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Strategic Supply Chain Management and Value Creation in Thailand's Buffalo Industry

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Abstract

Purpose: Amid the evolving landscape of consumer behaviors and increasing sustainability demands within the agricultural sector, Thailand's buffalo industry presently lacks the strategic supply chain integration vital for cultivating lasting consumer confidence. This study employs a mixed-methods approach to elucidate the mechanisms linking supply chain management, consumer perception, and the acceptance of buffalo products in developing countries, aiming to inform effective supply chain and market strategies. **Design/methodology/approach:** Qualitative data were collected through comprehensive interviews with stakeholders throughout the supply chain, including upstream actors such as buffalo farmers, midstream entities such as processors and distributors, and downstream sectors including government agencies, private entities, and policymakers. These insights were integrated with a quantitative analysis of 385 consumers, utilizing Structural Equation Modeling (SEM) to identify determinants that influence consumer acceptance. **Findings:** The study highlights that institutional collaboration among public, private, and academic sectors is crucial for dynamic supply chain integration. Perceived Consumer Awareness directly influences Trust, which significantly affects buffalo product acceptance, per the Innovation Adoption Theory framework. **Originality/value:** This research proposes strategic approaches to strengthen supply chain resilience through vertical and horizontal integration, enhancing stakeholder collaboration and efficiency to support innovative policies, effective communication, and value co-creation in Thailand's growing buffalo industry.

Keywords: Thai Buffalo Industry, Supply chain integration, Consumer trust, Product acceptance

JEL Classification Code: Q13, M31, O13

1. Introduction

Efficient and adaptable supply chains are regarded as essential for achieving a competitive advantage within industries, particularly in an era characterized by significant volatility and uncertainty (Ongkowijoyo et al., 2020). Adaptive Supply Chain Management facilitates the swift and effective response of supply systems to disruptions and fluctuations (Ha & Lee, 2024). Notably, the integration of supply chains across various hierarchical levels, both vertically and horizontally (supply chain integration), is instrumental in enhancing collaborative efficiency among organizations, ranging from producers and distributors to consumers. This integration directly influences the capacity to meet market demands and establish sustainable competitive advantages (Duong & Ha, 2021). Furthermore, the development of trust among entities within the supply chain has a direct impact on logistics efficiency and the ability to respond rapidly (Kim et al., 2024). Consequently, the management of a resilient supply chain—connected

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through various components and embedded with digital technology—is a critical factor in enabling industries to succeed and fortify their competitive positions at regional and global scales (Nong & Ha, 2025).

In particular, the buffalo industry exemplifies the necessity for such integrated and resilient supply chain strategies, as it has increasingly emerged as a high-potential sector in the global market. This growth is driven by increasing demand for buffalo-derived products, including milk, meat, and leather, particularly in Asia, the Middle East, and certain parts of Africa. To leverage this trend, nations with robust buffalo industries must establish agile and digitally integrated supply chains that facilitate traceability, quality assurance, and export competitiveness. India, Pakistan, and Vietnam have demonstrated significant advancements in this sphere, as evidenced by their expanding export volumes, government-led modernization initiatives, and the adoption of technology-driven practices that have fortified their buffalo value chains (Kumar et al., 2023).

India is recognized as a leading country in the global buffalo industry, with its buffalo population accounting for over 57% of the world's total, approximately 113 million animals, according to data from the Food and Agriculture Organization of the United Nations (FAO) for 2022. Buffaloes play an essential role in agriculture, milk production, and processing industries (FAOSTAT, 2023). India is the top producer of buffalo milk worldwide, with an annual output of up to 92 million tons, accounting for more than 50% of the global buffalo milk supply (Di Stasio & Brugiapaglia, 2021; Bardhan et al., 2019). It also remains one of the world's leading exporters of buffalo meat (also known as carabeef). In 2023, India exported over 1. 2 million tonnes of buffalo meat, earning more than $ 4 billion. The main destinations include countries in the Middle East and Southeast Asia (Relekar et al., 2024). A significant part of India's success can be attributed to managing a robust, integrated supply chain -from upstream to downstream -through large cooperative networks, such as the Gujarat Cooperative Milk Marketing Federation (GCMMF), which operates under the Amul brand. Amul is the largest buffalo milk product brand in the country (Bardhan et al., 2019). This supply chain includes key elements such as the grouping of farmers at the upstream level through more than 170,000 cooperatives, cold chain storage and transportation systems covering over 10, 000 points, over 200 dairy and meat processing plants nationwide, and the use of IoT and blockchain technologies for quality control and traceability of raw materials (Awan et al., 2021). This framework not only boosts efficiency in production and marketing but also provides income stability for more than 70 million small-scale farmers across the country (Anwar et al., 2025). Additionally, India has launched major national initiatives like the National Dairy Plan (NDP) and the Rashtriya Gokul Mission, which focus on genetically improving buffalo breeds, promoting modern farming practices, and offering credit schemes to farmers. These initiatives are vital to ensuring the long-term sustainability of the buffalo industry (Di Stasio & Brugiapaglia, 2021).

