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The Role of Digital Traceability Systems in Promoting Sustainable Development of Durian Export Supply Chains

Anchalee Hiranphaet

College of Logistics and Supply Chain, Suan Sunandha Rajaphat University, Thailand

Corresponding author

Email: Anchalee.hi@ssru.ac.th

Abstract

The global agri-food trade has made openness, food safety and sustainability increasingly important for doing business in other countries. Countries that import goods have made their rules about where products come from how to control chemical residues keeping the cold chain intact and being good for the environment to be stronger in the last few years. This is especially true for agricultural products that are worth a lot of money and go bad quickly (FAO, 2023; OECD, 2023). Because durian is sensitive to how it is handled and is becoming more popular on global markets, especially in East Asia it is a high-value tropical fruit that must meet strict quality and traceability standards.

The results show that digital traceability systems like QR code-based identification centralized data platforms and real-time logistics tracking make the durian export supply chain much more open, reliable and coordinated. From an operational point of view combining traceability data with logistics operations makes it easier to manage inventory the cold chain, and transportation which lowers the chances of losing products and having problems with logistics. Digital traceability is good for the economy because it makes exports more competitive and lowers the costs of doing business. It also makes better use of resources and cuts down on waste which is good for the environment. Finally, it helps society by getting more farmers involved, making sure that food safety rules are followed and making people more confident in durian products that are sent abroad. The study says that digital traceability systems are not only technological tools but also strategic tools for running a sustainable supply chain. The policy implications underscore the necessity for synchronized public-private support and capacity-building initiatives to enable agricultural exporters to implement scalable and contextually pertinent digital traceability.

Keywords: Digital traceability; Durian export supply chain; Sustainable development; Logistics integration; Agri-food systems

1. Introduction

The global agri-food trade has put more emphasis on openness food safety and sustainability as important conditions for getting into international markets. There are many parts to the supply chains for durian exports including smallholder farmers collection centres packing houses logistics service providers exporters and regulatory agencies. These actors often use disconnected information systems and limited data integration which leads to inefficiencies

information asymmetry and a higher chance of not following international standards (Kumar et al., 2023). Other Thai agri-food export sectors have similar problems. For example, poor integration of supply chain and innovation management makes it hard to be ready to export and do well in the digital age (Sarainmoon et al., 2025). This reduces losses and risks after harvest. This is consistent with findings from Thai agricultural export contexts, indicating that digital and innovation-driven supply chain management enhances export readiness by improving coordination and operational efficiency (Sarainmoon et al., 2025).

They also help social sustainability by making things more transparent getting more farmers involved and making consumers more confident in exported food products. Previous studies indicate that the amalgamation of supply chain management and innovation management competencies is essential for converting digital initiatives into enduring export results (Sarainmoon et al., 2025). Even though there is more research on digital traceability and sustainable supply chain management most of it looks at these topics separately. There isn't much research on how they work together in logistics-heavy export supply chains. Research on durian export supply chains is still limited both in terms of empirical studies and theoretical frameworks particularly in developing countries where digital limitations and coordination difficulties continue to exist (Zhang et al., 2024). This research investigates the function of digital traceability systems as integral elements of logistics and supply chain management and evaluates their impact on the sustainable development of durian export supply chains. By building on previous studies of supply chain and innovation management in Thai agricultural exports (Sarainmoon et al., 2025) the results are anticipated to enhance both academic inquiry and practical decision-making aiding policymakers and industry stakeholders in the development of more resilient and sustainable agri-food export systems.

1.1 Research Hypotheses

Based on the research objectives and the conceptual framework of this study the following hypotheses are proposed:

H1: Digital traceability systems have a positive effect on logistics performance in durian export supply chains.

H2: Digital traceability systems have a positive effect on the sustainable development of durian export supply chains.

H3: Logistics performance has a positive effect on the sustainable development of durian export supply chains.

H4: Logistics performance mediates the relationship between digital traceability systems and the sustainable development of durian export supply chains.

