.

The absence of integrated information systems is the root structural cause underlying most of the problems identified in Table 5. When demand signals from retailers fail to reach breeding farms, mismatches between supply and actual market demand systematically arise across all SCOR processes.

3.4 Integrated KPI Assessment

Based on the cross-actor SCOR analysis and Lean waste mapping, four key performance dimensions were assessed. Given the qualitative nature of the data collection (in-depth interviews and field observation), performance levels are reported using a descriptive scale (High / Moderate / Low) referenced directly to stakeholder testimony and observed conditions.

Table 5. Lean Waste Mapping of the Tilapia Supply Chain, Ubon Ratchathani

Problem	Lean Waste Type	SCOR Process Affected	Evidence Source
Low bargaining power of farmers due to transporter price-setting	Overproduction / Waiting	Source (Farm), Deliver (Farm)	In-depth interviews
Lack of coordination among supply chain stakeholders	Defects / Waiting	Plan (all actors)	Observation; no shared planning platform
Limited information sharing; no demand visibility	Waiting / Excess processing	Plan (all actors)	No demand data shared upstream
Inefficient transportation routes; no route optimization	Transportation	Deliver (Transporter)	Fragmented logistics; no routing system
Exposure to climate variability (temperature, seasonal flood)	Defects	Make (Cage Farm)	Climate change identified as key threat
Decentralized, uncoordinated input procurement	Inventory / Transportation	Source (all actors)	Separate procurement by each actor

Table 6. KPI Performance Assessment

KPI Dimension	SCOR Metric Category	KPI Score (1–5)	Descriptive Level	Primary Contributing Factor
Delivery lead time (farm to retailer)	Responsiveness	2	Low	Multiple uncoordinated handling stages; no scheduling system
Transportation cost efficiency	Cost	2	Low	Fragmented routing; no route optimization, each transporter operates independently
Stakeholder coordination	Reliability	1	Low	No shared information platform; each actor plans independently
Order fulfillment reliability	Reliability	3	Moderate	Demand is relatively stable domestically but subject to seasonal and climate-induced disruption
Farmer bargaining power / margin capture	Cost / Supply chain equity	2	Low	Structural dependence on transporter-wholesaler as sole buyer

The convergence of low scores across responsiveness, cost, and coordination metrics indicates that the current tilapia supply chain in Ubon Ratchathani operates significantly below its potential. The Make process at the cage farm level is biologically sound, but its value is systematically eroded by Plan and Deliver failures at every actor interface. This pattern is consistent with what Lean–Six Sigma literature describes as a systemic coordination failure rather than a localized operational defect.

4. Discussion

The most consequential finding of this study is structural rather than operational. The tilapia supply chain in Ubon Ratchathani is misaligned in a way that systematically transfers value from producers to intermediaries. Transporter-wholesalers simultaneously act as the sole buyer, price setter, and logistics provider, eliminating competitive pricing conditions. Farmers, lacking harvesting equipment and market knowledge, remain dependent on these actors. This pattern is consistent with Gao & Wongleedee (2025) and Bjorndal et al. (2014), who identify intermediary dominance and power asymmetry as key drivers of income suppression in smallholder systems. From a SCOR perspective, this imbalance is most evident in the Deliver process, where farm-gate prices are determined unilaterally (Supply Chain Council, 2012). The absence of price discovery mechanisms further destabilizes the Plan process, reinforcing a known systemic failure in aquaculture supply chains where limited information visibility degrades performance across all SCOR domains (Kruijsen et al., 2020).

SCOR-based analysis across all stakeholder tiers reveals that the Plan process is the weakest link throughout the system. Planning relies primarily on experience rather than structured demand data, resulting in weak demand signal transmission from downstream actors. This dysfunction propagates across subsequent processes: Source becomes reactive, Make poorly timed, and Deliver fragmented. Consequently, key performance indicators including lead time, coordination efficiency, and transportation cost, were assessed as low, despite technically sound grow-out practices. This systemic pattern aligns with findings by Mulyadi et al. (2025), who show that planning deficiencies are a primary source of downstream inefficiencies in agri-food logistics systems.

Lean analysis further clarifies how these inefficiencies manifest. Transportation and Waiting emerge as dominant waste types due to fragmented logistics controlled by individual transporters operating without shared routing or scheduling information. Repeated fish handling introduces both waiting-time waste and quality risks, including mortality and stress-induced weight loss, further reducing farmers' margins. Costa et al. (2018) similarly identify Transportation and Waiting as the most prevalent waste types in food supply chains. Evidence from DMAIC-based logistics studies in Thailand indicates that route standardization and improved coordination can reduce distribution costs by approximately 9% (Nanthasamroeng et al., 2021), suggesting that meaningful efficiency gains are achievable under coordinated interventions.