Vietnam has made considerable progress in developing indigenous buffalo breeds to improve its meat production capacity. Studies indicate genetic diversity among buffalo populations in Southeast Asia, which has been influenced by selective breeding and adaptation to local geographic and environmental conditions Vietnam's buffalo meat supply chain demonstrates strengths in connecting small-scale farmers with domestic data systems and markets. This is supported by government policies, including programmes from the Ministry of Agriculture and Rural Development (MARD) (MARD Department of Livestock, Asia Beef Network, 2023). Furthermore, Vietnam's exports of frozen beef and buffalo meat have experienced an average annual growth rate of 3.8% between 2018 and 2023, with the total value of frozen beef and buffalo meat imports reaching $957 million (Asia Beef Network, 2023). Vietnam's supply chain infrastructure emphasizes the application of technological expertise and market comprehension through the establishment of data networks and technology transfer initiatives. This enables small-scale farmers to adapt and improve the quality of their products consistently. Furthermore, it promotes new market opportunities through collaboration with the private sector, including model farms and processing facilities. Although farmers continue to engage in small-scale cultivation, they can integrate with sophisticated market systems (Asia Beef Network, 2023).

The supply chain of the dairy and beef industries in Pakistan is efficiently integrated both vertically and horizontally, particularly through the establishment of farmer cooperatives that connect smallholder farmers with processors and exporters. The development of standardised infrastructure, such as milk collection centres, halal slaughterhouses, cold chain systems, and distribution networks to international markets, plays a crucial role in increasing value addition and enhancing competitiveness (Magsi et al., 2021). Digital technologies, including RFID, IoT, and traceability systems, have been integrated into the halal meat supply chain to enhance accuracy, transparency, and comprehensive product traceability. One study indicates that IoT technology facilitates increased transparency and improves the efficiency of monitoring product status (Rejeb et al., 2021).

India has the strongest and most comprehensive supply chain in the region, with a network of over 170,000 cooperatives. Its cold chain system covers the entire country, supplemented by more than 200 processing plants, and

utilizes IoT and blockchain technology to control quality and track raw materials. This results in a highly efficient supply chain that supports the industry's sustainability. Vietnam has a supply chain focused on linking small-scale farmers to the domestic market through information systems and collaboration with the private sector. Although still small and with limited infrastructure, the adoption of technology and knowledge transfer helps enhance efficiency and creates ongoing opportunities for market expansion. Pakistan has developed a structured supply chain through farmers' cooperatives and a halal slaughter system, as well as the incorporation of digital technology in some areas. However, the cold chain infrastructure and slaughterhouses are not yet sufficiently widespread, limiting the country's ability to export and compete in the global market.

Although Thailand has a long-standing culture of buffalo farming, particularly in the Northeastern region, the structure of Thailand's buffalo industry remains fragmented and lacks integrated supply chains. The primary issues include the absence of high-value processed products, inconsistent quality standards, limited market access, and consumers' lack of confidence and knowledge regarding buffalo products. Furthermore, most supply chains continue to operate traditionally, lacking authentic connections between the agricultural sector, industry, and marketing, as well as failing to leverage digital technologies to enhance efficiency at each stage of production and distribution. Consequently, strategic research on supply chain management is crucial for the development of Thailand's buffalo industry. This process begins with understanding stakeholder contexts, analyzing the value chain, and studying consumer behavior to identify strategies that promote sustainable and internationally competitive policies and business models.

1.1. Research Objectives

This study aims to

1. Analyze the stakeholders in Thailand's buffalo industry and their role in supply chain integration.
2. Develop a buffalo industry value chain model to enhance economic efficiency and competitiveness.
3. Investigate consumer acceptance of buffalo-derived products and key market drivers affecting demand.
4. Identify supply chain inefficiencies and propose solutions for sustainable buffalo farming and product commercialization.

1.2. Research Gaps and Justification

Although existing research addresses supply chain management in the livestock industry at regional and international levels, a notable gap persists in studies specifically focused on the buffalo industry within the Thai context. Particularly, there is a demand for integrating the supply chain that encompasses small-scale farmers, accompanied by the implementation of systematic and suitable digital technologies. Consequently, this study is imperative in bridging this gap by developing a supply chain model tailored to the circumstances and challenges of the Thai buffalo industry, thereby fostering sustainability and competitiveness on both national and international scales. This research will serve as an essential foundation for the formulation of policies and strategies aimed at the sustainable development of the buffalo industry in the future.

2. Literature Review

2.1. The Significance of Supply Chain Integration within the Livestock Industry

Supply Chain Integration (SCI) constitutes a strategic management process dedicated to the meticulous coordination and linkage of activities among various entities within the value chain, extending from upstream to downstream, to establish an efficient and sustainable manufacturing and distribution system. This process holds particular significance in the livestock industry, characterized by complexity and susceptibility to risks, given that products are perishable and require precise management at each stage, including animal healthcare, feed management, and product processing. Structurally, SCI is delineated into two primary dimensions.

Vertical integration refers to the strategic coordination among entities that fulfill distinct roles within a supply chain, extending from raw material producers or farmers to processors and ultimately to final distributors. This form of integration is designed to enhance the seamless flow of goods and information, thereby mitigating delays and errors, reducing operational costs, and improving product quality control efficiency (Huo et al., 2014).

Horizontal integration constitutes a collaboration among entrepreneurs operating at the same level, such as a coalition of livestock farmers or cooperatives. It serves to enhance bargaining power, promote resource sharing, and expand market access. Furthermore, it facilitates the efficient exchange of knowledge and innovation within the group (Huo et al., 2014).

Integrated across two dimensions, it results in the supply chain system becoming a connected network that functions cohesively. In the livestock industry, the integration of accurate and timely information, such as traceability systems and data sharing among stakeholders in the supply chain, is exceedingly important for mitigating risks,

enhancing transparency in production and marketing processes, and supporting compliance with food safety standards and regulations (Aung & Chang, 2014). Although digital technology can effectively bolster Supply Chain Integration (SCI) operations, the core of SCI resides in fostering strategic collaboration among organizations to design and operate a flexible, efficient, and resilient value chain, thereby generating competitive advantages and ensuring long-term sustainability within the livestock industry (Huo et al., 2014).

