# A SCOR DIGITAL STANDARD-BASED FREAMEWORK FOR CIRCULAR E-WASTE SUPPLY CHAIN IN THAILAND

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**ABSTRACT**
**Purpose:** This study is to develop a practical framework that integrates Circular Supply Chain principles with the SCOR Digital Standard to improve E-waste management in Thailand. It aims to address environmental and operational challenge by promoting sustainable practices, stakeholder collaboration, digital innovation in developing economies.
**Design/methodology/approach:** This study adopts a conceptual framework approach, integrating Circular Supply chain principles and the designed EDR for E-DS process to align with circular strategies for E-waste management. Data were gathered from primary and secondary sources, including E-waste Consolidation centers reports, academic literature, and government policies relevant to Thailand's E-waste management context.
**Findings:** The study finds that integrating Circular Supply Chain principles with the SCOR Digital Standard enhances the effectiveness of e-waste management. Each SCOR DS process support circular practices, helping to reduce environmental impact and improve resource recovery. The framework encourages collaboration, digital innovation, and policy alignment for sustainable outcomes in developing economies.
**Practical Implication:** This study provides a practical roadmap for transforming circular economy principles into actionable logistics practices. The SCOR DS–based framework enables municipalities to establish traceable, community-integrated collection systems, while guiding recyclers and SMEs to enhance refurbishment and material recovery. Policymakers can apply it to operationalize EPR and cross-sector governance, supported by digital traceability tools. Overall, it fosters circular entrepreneurship, local job creation, and sustainable resource retention within domestic markets.
**Originality:** This study offers a novel integration of Circular Supply chain Concepts with the SCOR Digital Standard, specifically applied to E-waste management in a developing country context. It provides a strategic framework that addresses both environmental and operational challenges, highlighting the role of digital tools and stakeholder collaboration in achieving sustainable resource management.

## Introduction

Electronic waste (E-waste) has become a critical environmental and operational concern for developing economies, including Thailand. Between 2020 and 2025, Thailand generated an estimated 418,000 to 753,000 tons of E-waste annually, with less than 10% managed through formal collection and recycling systems (ITU, 2022; Bangkok Post, 2024). Informal sectors dominate the current landscape, with scavengers and unauthorized operators handling over 80% of discarded electronics—often through unsafe dismantling and open burning practices (BenarNews, 2024). Major waste processing clusters have emerged in provinces like Bangkok, Chachoengsao and Rayong, while, the provinces with the highest concentration of communities engaged in E-waste sorting and recycling activities are Kalasin, Buriram, and Ubon Ratchathani, yet many facilities face scrutiny over improper licensing and environmental compliance (Bangkok Post, 2024; CBS News, 2025).

Japan represents one of the most advanced cases of E-waste management in Asia, with a regulatory framework grounded in the Extended Producer Responsibility (EPR) principle under the *Act on Recycling of Specified Kinds of Home Appliances (HARL)* and the *Law for the Promotion of Effective Utilization of Resources (LPUR)* (OECD, 2025; WtERT, 2025). These laws make manufacturers and importers responsible for the full lifecycle of their products. Consumers are required to pay transportation and recycling fees, and retailers must collect used appliances when selling new ones. The system promotes transparency through recycling vouchers and public display of recycling fees (WtERT, 2025). Japan also demonstrates technological leadership with smart bins using AI and sensors, robotic sorting centers, and waste-to-energy incineration equipped with advanced filters to minimize environmental impact (WasterDirect, 2025; JICA, 2025). Despite these advancements, challenges persist, including low public participation, especially among university students, rapid device obsolescence, and occasional illegal waste trade (Trinh & Sakurai, 2025; Global E-waste Monitor, 2024). This context provides valuable lessons for developing economies such as Thailand, where E-waste management remains fragmented and dependent on informal sectors. Integrating the SCOR Digital Standard (SCOR DS) with circular economy principles can address these challenges by enhancing traceability, stakeholder collaboration, and community-based resource recovery.