The primary methodological contribution of this study lies in integrating SCOR, Lean, and DMAIC within a single analytical framework for smallholder aquaculture. SCOR identifies where inefficiencies occur, Lean specifies the types of waste involved, and DMAIC structures the improvement process (Gomaa, 2025). This integration allows qualitative insights from interviews and observations to be organized within a systematic problem-solving framework, even in the absence of complete quantitative datasets. Importantly, standardizing the Plan process through shared demand information would enable measurable baselines for continuous improvement, something not possible under current informal practices.

The proposed digital supply chain platform operationalizes this integrated framework by addressing three core deficiencies. First, shared demand data and simple forecasting tools aim to correct planning

failures by improving upstream visibility. Second, transparent price discovery mechanisms—such as reference pricing or recorded transaction data, seek to rebalance bargaining power and reduce dependence on unilateral pricing. Third, coordinated routing and scheduling functions aim to reduce transportation waste by consolidating delivery routes and minimizing redundant handling. These proposals align with Thailand's broader digital agriculture agenda, including the Thailand 4.0 and Agriculture 4.0 initiatives (Board of Investment, 2020; Ministry of Agriculture and Cooperatives, 2022), as well as ongoing aquaculture development programs (Department of Fisheries, 2024). However, successful implementation requires prior capacity-building, as digital readiness among smallholder farmers remains uneven.

The findings also align with broader sustainability frameworks, including the United Nations Sustainable Development Goals (SDGs) and Thailand's Bio-Circular-Green (BCG) Economy Model. Addressing intermediary dominance supports SDG 1 (No Poverty) and SDG 2 (Zero Hunger), particularly by improving smallholder income and productivity. Efficiency gains in logistics contribute to SDG 8 (Decent Work and Economic Growth), while reducing post-harvest losses supports SDG 12.3 on minimizing food loss. Within the BCG framework (NESDC, 2023), improved production practices align with the Bio economy, logistics optimization supports circular principles, and reduced resource utilization contributes to green economy goals. Future integration of Life Cycle Assessment metrics could further align the supply chain with national carbon reduction targets.

Despite these contributions, several limitations must be acknowledged. The study relies on purposive and snowball sampling from a sample of 20 key informants across stakeholder tiers, which supports analytical depth but limits statistical generalization. KPI assessment is based on expert-informed subjective scoring rather than direct measurement; therefore future research should establish quantitative baselines for rigorous evaluation. Furthermore, this study reaches only the Improve phase of DMAIC; the Control phase remains untested and represents an important direction for future work, including pilot implementation of routing optimization, the establishment of cooperative models, and the development of digital platform prototypes. Incorporating environmental performance indicators, such as greenhouse gas emissions, would also strengthen the framework's relevance to sustainability policy.

5. Conclusions and recommendations

5.1 Conclusions

This study analyzed the tilapia supply chain in Ubon Ratchathani using an integrated Lean–Six Sigma–SCOR framework and proposed improvement strategies supported by digital technologies. The chain follows a four-actor linear configuration dominated by transporter-wholesalers, who control pricing, purchase volume, and logistics, leaving cage farms with no effective alternative market access. Despite producing 11,601 tonnes valued at 670,867,000 baht annually and ranking 8th nationally, the sector operates significantly below its economic potential. SCOR analysis revealed dysfunctional Plan processes at all actor levels, characterized by a lack of demand forecasting, inter-actor coordination, or a shared information platform. Lean waste mapping identified Transportation and Waiting as the dominant non-value-added activities, arising from fragmented logistics and the absence of coordinated scheduling—with key performance indicators (lead time, transportation cost, and coordination efficiency) all assessed as Low. The integrated SCOR–Lean–DMAIC sequence provides a transferable analytical model extending industrial engineering methodologies to smallholder aquaculture supply chains.

5.2 Recommendations

In the short term (0–12 months), a weekly demand-sharing report circulated among transporters and cage farms via LINE or WhatsApp would reduce the information vacuum at the Plan level; standardizing juvenile fish grading and delivery scheduling between breeding and cage farms would cut waiting time and improve grow-out planning; and introducing GAP certification for cage farms, supported by the Inland Fisheries Research and Development Center, would establish a quality baseline for domestic and export markets. In the medium term (12–36 months), a consolidated transport-routing pilot among several transporters would lower delivery costs and generate necessary performance data, while forming a farmer cooperative would restructure bargaining power and allowing cage farms to negotiate directly with buyers and access higher-value channels. In the long term (36+ months), a phased digital platform integrating demand forecasting, price transparency, and route optimization should be implemented with Thai ag-tech partners, with carbon footprint metrics incorporated into performance monitoring given the emission intensity of tilapia and tightening export disclosure requirements.

5.3 Theoretical Contributions

This study contributes three advances to the supply chain management literature: (1) methodological integration-demonstrating a structured sequence that unifies the SCOR, Lean TIMWOOD, and DMAIC frameworks, applied here for the first time to smallholder aquaculture; (2) contextual extension-applying industrial supply chain frameworks to a live-product logistics context governed by biological production cycles and structural market power imbalances; and (3) empirical baseline- providing the first systematic, SCOR-based performance assessment of the Ubon Ratchathani tilapia supply chain, against which future interventions can be evaluated.