2.2. The Integration of the Supply Chain within the Buffalo Industry

The buffalo industry makes a significant contribution to the agricultural economies of numerous countries in the Asian region, particularly in the production of milk, meat, and leather goods (FAOSTAT, 2023). The competitiveness of this sector relies on efficient management and the integration of supply chains (SCI), which connect stakeholders ranging from smallholder farmers to consumers (de Toni & Tonchia, 2008; Nong & Ha, 2025).

Supply Chain Integration (SCI) entails the systematic coordination and connection of activities and information among stakeholders within the supply chain to improve efficiency, transparency, and resilience in response to market demands (Huo et al., 2014; Aung & Chang, 2014). In the context of the buffalo industry, SCI facilitates the management of the complexities associated with fragile products and promotes collaboration both vertically and horizontally (Huo et al., 2014), thereby enhancing traceability, logistics management, and market access (Kim et al., 2024; Rejeb et al., 2021). The examples of supply chain integration in the buffalo industry of progressive countries are as follows:

India has integrated the entire supply chain through more than 170,000 cooperative networks, a comprehensive cold chain system, and over 200 processing plants, utilizing IoT and blockchain technology to control quality and carry out traceability, making India the largest producer and exporter of buffalo products in the world (Awan et al., 2021; Anwar et al., 2025).

Pakistan has halal infrastructure, farmers' cooperatives, and a central milk collection centre. It has begun employing RFID and IoT to enhance transparency in the supply chain, although cold chain infrastructure remains limited and quality standards are inconsistent (Rejeb et al., 2021).

Vietnam focuses on connecting small-scale farmers with domestic markets through support from both government and private sectors, using data systems and technology transfer, although the supply chain is still in the early stages of development (Asia Beef Network 2023)

The effective integration of supply chains within the water buffalo industry necessitates the seamless linkage of processes, infrastructure, and data, supported by suitable technologies and policies (Huo et al., 2014; Nong & Ha, 2025). Countries that achieve effective supply chain integration are generally characterized by high resilience, superior quality, and expanded market reach (Kim et al., 2024). For Thailand, despite a longstanding history of water buffalo husbandry, particularly in the northeastern region, the supply chain remains disjointed and lacks systematic integration (Nong & Ha, 2025). A significant challenge is producing high-value, processed products with inconsistent quality standards, limited market access, and insufficient consumer confidence. The majority of the supply chain continues to operate through traditional means, with limited connectivity among farmers, processors, and end markets. The restricted adoption of digital technology adversely affects operational efficiency and pace. While nations such as India, Pakistan, and Vietnam have successfully developed and efficiently integrated supply chains within the buffalo industry, Thailand continues to encounter challenges related to unstructured connections among farmers, producers, processors, and consumers. The management framework across the entire supply chain lacks a centralized coordination mechanism, which is further compounded by insufficient data and inadequate technological support systems. Consequently, this hampers the overall supply management's ability to compete with other countries in the region (de Toni & Tonchia, 2008; Le et al., 2022).

2.3. Stakeholder Analysis and Systemic Linkages in the Value Chain of Thailand's Buffalo Industry

The buffalo industry in Thailand exhibits distinct socio-economic and cultural characteristics, particularly in the Northeastern and Northern regions, where buffaloes are esteemed not only for their economic utility but also as integral elements of local identity and community life (Chantarat et al., 2022). However, as Thailand endeavors to transform the buffalo sector into a competitive and value-driven industry aligned with regional and global market demands, it becomes essential to adopt a strategic and systemic understanding of stakeholder roles along the entire value chain. To facilitate this, the Triple Helix Model (Etzkowitz & Leydesdorff, 2000) offers a conceptual framework for analyzing industrial development through the interaction of three principal actors: government, academia, and industry. Within the Thai buffalo sector, this model exposes enduring gaps, such as the limited commercialization of academic research related to breed improvement, feed innovation, and value-added processing technologies. These deficiencies highlight the necessity for a more cohesive collaboration strategy among key sectors.

Moreover, the Value Chain-Based Stakeholder Mapping

Framework (Freeman, 1984; Porter, 1985) supports the identification and analysis of stakeholders across the entire spectrum—from upstream (buffalo farmers, breeders, and local communities), midstream (collectors, processors, exporters), to downstream (domestic and international consumers). This mapping underscores the diverse roles, influences, and interdependencies within the industry. For example, while processors are vital in ensuring product quality, they often face limitations in accessing innovations and financing. Similarly, smallholder farmers encounter obstacles to adopting advanced breeding technologies, securing credit facilities, and establishing sustainable market linkages. Stakeholder analysis provides valuable insights into the structural weaknesses of Thailand's buffalo supply chain and offers guidance for strengthening relationships—shifting the focus from transactional exchanges toward strategic partnerships that foster integrated development. Significantly, the analysis also emphasizes the role of end consumers in niche markets, such as health-conscious buyers or international clients, who serve as key drivers of innovation and demand-led transformation. These consumers facilitate the alignment of market expectations with supply chain capabilities, thereby contributing to Thailand's broader objective of transitioning its traditional agricultural sector into a knowledge- and value-oriented economy (Chaiyarat, 2021).