1.2 Research Objective

1.2.1 To examine the effect of digital traceability systems on logistics performance in durian export supply chains.

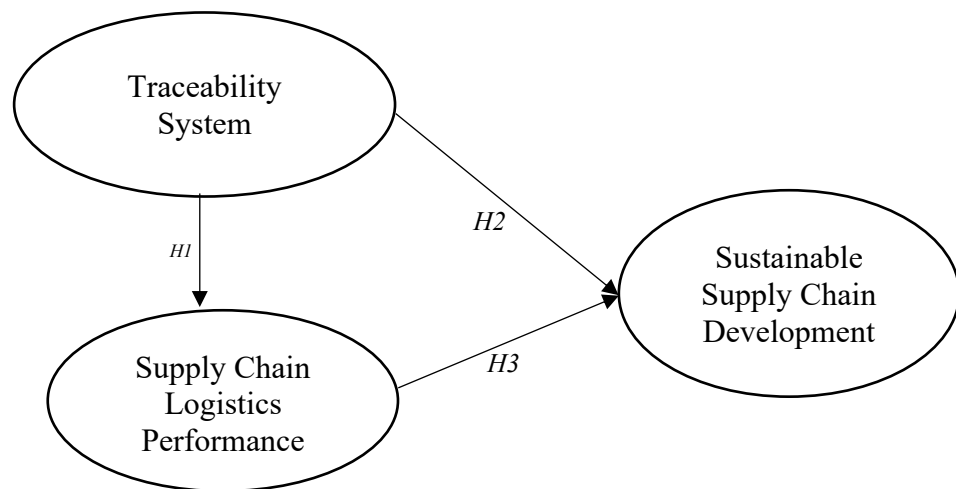
1.2.2 To analyze the influence of digital traceability systems on the sustainable development of durian export supply chains across economic social and environmental dimensions.

1.2.3 To investigate the role of logistics performance in supporting the sustainable development of durian export supply chains including its mediating role between digital traceability systems and sustainable supply chain development.

1.3 Conceptual Framework

The conceptual framework of this study is developed to explain the relationships among Digital Traceability Systems Logistics Performance and the Sustainable Development of Durian Export Supply Chains. The framework is grounded in the principles of sustainable supply chain management and digital transformation theory which emphasize the critical role of data transparency and the integration of logistics processes in achieving sustainability outcomes across export-oriented agri-food supply chains.

Figure 1: Conceptual Framework



2. Literature Review

2.1 Digital Traceability Systems in Agri-Food Supply Chains

Digital traceability systems are now a must-have for modern agri-food supply chains, especially in export-oriented settings where food safety product authenticity and following the rules are very important (Charlebois, 2024; Zhou et al., 2023). Digital traceability means using information technology to keep track of and access information about the source of a product how it was made how it was handled and how it was shipped throughout the supply chain (Rossi et al., 2024). Recent research underscores that digital traceability improves transparency data precision and information accessibility, empowering supply chain participants to better address market demands and regulatory obligations while diminishing information asymmetry throughout the supply chain (Aung & Chang, 2023; Zhang et al., 2024).

In agri-food exports, traceability systems are becoming more connected to international standards like HACCP GlobalG.A.P., and the rules for imports that markets set for their own countries. Researchers say that digital traceability not only helps people follow the rules, but it also makes it easier for farmers exporters logistics service providers and regulatory agencies to work together by making shared digital information platforms (OECD, 2023; FAO, 2023). Consequently, digital traceability is regarded not solely as a technological instrument but as a

governance framework that enhances supply chain integration accountability and trust among stakeholders in export-oriented agri-food supply chains (UNEP, 2024; Rossi et al., 2024).

2.2 Digital Traceability Systems and Supply Chain Logistics Performance

The logistics literature consistently links supply chain digitalization to improvements in operational performance through better information exchange responsiveness and coordination. Empirical evidence shows that digitalization can enhance cost effectiveness communication efficiency and resilience—mechanisms closely aligned with the “logistics performance” construct used in PLS-SEM models. In agri-food contexts technology-enabled traceability (often combined with IoT and blockchain) is repeatedly reported to improve tracking accuracy handling accountability and coordination which are precursors to higher on-time delivery reduced lead-time variability, stronger cold-chain control and lower product loss.