To address these issues, national authorities have introduced several policy initiatives, including Thailand's Strategic Plan on Integrated E-waste Management (2022–2026) and a proposed Waste Electrical and Electronic Equipment (WEEE) Act incorporating Extended Producer Responsibility (EPR) principles (Enviliance, 2024; PCD, 2023). However, enforcement remains fragmented, digital traceability is limited, and informal actors remain largely excluded from official frameworks. In parallel, public-private efforts like the "HUB of E-Waste" and Bangkok's e-waste drop-off points have increased public awareness but lack supply chain integration at scale (AIS, 2023; BMA, 2024).

This study responds to these challenges by proposing a digitally-enabled, circular supply chain model for E-waste management based on the SCOR Digital Standard (SCOR DS). As global supply chains decouple and localize, Thailand and similar economies must reimagine waste as a resource. By integrating SCOR DS's structured process logic with circular principles, this research aims to offer a scalable framework that addresses traceability, resource recovery, and cross-sector collaboration to advance sustainable E-waste management.

## Literature Review

Japan's E-waste management system has often been cited as a model in the academic and policy literature for its comprehensive integration of regulatory, technological, and behavioural mechanisms (OECD, 2025; Pakistan Journal of Chemistry, 2025). Its dual legislation, the Act on Recycling of Specified Kinds of Home Appliances (HARL) and the Law for the Promotion of Effective Utilization of Resources (LPUR), embodies the polluter-pays and Extended Producer Responsibility (EPR) principles. These frameworks assign producers the responsibility for collection, transportation, and recycling of products such as televisions, refrigerators, air conditioners, and washing machines. Consumers are involved through fee-based returns at municipal offices and retailers, creating a transparent, traceable collection ecosystem (WtERT, 2025).

Japan's use of AI, robotics, and waste-to-energy technologies also represents a key technological benchmark (WasterDirect, 2025; JICA, 2025). Recycling plants leverage robotic sorting and rare-earth metal recovery, while over 1,000 incineration facilities integrate advanced filtration to reduce emissions and generate energy. Despite these advances, several studies highlight continuing challenges—such as the growing complexity of small devices, limited citizen engagement, and illegal transboundary waste movement (Trinh & Sakurai, 2025; Global E-waste Monitor, 2024).

These lessons underscore that effective E-waste management depends not only on strong laws and technologies but also on public participation, data-driven traceability, and localized collaboration. Hence, Japan's model offers key insights for Thailand and other ASEAN nations, where informal collection networks remain vital. The SCOR DS–CSC framework proposed in this study builds upon these lessons by linking global standards with community-based circular practices to strengthen reverse logistics, promote extended producer accountability, and operationalize sustainability transitions. The increasing complexity of managing electronic waste (E-waste) within supply chains has led to the evolution of strategic frameworks rooted in reverse logistics and circular supply chain (CSC) thinking. Recent studies emphasize the critical role of digitally enabled CSCs in addressing environmental, operational, and stakeholder coordination challenges.

Che Hassan and Osman (2025) conducted a systematic review identifying reverse logistics as a key enabler of circularity, particularly when integrated with digital tools such as IoT, blockchain, and AI. These tools enhance traceability and stakeholder coordination, especially in decentralized or informal systems. Sonar et al. (2024) highlighted several barriers to reverse logistics implementation in developing countries—particularly uncertainty in return flows, lack of economic incentives, and high operational costs—emphasizing the importance of tailored strategies for circular E-waste flows.

He et al. (2024) explored lifecycle assessments (LCA) of E-waste systems and emphasized the need for integrated digital infrastructure to support environmental decision-making. Mahmoud et al. (2024) further classified CSC modelling approaches, noting the potential for optimization techniques to improve resource recovery and system efficiency. In line with this, Mbago (2025) identified practical reverse logistics strategies that facilitate circular transitions in developing contexts, reinforcing the value of integrated policy and community-level engagement.