2.4. Market-Integrated Supply Chain and Consumer Behavior in the Buffalo Industry

The development of the cattle industry in Thailand currently encounters strategic challenges in generating commercial value. This factor has a significant impact on supply chain efficiency and the industry's competitiveness at both national and international levels. The commercial integration of the supply chain, known as the market-integrated supply chain, involves the systematic coordination of activities spanning from production and processing to transportation and distribution. Such coordination aims to establish consistency and facilitate prompt responses to consumer behaviors and needs, as well as adapt to long-term changes in the marketing environment (Christopher, 2016; Noersasongko et al., 2022). In this context, analyzing consumer behavior is thus crucial for fostering such integration. Specifically, within niche markets characterized by specialized features—such as groups of consumers emphasizing health considerations or customer segments seeking products that reflect their identity and cultural values—comprehending the factors and motivations influencing purchasing decisions for buffalo products, including buffalo meat, buffalo milk, or value-added processed items, is essential for developing effective production and marketing strategies (Putithanarak et al., 2022). Nevertheless, the primary challenge facing the Thai buffalo industry is the lack of continuity and integration within the supply chain, resulting in a fragmented supply system. This impairs the system's capacity to quickly and effectively adapt and respond to market demands. The absence of an efficient mechanism for transmitting information and feedback from downstream stakeholders (consumers) to upstream entities (farmers and producers) constitutes a significant obstacle, leading to a misalignment of production with genuine market needs, and consequently, missed opportunities for the development of innovative, value-added products that accurately address specific market segment requirements (Ratanamaneesakul & Suraraksa, 2025).

Furthermore, distribution channels and logistics innovation are regarded as crucial mechanisms in fortifying and enhancing the resilience of the supply chain. They facilitate improved delivery efficiency, cost reduction, and the cultivation of consumer confidence within the target market (Rahayu et al., 2025). Well-managed channels, combined with the utilization of advanced logistics technologies, constitute a decisive factor in expanding market presence both domestically and internationally, as well as establishing product differentiation that guarantees quality and fulfills the diverse requirements of niche markets (Christopher, 2016). Insights from other regions, including India and Vietnam, demonstrate that integrating logistics systems, consumer behavior research, and systematic brand development can substantially enhance the competitiveness of buffalo industries in both domestic and export markets (FAOSTAT, 2023; Ha & Lee, 2024; Sasidhar et al., 2013). Consequently, conducting comprehensive studies—both quantitatively and qualitatively—about consumer demands at various stages of the supply chain is a vital instrument for fostering innovation and enhancing the value of Thai buffalo products. Ultimately, the advancement of the Thai buffalo supply chain towards complete commercial integration necessitates robust collaboration among governmental authorities, private enterprises, and educational institutions. This encompasses the development of comprehensive consumer databases, research and development initiatives for product innovation, and the implementation of a traceability system, which is integral to fostering trust and enhancing customer satisfaction in both domestic and export markets (Noersasongko et al., 2022; Rahayu et al., 2025).

2.5. Trust-Building Mechanism in Supply Chain

In the pursuit of advancing Thailand's buffalo industry toward a Business-Integrated Supply Chain, cultivating "consumer confidence" is regarded as a crucial strategic element that can facilitate the acceptance of buffalo

products. The Trust-Building Mechanism in Supply Chain, as proposed by Christopher (2016), indicates that confidence-enhancing mechanisms within the supply chain can be established through the management of key components, including (1) information transparency, (2) product quality certification, (3) effective communication between producers and consumers and (4) awareness of product traceability. In the context of the Thai buffalo industry, the development of these mechanisms will help mitigate consumer uncertainty and foster product acceptance by establishing long-term relationships among brands, producers, and consumers.

Furthermore, the research conducted by Kim, Lee, and Ha (2024), titled An Empirical Study on the Effect of Trust between Firms in the Supply Chain on Agility and Logistics Performance concludes that cognitive trust exerts a direct influence on the speed, flexibility, and responsiveness of the supply chain. Conversely, affective trust affects speed and responsiveness but does not foster structural flexibility. This indicates that establishing a supply chain system with transparent information, certification standards, and feedback mechanisms will significantly contribute to enhancing cognitive trust and supporting the long-term flexibility of the supply chain within the Thai buffalo industry. Simultaneously, Lee and Kim (2024), in their publication on trust, long-term orientation, and relationship performance, also found that cognitive trust can develop into emotional trust, which subsequently promotes a long-term orientation within relationships among supply chain partners. This progression positively impacts overall relationship performance, thereby supporting the notion that establishing structural trust influences not only consumers and producers but also extends to other commercial partners such as farmers, processors, and distributors, who collaborate in the design and development of a sustainable supply chain.

When consumer confidence is consistently established, it facilitates the systematic collection of market demand data, which can then be communicated to the upstream entities in the supply chain, including farmers and producers. This process enables the adjustment of production methods to accurately align with commercial demand, thereby enhancing the resilience, responsiveness, and development of an integrated supply chain encompassing production, processing, transportation, and marketing efficiently (Ratanamaneesakul & Suraraksa, 2025). Furthermore, insights derived from India and Vietnam demonstrate that the development of a supply chain framework centered on "consumer trust" is a critical element that effectively facilitates the transition of the buffalo industry into a contemporary market system with confidence (FAOSTAT, 2023; Ha & Lee, 2024). Within this framework, cultivating consumer confidence necessitates the systematic enhancement of consumer awareness. This concept can be elucidated through the Perceived Consumer Awareness framework, which comprises four sub-dimensions (1) product awareness, (2) awareness of features, (3) trial use, and (4) channels of perception. Both the Hierarchy of Effects Model (Lavidge & Steiner, 1961) and the Diffusion of Innovations Theory (Rogers, 2003) suggest that consumer decision-making generally initiates with awareness and gradually advances to interest, confidence, and acceptance of the product through a process of learning and direct experience.