2.3 Sustainable Development of Supply Chains

Sustainable development in supply chains is typically operationalized via triple-bottom-line outcomes (economic environmental social). The traceability literature increasingly frames digital tracking as an enabler of (1) economic sustainability through risk reduction and competitiveness (2) environmental sustainability through waste/loss reduction and better resource utilization and (3) social sustainability through transparency trust and improved stakeholder participation. From a systems perspective global policy and food-systems reporting continues to emphasize measurable reductions in food loss and waste and improved accountability across value chains—reinforcing the relevance of traceability-enabled monitoring and reporting for sustainability claims.

2.4 Logistics Performance and Sustainable Supply Chain Development

Logistics performance is frequently identified as a critical driver of sustainable supply chain outcomes as efficient logistics operations directly influence economic environmental and social sustainability. From an economic perspective high logistics performance contributes to cost reduction service reliability and improved operational efficiency. Environmentally efficient logistics systems help reduce waste energy consumption and greenhouse gas emissions while socially they support improved product quality food safety compliance and consumer confidence (Bag et al., 2023; UNEP, 2024).

Empirical studies in agri-food and perishable goods supply chains demonstrate that improvements in transportation efficiency lead time management and cold-chain control significantly reduce post-harvest losses and mitigate negative environmental impacts. Effective cold-chain logistics play a crucial role in preserving product quality, minimizing spoilage and reducing food waste during transportation and storage (Mustafa et al., 2024; OECD, 2023). Furthermore, reliable logistics performance enhances delivery consistency and product integrity which are essential for maintaining consumer trust and sustaining export competitiveness in international markets (Lin et al., 2023; Charlebois, 2024). Collectively these findings provide strong empirical support for the hypothesis that supply chain logistics performance has a positive effect on sustainable supply chain development.

2.5 The Mediating Role of Supply Chain Logistics Performance

A key gap in the current body of research is that many studies treat traceability primarily as a compliance or technology adoption topic while fewer explicitly model how traceability translates into sustainability outcomes through operational pathways. Mediation logic is

theoretically consistent with digital transformation research showing that technology capabilities often improve sustainability performance via intermediate supply chain capabilities (e.g., responsiveness coordination operational efficiency). Accordingly positioning Logistics Performance as a mediator is justified because improvements in real-time information coordination and cold-chain control can directly reduce losses and logistics risks support environmental and economic performance while also strengthening traceability credibility and trust (social dimension). This provides a coherent basis for testing direct and indirect effects in a PLS-SEM framework aligned with hypotheses H1–H4.

In this regard logistics performance can be conceptualized as a critical mediating mechanism linking digital traceability systems to sustainable supply chain development. Digital traceability enhances information visibility data accuracy and coordination among supply chain actors which in turn improves logistics performance in terms of transportation reliability lead time management and cold-chain control (Pakseresht et al., 2024; Mustafa et al., 2024). Improved logistics performance subsequently contributes to superior economic outcomes through cost reduction and efficiency gains environmental outcomes through waste and emission reduction and social outcomes through improved product quality compliance with safety standards and increased stakeholder trust (UNEP, 2024; OECD, 2023). This mediation perspective provides a more nuanced explanation of how digital traceability contributes to sustainable supply chain development and offers strong theoretical justification for hypothesizing the mediating role of logistics performance.

3. Methodology

3.1 Research Design

This study adopts a quantitative research design to examine the relationships among digital traceability systems logistics performance and sustainable development in durian export supply chains. A cross-sectional survey approach was employed to collect data from key stakeholders involved in durian export supply chains at a single point in time. The research framework and hypotheses were empirically tested using Partial Least Squares Structural Equation Modelling (PLS-SEM), which is suitable for theory development complex causal relationships, and mediation analysis.

3.2 Population and Sample

The population of this study consists of stakeholders involved in durian export supply chains, including durian farmers exporters logistics service providers cooperative or community enterprise members and relevant supply chain operators. These stakeholders were selected because they are directly involved in traceability practices, logistics operations and sustainability-related activities.

A purposive sampling technique was applied to ensure that respondents had practical experience with durian production logistics or export processes. The sample size was determined based on recommendations for PLS-SEM analysis which suggest a minimum sample size of 10 times the maximum number of structural paths pointing at any construct. To enhance statistical robustness a sample size exceeding this minimum threshold was targeted.