6. References

- Bjorndal, T., Child, A., & Lem, A. (Eds.). (2014). Value chain dynamics and the small-scale sector: Policy recommendations for small-scale fisheries and aquaculture trade. FAO Fisheries and Aquaculture Technical Paper No. 581. Food and Agriculture Organization of the United Nations.
- Board of Investment of Thailand. (2020). Farmnovation: Smart farming in Thailand [Investment promotion brochure]. Office of the Board of Investment. https://www.boi.go.th/upload/content/TIR7_Aw_Smart%20farming_5e5dc88fa8284.pdf
- Costa, L. B. M., Godinho Filho, M., Fredendall, L. D., & Gomez Paredes, F. J. (2018). Lean, six sigma and lean six sigma in the food industry: A systematic literature review. *Trends in Food Science and Technology*, 82, 122–133. <https://doi.org/10.1016/j.tifs.2018.10.002>
- Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). SAGE Publications.
- Department of Fisheries. (2024). Statistics of freshwater aquaculture production 2023 (Document No. 7/2024). Fisheries Development Policy and Planning Division, Department of Fisheries, Ministry of Agriculture and Cooperatives. (in Thai)
- Mahmud, A., Parikh, P., Ahmed, J. U., Alam, M. J., Mostafizur, R. M., Shijun, D., Begum, I. A., Akhtar, F., Siddika, S., & McKenzie, A. M. (2026). Fish value chain analysis: A scoping review. *Frontiers in Sustainable Food Systems*, 10, Article 1673453. <https://doi.org/10.3389/fsufs.2026.1673453>
- Gao, Y., & Wongleedee, K. (2025). Problems in Thailand's smallholder supply chains. In *Proceedings of the International Academic Multidisciplinary Research Conference Beijing 2025 (ICBTS 2025 Beijing)*, 235–240. College of Hospitality Industry Management, Suan Sunandha Rajabhat University. <http://icbtsproceeding.ssru.ac.th/index.php/ICBTSBEIJING2025/article/view/1511>
- Colt, J., & Fornshell, G. (2014). Water quality in tilapia transport, from farm to retail: A review of hauling systems and holding system protocols. *Global Aquaculture Advocate*. Global Seafood Alliance. <https://www.globalseafood.org/advocate/water-quality-in-tilapia-transport/>
- Gomaa, A. H. (2025). Optimizing manufacturing supply chains using a strategic Lean Six Sigma framework: A case study. *International Journal of Inventive Engineering and Sciences*, 12(3), 20–30. <https://doi.org/10.35940/ijies.F8211.12030325>

- Kruijssen, F., Tedesco, I., Ward, A., Pincus, L., Love, D., & Thorne-Lyman, A. L. (2020). Loss and waste in fish value chains: A review of the evidence from low and middle-income countries. *Global Food Security*, 26, 100434. <https://doi.org/10.1016/j.gfs.2020.100434>
- Ministry of Agriculture and Cooperatives. (2022). MOAC creates opportunities for Thailand in the era of the world's food shortages: Accelerating the upgrade of government e-services towards MOAC 4.0. Ministry of Agriculture and Cooperatives. (in Thai). Retrieved from <https://www.opsmoac.go.th/dceng-news-files-441391791230>
- Mulyadi, F., Purnama, S. M., Muhammad, D. H., Jaitiang, D., Onitsuka, K., Inggrida, J. A., Andriani, D. R., Purwanto, E., Supriyadi, S., & Islamy, R. A. (2025). Assessing supply chain efficiency and sustainability in public food logistics using the SCOR model: Evidence from Perum BULOG Kediri, Indonesia. *International Journal of Sustainable Development and Planning*, 20(10), 4187–4193. <https://doi.org/10.18280/ijstdp.201010>
- Nanthasamroeng, N., Phayatham, P., & Suwandee, M. (2021). An application of Lean Six Sigma logistics for an improvement for supplies warehouse in a body & paint repairing center. *RMUTJ Journal Science and Technology*, 14(2), 14–27. <https://ph01.tci-thaijo.org/index.php/rmutjo/article/view/244243> (in Thai)
- Office of the National Economic and Social Development Council. (2023). The thirteenth national economic and social development plan (2023–2027). NESDC. https://www.nesdc.go.th/wp-content/themes/plant3-child/assets/pdf/13/article_file_20230615134223.pdf
- Supply Chain Council. (2012). Supply chain operations reference (SCOR) model overview: Version 11.0. Supply Chain Council.
- Thamke, M. (2020). Application of Lean Six Sigma in the Indian marine products industry [Bachelor's thesis]. Vaasan Ammattikorkeakoulu University of Applied Sciences.
- Tortorella, G. L., Vergara, A. M. C., Garza-Reyes, J. A., & Sawhney, R. (2020). The effect of Lean Six Sigma practices on food industry performance: Implications of the sector's experience and typical characteristics. *Food Control*, 113, 107148. <https://doi.org/10.1016/j.foodcont.2020.107148>
- Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). Thousand Oaks, CA: Sage.