As consumer awareness across the four dimensions increases, it consequently enhances the "confidence mechanism" within the supply chain, as defined by Christopher (2016). Specifically, when consumers obtain product information through trusted channels and experience the product directly, it contributes to affirming transparency, certification, and traceability—elements that are vital in establishing trust at a structural level.

Therefore, cultivating consumer awareness not only influences purchasing behavior but also serves as a "connective mechanism" between the end market and the source of production, thereby facilitating the development of a Market-Integrated Supply Chain capable of adapting efficiently and sustainably to consumer demand.

3. Research Methodology

This research adopts a mixed methods approach within a Sequential Exploratory Design, commencing with qualitative research to examine components, context, and detailed issues related to supply chain management in the buffalo industry of Thailand. Subsequently, the findings are utilized to develop instruments and analytical frameworks in a quantitative phase (Creswell & Plano Clark, 2018).

3.1. Qualitative Research

The sample groups in qualitative research are selected through purposive sampling, grounded in the principle of maximum variation sampling (Patton, 2002), which aims to capture diverse perspectives from stakeholders within the supply chain, including contrasts.

1) Twenty buffalo farmers from regions with a high prevalence of buffalo husbandry were considered, considering the diversity in farm size and husbandry practices.

2) Ten agri-entrepreneurs engaged in the processing or marketing of buffalo products.

3) Five medium- to large-scale buffalo farm operators who have attained commercial success.

4) Six government officials representing six regions of

Thailand.

The interview was conducted using an in-depth interview approach, employing a semi-structured method, which involved designing a pre-prepared interview protocol to ensure that the questions aligned with the research objectives. Participants were allowed to expand on topics they had direct experience with before the interview. Permission was obtained from the relevant department in advance to schedule the interviews and to request approval from the involved organization and individuals formally. The interviews took place at the participants' locations, such as farms, offices, or business sites, which were convenient for discussion and ensured privacy. All interviews were audio-recorded using digital devices, with participants' consent obtained prior to the start, using ethical research practices. The researcher manually transcribed all recordings to gain a thorough understanding of the context and content of the in-depth data. Each interview lasted approximately 1 hour and 30 minutes.

When assessing the number of informants in each group in conjunction with the characteristics of the research topic during data collection, the point of data saturation is usually reached when no novel significant issues emerge, particularly when the content is specialized and the informants possess knowledge directly pertinent to the research subject. This aligns with the approach of Guest, Bunce, and Johnson (2006), which indicates that research utilizing a well-structured sample can attain data saturation within a relatively small sample size.

Qualitative data analysis employs the method of Qualitative Content Analysis. 1) Transcribing and familiarizing oneself with the data. All interview recordings are transcribed meticulously into text, and repeated readings are performed to comprehend the overall content for each question. 2) Structuring and categorizing. The transcribed data are organized and grouped according to the main topics and subtopics specified in the interview guide. 3) Identifying issues and patterns within each category (question topic) The researcher reviews and highlights significant issues, patterns, ideas, or prominent opinions that recur in the responses of the informants. 4) Interpretation and summarizing, The researcher interprets the meanings of the issues and patterns identified within each category and synthesises these into findings that address the research questions for each section.

The validation of the credibility of qualitative data analysis (Qualitative Trustworthiness) involves the process of member checking, where preliminary analysis results are returned to respondents for verification.

3.2. Quantitative Research

Quantitative analysis involves investigating the factors that contribute to Trust-Building Mechanisms within the Supply Chain. The elements incorporated within the quantitative research framework encompass the Perceived Consumer Awareness framework, trusts towards buffalo and related products, and acceptance of adoption. (Lavidge & Steiner, 1961; Rogers, 2003)

The questionnaire serves as a methodological instrument for data gathering. It encompasses a section on personal information presented in a closed-ended format for assessing Perceived Consumer Awareness, trusts towards buffalo and related products, and the acceptance of adoption. Responses are recorded using a 5-point Likert scale. An initial validation was performed utilizing the Index of Content Validity (IOC) by five experts, with values exceeding 0.05 deemed acceptable. Data collection was executed through random sampling from a sample comprising 32 individuals. The alpha coefficient is as follows.

1) Perceived Consumer Awareness Cronbach's Alpha 0.96

2) Trust towards buffalo and related products Cronbach's Alpha 0.95

3) Adoption acceptance Cronbach's Alpha 0.97

4) Overview Cronbach's Alpha 0.97

The sample size deemed appropriate for analyses performed using a path analysis model was considered. In this study, a total of 385 participants were employed, a number regarded as sufficient for Structural Equation Modeling (SEM) analysis, as recommended by Hair et al. (2010). They suggest that the sample size should range from 5 to 10 individuals per observed variable and should not fall below 200 participants to ensure the reliability and statistical robustness of the findings. This aligns with the guidelines established by Schumacker and Lomax (2010), who recommend a minimum of 10 to 20 individuals per observed variable when estimating the model.