From a digitalization lens, the SCOR framework has increasingly been adopted as a backbone for structuring digital supply chains. A review by Zhang et al. (2023) examined SCOR-aligned frameworks for supply chain decoupling, showing their capacity to manage local resource flows through dynamic feedback and orchestrated planning. An emerging body of research focuses on the opportunities and limitations of digital SCOR deployment in sustainability transitions (ResearchGate, 2024).

In Thailand, Panyagometh (2024) analyzed household E-waste behaviours and logistics barriers, finding that inefficient collection systems and lack of public-private integration remain key gaps. A case study by Thongkaow et al. (2022) evaluated informal dismantling communities and underscored material losses in the absence of formal oversight. Meanwhile, ERIA (2023) reported widespread informal collection in ASEAN countries, with low rates of environmentally sound recycling.

Locally, initiatives such as the E-waste Dismantling Community in Buriram province (2020) have demonstrated the potential of community-scale operations but revealed gaps in hazardous waste handling. Such studies emphasize the urgency for Thailand to adopt structured, digitally traceable, and circular logistics models that include the informal sector and support localized implementation.

These contributions collectively validate the need for a hybrid model integrating SCOR Digital Standard processes with CSC logic, particularly in developing economies facing infrastructure, policy, and stakeholder alignment challenges.

## Methodology

This study adopts a qualitative design-based research methodology with elements of applied systems design and exploratory case study. The primary goal is to develop a SCOR Digital Standard-Based Framework for Circular E-Waste Supply Chain tailored to the Thai context while ensuring applicability across similar developing economies.

### 1.Research Design

The research is structured into three phases: (1) exploratory assessment, (2) framework design, and (3) validation through expert consultation. A combination of inductive reasoning and design thinking was applied to analyze existing systems and co-develop the framework.

### 2.Population and Sample

The population of the study includes stakeholders in the E-waste management ecosystem in Thailand. This comprises municipal officials, licensed recycling firms, informal sector collectors (e.g., “saleng”), community organizations, and academic experts in logistics and environmental science.

The purposive sampling technique was employed to select 25 key informants across four stakeholder groups:8 representatives from local municipalities in Ubon Ratchathani and Buriram, 5 executives from licensed E-waste recyclers,7 members of informal sector networks (collectors, dismantlers), 5 academic and policy experts in circular logistics.

### 3.Data Collection Tools

Three primary tools were utilized:

3.1 Semi-structured interviews with key informants.

3.2 Document review of national policies, academic literature, and technical SCOR documentation.

3.3 Stakeholder mapping workshops using digital whiteboarding tools (e.g.canva) to co-design process elements.

### 4.Data Analysis

Data from interviews were thematically analyzed using NVivo 12 software. Coding categories were based on SCOR DS process levels (Orchestrate, Plan, Order, Source, Transform, Fulfill, Return). Thematic analysis was used to identify barriers, enablers, and process gaps across the E-waste supply chain.

Document analysis triangulated policy gaps and verified alignment with SCOR DS structure. Cross-validation was performed through expert reviews with 5 logistics and environmental policy specialists and workshops with 25 local stakeholders (municipal officers, recyclers, informal collectors, and educators).

### 5.Framework Design Process

The design of the SCOR DS-based framework followed six steps:

Step1: System mapping – Flowcharting the current E-waste management system using stakeholder inputs.

Step2: SCOR alignment – Mapping system processes onto SCOR DS Level 0–3.

Step3: Gap analysis – Identifying missing or inefficient processes based on stakeholder feedback.

Step4: Digital integration – Embedding traceability and data systems (ERD structure).

Step5: Circularity embedding – Integrating CSC principles into each SCOR process with a focus on reuse, recovery, and responsible disposal.

Step6: Validation – Conducting feedback sessions and scenario walkthroughs with sample users to finalize the model structure.