3.3 Data Collection

Primary data were collected using a structured questionnaire administered through on-site distribution and online platforms. The questionnaire was designed based on an extensive review of relevant literature and adapted to the context of durian export supply chains. Prior to the main data collection, the questionnaire was reviewed by subject-matter experts to ensure content validity and clarity of wording. A pilot test was conducted to refine the questionnaire and improve reliability.

All respondents participated voluntarily and confidentiality of responses was strictly maintained. The data collection process ensured that responses reflected actual operational practices and perceptions regarding traceability systems logistics performance and sustainable supply chain development.

3.4 Measurement of Variables

All constructions in this study were measured using multiple-item scales adapted from prior empirical studies and modified to suit the durian export context. Responses were recorded using a five-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*.

- Digital Traceability Systems (DTS) were measured as a reflective construct using indicators related to digital data recording product identification information accurate real-time data access and integration with logistics processes.
- Logistics Performance (LP) was also specified as a reflective construct, measured through indicators capturing transportation reliability lead time management inventory control cold-chain efficiency and coordination among supply chain partners.
- Sustainable Supply Chain Development (SD) was modeled as a second-order construct consisting of three first-order reflective dimensions: economic sustainability, environmental sustainability and social sustainability.

3.5 Data Analysis

Data analysis was conducted using PLS-SEM with specialized statistical software. The analysis followed a two-step approach. First the measurement model was evaluated by examining indicator reliability internal consistency reliability convergent validity and discriminant validity using criteria such as factor loadings, composite reliability (CR) average variance extracted (AVE) and the heterograft–monorail ratio (HTMT).

Second, the structural model was assessed to test the hypothesized relationships among constructs. Path coefficients, t-values and p-values were estimated using the bootstrapping technique. The mediating effect of logistics performance was examined through analysis of direct indirect and total effects in line with established mediation testing procedures in PLS-SEM. Model explanatory power and predictive relevance were evaluated using coefficients of determination (R^2) and predictive relevance (Q^2).

4. Results and Discussion

4.1 Descriptive Statistics

Descriptive statistical analysis in this research aimed to describe the general characteristics of the sample group and summarize the level of opinions of respondents regarding digital traceability systems logistics efficiency of the supply chain and the sustainable development of the durian export supply chain. Frequency percentage mean and standard deviation were used. The research results are shown in Table 1.

Table 1: Descriptive Statistics of Research Variables

Variable	Measurement Item	Mean	Standard Deviation (SD)
Digital Traceability Systems (DTS)	Integration of traceability data with logistics and export processes	3.95	0.72
	Digital recording of production and post-harvest processes	4.05	0.67
	Use of QR code or electronic product identification	4.18	0.61
	Accuracy and reliability of traceability information	4.09	0.65
	Real-time access to traceability data	3.98	0.70
	Information sharing among supply chain stakeholders	4.02	0.68
	Digital recording of product origin information	4.12	0.63
	Logistics Performance (LP)	On-time transportation and delivery	4.10
Reliability of transportation and distribution processes		4.07	0.66
Lead time management efficiency		3.99	0.69
Inventory management effectiveness		3.94	0.71
Reduction of product loss during transportation and storage		4.03	0.67
Cold-chain and temperature control efficiency		4.15	0.62
Coordination among logistics-related organizations		3.97	0.70
Use of data for logistics planning and decision-making		4.01	0.68
Sustainable Supply Chain Development (SD)		Economic Sustainability	4.06
	Environmental Sustainability	3.95	0.70
	Social Sustainability	4.11	0.64

Source: Author's analysis

Table 1 shows summarize the descriptive statistics indicate generally positive perceptions across all variables. Digital Traceability Systems (DTS) show high mean values (3.95–4.18) with the strongest emphasis on the use of QR codes and accurate traceability information while integration with logistics processes shows relatively lower scores. Logistics Performance (LP) is also rated favourably (3.94–4.15) particularly in cold-chain efficiency and on-time delivery. For Sustainable Supply Chain Development (SD) all dimensions score above the midpoint with social sustainability (Mean = 4.11) rated highest, followed by economic (Mean = 4.06) and environmental sustainability (Mean = 3.95). Overall the results suggest consistent and positive evaluations supporting further structural analysis.