The researcher devised a multistage sampling procedure. Step 1 involved Cluster Sampling of major provinces representing each region of the country, selected based on economic size and population. Step 2 employed Purposive/Convenience Sampling of individuals aged 18 years and older. The age of 18 years and above aligns with the guidelines set forth by the National Statistical Office of Thailand for classifying the adult population, which is capable of providing independent information and giving informed consent (National Statistical Office of Thailand, 2022).

The statistical methodologies employed for analysis encompass descriptive statistics. The analysis of factor loadings of variables (Factor Loading) and Composite Reliability (CR) should attain a value exceeding 0.70. The Average Variance Extracted (AVE) is expected to have a

value greater than 0.50 (Hair et al., 2010). Goodness of Fit indicators include Goodness of Fit Index (GFI), which assesses the degree of model fit; the Comparative Fit Index (CFI) (Hair, et al., 2010). The Root Mean Squared Error of Approximation (RMSEA) should be less than 0.10 (Hair et al., 2010). Furthermore, the variance Inflation Factor (VIF) and tolerance values should not exceed 10 (Hair et al., 2010).

4. Results

4.1. Qualitative Findings

Stakeholder analysis utilizing the Value Chain-Based Stakeholder Mapping Framework (Freeman, 1984; Porter, 1985) serves to identify and comprehend the roles, relationships, and influence of stakeholders at each hierarchical level, from upstream farmers and buffalo breeders to midstream gatherers and processors, and finally to downstream domestic consumers. Nevertheless, processors frequently encounter limitations in accessing innovation and funding sources, akin to small-scale farmers who face difficulties in implementing breeding technologies. Consequently, stakeholder analysis is a crucial tool for identifying deficiencies and developing collaboration strategies that promote the integration and sustainability of a supply chain system.

Analysis of Stakeholders in Thailand's Buffalo Supply Chain System. The qualitative aggregation results aim to analyze the roles and relationships of stakeholders within Thailand's buffalo supply chain system. The researchers identified that stakeholders encompass various agencies and organizations engaged in production and processing activities, ranging from buffalo farmers to end consumers. These stakeholders encounter both positive and negative impacts, either directly or indirectly. Stakeholders can be categorized into three principal groups.

1) Key Stakeholders This group consists of individuals who hold pivotal and direct roles within Thailand's buffalo supply chain system. It includes buffalo farmers (initial suppliers), producers of goods and services directly related to buffalo, and end consumers. Stakeholders within this category are recognized as primary stakeholders due to their critical contribution to the success of the supply chain and their role in creating value within the industry (Freeman, 1984; Porter, 1985).

2) Primary stakeholders. This group consists of individuals who are directly affected by the supply chain system, both positively and negatively. This includes communities involved in cattle rearing, which may be influenced by the operations and policies within the system.

3) Secondary stakeholders comprise entities that hold an indirect interest in the system, without directly influencing the production of goods or services. These stakeholders function as supporters or connectors within the system, including government agencies such as the Department of Livestock, veterinary associations, educational institutions, relevant researchers in agricultural technology, funding entities, and financial institutions (Etzkowitz & Leydesdorff, 2000).

4) Monitor (Low power, low interest). This group possesses limited influence and minimal interest; consequently, it should be monitored periodically to anticipate possible developments. Stakeholders within this group comprise individual stakeholders or other supportive entities not directly engaged in the production or marketing processes.

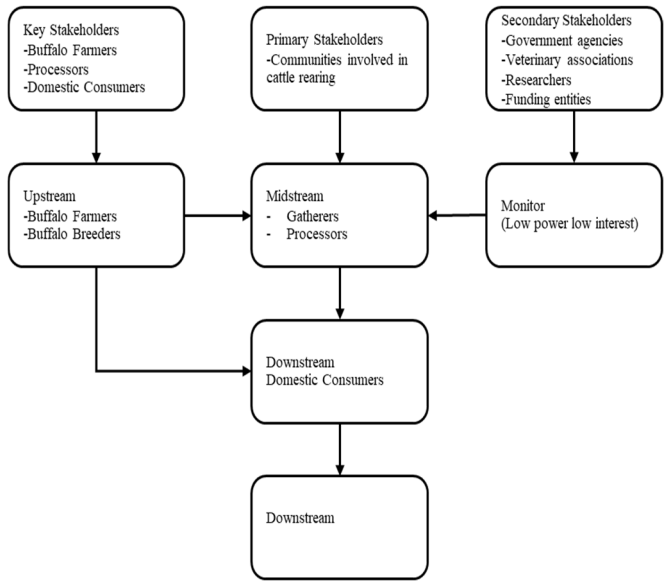

Figure 1: Three Principal Groups of Stakeholders

Classifying stakeholders in this manner enables researchers and managers to effectively develop strategies for managing relationships and communications tailored to each group. This methodology aligns with the development of sustainable and efficient supply chain systems (Bryson, 2004).

4.2. Quantitative Findings

4.2.1. Measurement Model Assessment

Preliminary data analysis aimed at evaluating the relationship among latent variables Perceived Consumer Awareness (PC), trust towards buffalo and related products (TR), and acceptance of adoption. (AD). This analysis is conducted through the computation of multiple correlation coefficients, specifically Pearson's Correlation Coefficient,

in conjunction with assessments of discriminant validity, which consider the Average Variance Extracted (AVE) and Variance Inflation Factor (VIF).

The analysis results indicate that the variable AD has a mean value of 4.31 and a standard deviation (S.D.) of 1.03. The Average Variance Extracted (AVE) is 0.767, surpassing the minimum recommended threshold of 0.50 based on the criteria established by Fornell and Larcker (1981). Additionally, the square root of AVE (√AVE) is 0.8751, exceeding its correlations with all other variables. This demonstrates sufficient discriminant validity.