## Results

The proposed SCOR DS–CSC Integrated Framework comprises four levels:

- Level 0 (Core): 7 SCOR DS processes — Orchestrate, Plan, Order, Source, Transform, Fulfill, Return.
- Level 1 (Process Structuring): Mapped to SCOR DS codes (e.g., OE1–OE13, P1–P6, S1–S4) and localized for Thai context (LAO coordination, digital orders, informal sourcing).
- Level 2 (Configuration): Defines localized configurations such as drop-point planning, informal collector registration, and community repair hubs.
- Level 3 (Activities): Specifies actionable steps (e.g., ORC.1 monthly stakeholder meetings; PLR.1 GIS mapping; TRF.2 hazardous isolation).

### Level 0: Core Process Definitions

1. **Orchestrate**: Activities associated with the integration and enablement of supply chain strategies, including business rules, enterprise planning, human resources, network design, data analytics, contracts, compliance, risk management, ESG initiatives, circular economy actions, and performance management.
2. **Plan**: Activities related to developing roadmaps to operate the supply chain. Planning is applied across Order, Source, Transform, Fulfill, and Return processes, including requirement determination.
3. **Order**: Activities related to the customer purchase or return of products and services, including attributes such as order placement, locations, payment methods, pricing, and fulfillment status.
4. **Source**: Activities associated with procuring, scheduling, receiving, and transferring products and services from both formal and informal channels.
5. **Transform**: Activities associated with product creation or modification, including assembly, disassembly, refurbishment, repair, recycling, and reconditioning.
6. **Fulfill**: Activities associated with executing orders or services, including scheduling delivery, picking, packing, shipping, installation, and invoicing.
7. **Return**: Activities related to reverse flows, including diagnosing returned goods, determining reuse or recycling pathways, and routing hazardous components into proper treatment.

| SCOR DS Level 0 | Level 1 Process | Circular Supply Chain Integration for E-waste (Thailand Context) |
|---|---|---|
| **Orchestrate** | Orchestrate Ecosystem Alignment | Establish multi-level coordination between local authorities (LAOs), schools, temples, community collectors (saleng), and certified recyclers. Integrate policy instruments, digital dashboards, and ESG performance indicators to support data transparency and inclusive decision-making. |
| **Plan** | Plan Supply Chain and Reverse Logistics | Develop localized supply chain roadmaps incorporating e-waste collection, repair, and recycling routes. Use participatory planning with schools and community groups to forecast volumes and design drop-point networks aligned with municipal operations. |
| **Order** | Manage Digital Return Orders | Implement mobile or web-based platforms (e.g., LINE OA, QR systems) for citizens to register return orders, schedule pickups, and track processing status. Promote accountability through digital traceability from household to recycling facility. |

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|---|---|---|
| **Source** | Source Secondary and Informal Inputs | Formalize collaboration with informal collectors and local repair shops as secondary resource suppliers. Establish quality verification systems for collected materials and incentivize participation through reward points or community benefit schemes. |
| **Transform** | Transform and Refurbish Components | Create community-based disassembly and refurbishment centers (e.g., schools or temples) for safe dismantling, sorting, and reconditioning of components. Embed circular practices such as reuse, material recovery, and safe handling of hazardous items. |
| **Fulfill** | Fulfill and Redistribute Recovered Products | Deliver refurbished electronics or upcycled components to schools, clinics, and public service units. Facilitate CSR-led redistribution and ensure quality verification through QR-based confirmation or signed proof of delivery. |
| **Return** | Return, Diagnose, and Reinstate Materials | Manage the reverse flow of electronics from users to collection points and recyclers. Conduct diagnostics, sorting, and proper hazardous waste routing. Integrate return data into municipal databases for monitoring recovery efficiency and environmental impact. |