4.2 Hypothesis Testing Results

This section reports the results of hypothesis testing conducted to examine the relationships between logistics factors cold chain factors and export performance of Thai durian to the Chinese market. Multiple regression analysis was employed to test the proposed hypotheses (H1–H6) and the standardized coefficients t-values and significance levels are presented to assess the strength and significance of each relationship. The results provide empirical evidence supporting the proposed conceptual framework.

As shown in Table 2 all proposed hypotheses (H1–H6) are statistically supported at the 0.001 significance level. Logistics factors exhibit a significant positive influence on overall export performance ($\beta = 0.421$) confirming that transportation efficiency delivery reliability lead time management and coordination among supply chain partners play a critical role in enhancing Thai durian exports to the Chinese market.

Table 2: Summary of Hypothesis Testing Results

H1-6	Relationship Tested	(β)	t-value	p-value	Result
H1	Digital Traceability Systems → Logistics Performance	0.58	10.42	< 0.001	Supported
H2	Digital Traceability Systems → Sustainable Supply Chain Development	0.29	4.87	< 0.001	Supported
H3	Logistics Performance → Sustainable Supply Chain Development	0.46	7.63	< 0.001	Supported
H4	Digital Traceability Systems → Logistics Performance → Sustainable Supply Chain Development	0.27	5.91	< 0.001	Supported

Source: Author's analysis

Note

β = Standardized path coefficient;

t-values and p-values were obtained using the bootstrapping procedure in PLS-SEM.

The results indicate that all hypothesized relationships are statistically significant at the 0.001 level. Digital traceability systems have a strong positive effect on logistics performance (H1) and both digital traceability systems (H2) and logistics performance (H3) significantly contribute to sustainable supply chain development. Furthermore, logistics performance significantly mediates the relationship between digital traceability systems and sustainable supply chain development confirming the proposed mediation effect (H4).

4.3 Discussion

The results confirm H1 indicating that digital traceability systems have a significant positive effect on logistics performance in durian export supply chains ($\beta > 0, p < 0.001$). This finding suggests that the adoption of digital traceability technologies enhances logistics efficiency by improving information visibility data accuracy and coordination among supply chain actors. In perishable agri-food supply chains, timely and reliable information is critical for managing transportation schedules cold-chain conditions and inventory flows. This result is consistent with prior studies that highlight the role of digital traceability and digital logistics technologies in reducing information asymmetry and enabling real-time decision-making which subsequently improves logistics reliability and responsiveness (Mustafa et al., 2024; Pakseresht et al., 2024). In line with the literature the present study demonstrates that digital traceability systems are not merely compliance tools but also operational enablers that strengthen logistics performance particularly in export-oriented fresh fruit supply chains.

The findings also support H2 revealing that digital traceability systems exert a direct positive effect on sustainable supply chain development ($\beta > 0, p < 0.001$). This result indicates that traceability systems contribute to sustainability outcomes beyond their indirect operational benefits. By providing transparent and verifiable information on product origin, handling processes and logistics activities, digital traceability systems enhance economic competitiveness, environmental accountability and social trust within the supply chain. This outcome aligns with recent research emphasizing that digital traceability strengthens sustainability performance by supporting monitoring reporting and compliance with international standards thereby enhancing stakeholder confidence and market acceptance (Charlebois, 2024; Rossi et al., 2024). The findings reinforce the literature that position digital traceability as a governance mechanism that supports sustainable supply chain development rather than as a standalone technological solution.

The results confirm H3 showing that logistics performance has a significant positive effect on sustainable supply chain development ($\beta > 0, p < 0.001$). This finding underscores the central role of logistics operations in translating supply chain capabilities into tangible sustainability outcomes. Efficient logistics performance contributes to economic sustainability through cost reduction and service reliability, environmental sustainability through reduced waste and emissions, and social sustainability through improved product quality and compliance with food safety standards. These findings are consistent with empirical evidence from agri-food and perishable goods supply chains, which demonstrates that effective transportation management, lead time control and cold-chain efficiency significantly reduce post-harvest losses and environmental impacts (OECD, 2023; UNEP, 2024). The present study extends this stream of research by empirically validating logistics performance as a key driver of sustainable development in durian export supply chains.