Concerning the PC variable, the mean value is 3.95 (Standard Deviation = 0.66), the Average Variance Extracted (AVE) is 0.704, and the square root of AVE is 0.8391. These metrics surpass the correlations with TR ($r = 0.073$) and AD ($r = 0.274$, $p < 0.01$), thus demonstrating apparent discriminant validity among the variables. Similarly, the TR variable exhibits a mean of 4.12 (Standard Deviation = 0.77), AVE of 0.745, and square root of AVE of 0.8631, all of which exceed the correlations with AD ($r = 0.309$, $p < 0.01$) and PC ($r = 0.073$).

Furthermore, the Variance Inflation Factor (VIF) values for PC and TR are less than the threshold of 5 (PC = 1.069; TR = 1.065), signifying the absence of multicollinearity issues within the model. Consequently, the structural relationship analysis may be performed appropriately.

4.2.2. Results of the Structural Equation Model Analysis (Model Fit Indices)

The results are within acceptable limits, with a P-value of 0.07, which exceeds the predetermined threshold of 0.05, indicating that the model does not differ significantly from the empirical data. The Relative Chi-square (χ^2/df) is 1.433, below the accepted threshold of 2, thereby indicating an adequate model fit. The GFI and CFI indices are 0.981 and 0.993, respectively, both surpassing the standard criterion of 0.95. Furthermore, the RMR and RMSEA values are 0.018 and 0.034, respectively, both of which are below the threshold of 0.05. Collectively, these indicators demonstrate that the model exhibits a highly commendable fit with the actual data.

Table 1: Model Fit Indices

Model Fit Indices	Criteria	Results	Assessment
P-value	> 0.05	0.07	Acceptable
Relative Chi-square (χ^2/df)	< 2.0	1.433	Good fit
Goodness-of-Fit Index (GFI)	≥ 0.95	0.981	Excellent fit
Comparative Fit Index (CFI)	≥ 0.95	0.993	Excellent fit
Root Mean Square Residual (RMR)	< 0.05	0.018	Excellent fit
Root Mean Square Error of Approximation (RMSEA)	< 0.05	0.034	Excellent fit

4.2.3. Testing of Hypotheses

The relationships between various variables are characterized by standardized coefficients (β) and statistical test values (t-value), which are statistically significant as follows.

H1 Perceived Consumer Awareness (PC) has a significantly positive impact on trust towards buffalo and related products (TR) with a coefficient β of 1.36 and a t-value of 4.15 at a significance level of $p < 0.001$, supporting hypothesis 1.

H2 Perceived Consumer Awareness (PC) has a significantly positive effect on acceptance of adoption (AD), with a coefficient β of 1.10 and a t-value of 2.95 at a significance level of $p < 0.01$, supporting hypothesis 2.

H3 Trust in buffalo and related products (TR) has a significantly positive impact on the acceptance of adoption (AD), with a coefficient β of 0.36 and a t-value of 3.92 at a significance level of $p < 0.001$, supporting Hypothesis 3.

Table 2: Testing of Hypotheses

Path	Standardized Coefficient (β)	t-value	Significance Level	Hypothesis Supported
Perceived Consumer Awareness (PC) → Trust (TR)	1.36	4.15	< 0.001	Yes (H1 supported)
Perceived Consumer Awareness (PC) → Adoption Acceptance (AD)	1.10	2.95	< 0.01	Yes (H2 supported)
Trust (TR) → Adoption Acceptance (AD)	0.36	3.92	< 0.001	Yes (H3 supported)

In addition, the analysis of direct, indirect, and total influence revealed that the model can explain 15.6 percent of the variance in confidence ($R^2 = 0.156$) and 31.2 percent of the variance in acceptance of adoption (AD) ($R^2 = 0.312$), which is considered moderate. The direct influence of perception on acceptance of adoption (AD) is β = 1.10, while confidence has a direct effect of β = 0.36. The indirect influence of perception through confidence is β = 0.49, resulting in a total influence of β = 1.59.

Table 3: Direct, Indirect, and Total Influence

Effect	Standardized Coefficient (β)
Direct effect of PC → AD	1.10
Direct effect of TR → AD	0.36
Indirect effect of PC via TR → AD	0.49
Total effect of PC → AD	1.59

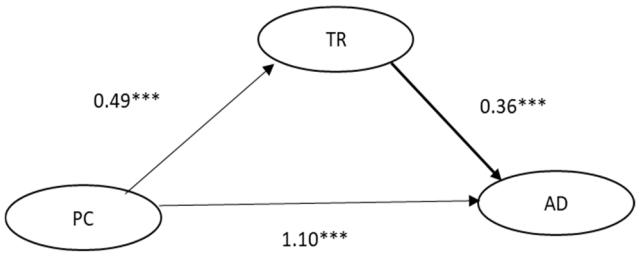

Figure 2: Standardized Coefficient (β)

Based on the preceding analysis, it can be concluded that Perceived Consumer Awareness (PC) has a direct influence on trust in buffalo and related products (TR). Furthermore, confidence functions as a partial mediator between the acceptance of adoption (AD) and the other variables, in a statistically significant manner.