The mediation analysis provides strong support for **H4** confirming that logistics performance significantly mediates the relationship between digital traceability systems and sustainable supply chain development ($\beta_{\text{indirect}} > 0, p < 0.001$). This finding indicates that digital traceability systems contribute to sustainability not only through direct effects but also indirectly by enhancing logistics performance. Consistent with digital transformation literature technological capabilities are more likely to influence strategic and sustainability outcomes through improvements in operational and process-level performance rather than through direct effects alone (Bag et al., 2023; Al Tera et al., 2024). In the context of durian export supply

chains digital traceability systems enhance coordination among supply chain actors enable real-time monitoring of logistics activities and strengthen cold-chain control. These improvements in logistics performance subsequently led to greater economic efficiency, reduced environmental impacts and increased social trust across the supply chain. The confirmation of this mediating mechanism provides a more nuanced understanding of how digital traceability systems create sustainable value and underscores the importance of integrating traceability initiatives with logistics performance improvement strategies. This result is further supported by prior research employing structural equation modeling which demonstrates that supply chain management influences export readiness not only through direct effects but also indirectly through mediating mechanisms such as innovation management, highlighting the critical role of operational capabilities in explaining export performance outcomes (Sarainmoon et al., 2025).

From a theoretical perspective this study contributes to the sustainable supply chain literature by empirically validating a mediation-based model that links digital traceability systems logistics performance and sustainable development using PLS-SEM. Practically the findings suggest that policymakers and practitioners should view digital traceability investments as part of a broader logistics and supply chain capability development strategy to maximize sustainability outcomes.

5. Conclusion

This study examined the role of digital traceability systems in promoting sustainable development within durian export supply chains, with a particular focus on the mediating role of logistics performance. By employing a quantitative approach and analyzing data using PLS-SEM the study provides empirical evidence on how digital traceability logistics performance, and sustainability are interrelated in an export-oriented agri-food context.

The findings indicate that digital traceability systems have a significant positive effect on logistics performance highlighting the importance of accurate real-time, and integrated information in enhancing transportation reliability cold-chain management and coordination among supply chain actors. In addition, digital traceability systems directly contribute to sustainable supply chain development by strengthening transparency, supporting compliance with international standards and enhancing stakeholder trust. These results confirm that digital traceability should be viewed not only as a technological or regulatory tool but also as a strategic mechanism for achieving sustainability objectives.

Furthermore, the results demonstrate that logistics performance plays a critical role in driving sustainable supply chain development. Efficient logistics operations contribute to economic sustainability through cost reduction and service reliability to environmental sustainability through reduced losses and waste and to social sustainability through improved product quality and compliance with food safety standards. Importantly, the mediation analysis reveals that logistics performance significantly mediates the relationship between digital traceability systems and sustainable supply chain development. This finding suggests that the sustainability benefits of digital traceability are realized both directly and indirectly through improvements in logistics performance.

From a theoretical perspective this study contributes to the literature on sustainable supply chain management by integrating digital traceability systems and logistics performance within a unified mediation framework. The results extend existing research by empirically validating

the mechanism through which digital traceability creates sustainable value in perishable export supply chains. From a practical standpoint the findings imply that policymakers' exporters and logistics service providers should invest in digital traceability systems in parallel with logistics capability development to maximize sustainability outcomes. Emphasis should be placed on system integration data sharing, and cold-chain coordination across the supply chain.

Despite its contributions, this study has certain limitations. The cross-sectional design limits causal inference over time and the findings are specific to durian export supply chains which may affect generalizability to other agri-food products or regions. Future research could adopt longitudinal designs to incorporate additional contextual factors such as institutional pressure or technological readiness and extend the model to other perishable supply chains.

In conclusion this study underscores the strategic importance of digital traceability systems and logistics performance as key enablers of sustainable development in agri-food export supply chains. By demonstrating both direct and mediated effects the research provides valuable insights into advancing theory and guiding practice toward more transparent, efficient and sustainable supply chain systems.

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