5. Discussion

5.1. Management of Stakeholders within the Buffalo Supply Chain Framework

The analysis of the buffalo supply chain system in Thailand, within the framework of the Triple Helix Model (Etzkowitz & Leydesdorff, 2000), highlights the importance of strategic collaboration among the government sector, academia, research institutions, and the business and agricultural sectors. This cooperation aims to establish competitive advantages and facilitate the efficient advancement of innovation. Numerous scholarly studies affirm that collaboration among these three sectors constitutes a fundamental factor in the development of industries reliant on knowledge and technology (Etzkowitz, 2008). Within the Thai cattle supply chain system, the government, particularly the Department of Livestock Development, functions as the policymaker and supporter of system development. This encompasses quality control and production standards. Educational institutions and researchers contribute to the development of innovations, such as breeding improvements and processing technologies, while farmers and entrepreneurs are responsible for production and processing to meet market demands. Nevertheless, a significant limitation has been identified: the incomplete linkage between the research sector and the business and agricultural sectors, resulting in technologies and innovations not being widely implemented (Lee et al., 2019). This correlates with research findings indicating that a lack of cooperation between sectors affects the ability to adapt and generate value within the supply chain (Carayannis & Campbell, 2012).

Regarding supply chain integration, as outlined in the Supply Chain Integration Framework (Flynn et al., 2010), it has been established that both vertical and horizontal integration have a direct impact on the efficiency of supply chain operations, contributing to the development of competitive advantages. This is especially apparent in industries characterized by high complexity and uncertainty, such as the agriculture and animal processing sectors (Gimenez et al., 2012). Vertical integration functions to mitigate risks and improve efficiency within production and distribution processes, while horizontal integration supports the formation of collaborative networks, enhances bargaining power, and facilitates resource sharing (Frohlich & Westbrook, 2001).

The analysis of stakeholders emphasizes the necessity of enhancing these integration mechanisms, particularly by providing support to smallholder farmers and small-scale processors in their efforts to more effectively access technology and funding. Additionally, the establishment of efficient information and communication systems among stakeholders at all levels is crucial (Mentzer et al., 2001). Furthermore, managing stakeholders according to their respective levels of authority and interest, as advocated by Stakeholder Theory (Freeman, 1984), will aid in mitigating conflicts and fostering cooperation within a sustainable supply chain system. Therefore, the development of the Thai buffalo supply chain should prioritize comprehensive coordination that promotes innovation through collaboration among all relevant parties and integrates the supply chain at every level to augment value and secure the long-term sustainability of the industry (Christopher, 2016).

5.2. Trust-Building Mechanism within the Supply Chain

The findings affirm the vital role of Perceived Consumer Awareness (PC) as a direct precursor to trust in buffalo and related products (TR) and the adoption of acceptance (AD). This observation aligns with Rogers (2003) Adoption of Innovation Model, which asserts that knowledge and product awareness are fundamental entry points in the process of adopting innovations. This is particularly pertinent in the context of buffalo products, which frequently face social perception biases. Providing accurate information concerning product attributes and facilitating opportunities for product trial markedly contribute to the development of trust.

In this regard, trust serves as a psychological mechanism that partially mediates the relationship between awareness and acceptance. This outcome corroborates the findings of Kim and Chung (2011), who contended that consumer trust in the safety and origin of food influences purchase intentions. Additionally, it supports Verbeke (2005) emphasis on the importance of transparency, safety, and

traceability mechanisms within the supply chain as key drivers of consumer trust.

Enhancing the acceptance of buffalo products necessitates an integrated supply chain that incorporates insights into consumer behavior, primarily through vertical and horizontal linkages between producers and end consumers. This market-oriented approach enables consumers to understand better and trust the origin, production processes, and value propositions of the products. The design of such a supply chain should include traceability systems, quality assurance standards, and storytelling that emphasize sustainability and local identity.

This integration not only promotes consumer acceptance but also reduces long-term supply chain risks. In the context of animal-based niche products, which are often sensitive to cultural familiarity and consumer beliefs, aligning market information with supply chain design becomes a strategic necessity for the sustainable development of the buffalo industry.

6. Conclusions

This study emphasizes the significance of Perceived Consumer Awareness (PC) as an antecedent variable that notably influences trust in buffalo and related products (TR) as well as the acceptance of livestock adoption (AD) by consumers. This is consistent with the Adoption of Innovation Model (Rogers, 2003), which posits that knowledge and perception of products constitute the initial stages of the acceptance process. Particularly in the context of animal products, where social perception biases are present, enhancing awareness of characteristics, promoting trial use, and utilizing effective communication channels directly enhance consumer confidence.

The discovery that confidence acts as a mediating variable partly aligns with the research of Kim and Chung (2011), which shows that consumers' trust in the quality and source of food directly affects their purchase intentions. For buffalo-derived products, which remain unfamiliar to some consumers, building trust through product standards, communication channels, and certification is therefore crucial (Verbeke, 2005).

Research that warrants further development should employ strategic issues. Enhancing the acceptance of buffalo products should incorporate an integrated marketing communication strategy in conjunction with research data utilization to improve perception among the target audience. This also involves promoting farmers and small-scale producers to understand the development of a regional brand that emphasizes cultural values, health, and sustainability of consumption, which will contribute to increasing the product's value and credibility over the long term.

7. Limitations

This research has certain limitations, including the conceptual framework employed, which does not comprehensively encompass economic perspectives nor conduct detailed system logistics simulations. Specifically, the analysis based on Dynamic Capabilities or system models (Simulation Models) that mirror real-world supply chain adaptations. Furthermore, measurements of consumer behavior are still derived from perceptions rather than actual purchase data, such as sales figures or tracking system data, which may impact the precision of policy recommendations in practical applications.

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