Table 1: SCOR DS–CSC Framework Level0-1

| Process | Level 2 Activities | Application in Local Communities |
|---|---|---|
| **Orchestrate** | Multi-stakeholder governance; ESG dashboard | Municipalities coordinate schools, health units, informal collectors, recyclers |
| **Plan** | Drop-point network design; reverse routes | Schools/temples as collection hubs; saleng (informal collectors) route mapping |
| **Order** | Digital return requests; order tracking | LINE OA/Google Form to issue “return tickets” with QR tracking |
| **Source** | Registration of informal suppliers; quality checks | ID-based registration for collectors; sorting PCB, batteries, plastics |
| **Transform** | Community disassembly and testing | “Repair clinic days” at schools; safe dismantling with isolation of hazardous parts |
| **Fulfill** | Redistribute usable items; verify delivery | CSR projects, redistribution to schools and households, confirmed via QR scan |
| **Return** | Community-based collection; hazardous routing | Drop-off via schools, temples, mobile collection trucks; routing to certified plants |

Table 2: Level 2: Configuration (Localized Implementation in Thai Communities)

| Process | Activity Code | Activity Name | Description (Local Application) |
|---|---|---|---|
| **Orchestrate** | ORC.1 | Stakeholder meeting | Monthly coordination between LAO, schools, VHVs, informal collectors. |

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|---|---|---|---|
| | ORC.2 | ESG dashboard reporting | Publish reuse/recycle rates and GHG reduction data for community. |
| | ORC.3 | Green Drop Point certification | Certify schools/temples as official e-waste collection points. |
| | ORC.4 | Risk & compliance monitoring | Ensure safe handling and legal compliance in community practices. |
| **Plan** | PLR.1 | Drop-point mapping | Map schools, temples, shops as e-waste return hubs. |
| | PLR.2 | Collection scheduling | Weekly/monthly return events organized by LAO/schools. |
| | PLR.3 | Reverse logistics route design | Optimize collection routes for saleng and municipal trucks. |
| | PLR.4 | Seasonal volume forecasting | Anticipate return spikes (school terms, festivals). |
| **Order** | ORD.1 | Digital return ticket | Citizens create requests via LINE OA or Google Form. |
| | ORD.2 | Pickup slot assignment | Allocate pickup times for informal collectors or LAO trucks. |
| | ORD.3 | QR-based order tracking | Tag devices with QR/serial codes for traceability. |
| | ORD.4 | Lifecycle closure | Confirm completion: reuse, recycle, or disposal. |
| **Source** | SRC.1 | Register informal collectors | Community-level ID + QR code registration. |
| | SRC.2 | Safety training | Basic e-waste handling guidelines for saleng/local shops. |
| | SRC.3 | Material inspection | Sorting PCB, batteries, plastics before recycling. |
| | SRC.4 | Incentive allocation | Provide reward points or coupons for compliant returns. |
| **Transform** | TRF.1 | Community disassembly | Repair/disassembly “clinic days” at schools or temples. |
| | TRF.2 | Hazardous part isolation | Securely separate batteries, PCBs, CRTs. |
| | TRF.3 | Testing reusable components | Screen functional boards, screens, batteries. |
| | TRF.4 | QR labeling | Label refurbished parts with QR for tracking. |
| **Fulfill** | DLV.1 | Redistribution planning | Plan delivery to schools, clinics, or CSR programs. |
| | DLV.2 | CSR/community redistribution | Host events for donating refurbished electronics. |

| | | | |
|---|---|---|---|
| | DLV.3 | Assign delivery tasks | Allocate tasks to saleng or community trucks digitally. |
| | DLV.4 | Delivery confirmation | Validate delivery via QR scan or signed receipt. |
| **Return** | RTM.1 | Community-based collection | Drop-off points at schools/temples or mobile units. |
| | RTM.2 | Diagnostic testing | Portable tools to test batteries and boards. |
| | RTM.3 | Sorting & binning | Classify into reuse/recycle/hazard categories. |
| | RTM.4 | Digital record keeping | Record returns via mobile app or community logbook. |

Table 3: SCOR DS Level 3: Activities (Community-based Examples)

In the design and development of the E-waste information management system and the WeeeU application for reporting repairs, buying, selling, and exchanging second-hand electrical and electronic devices, the system can be presented using an Entity-Relationship (ER) diagram and a sample dashboard interface, as illustrated below.

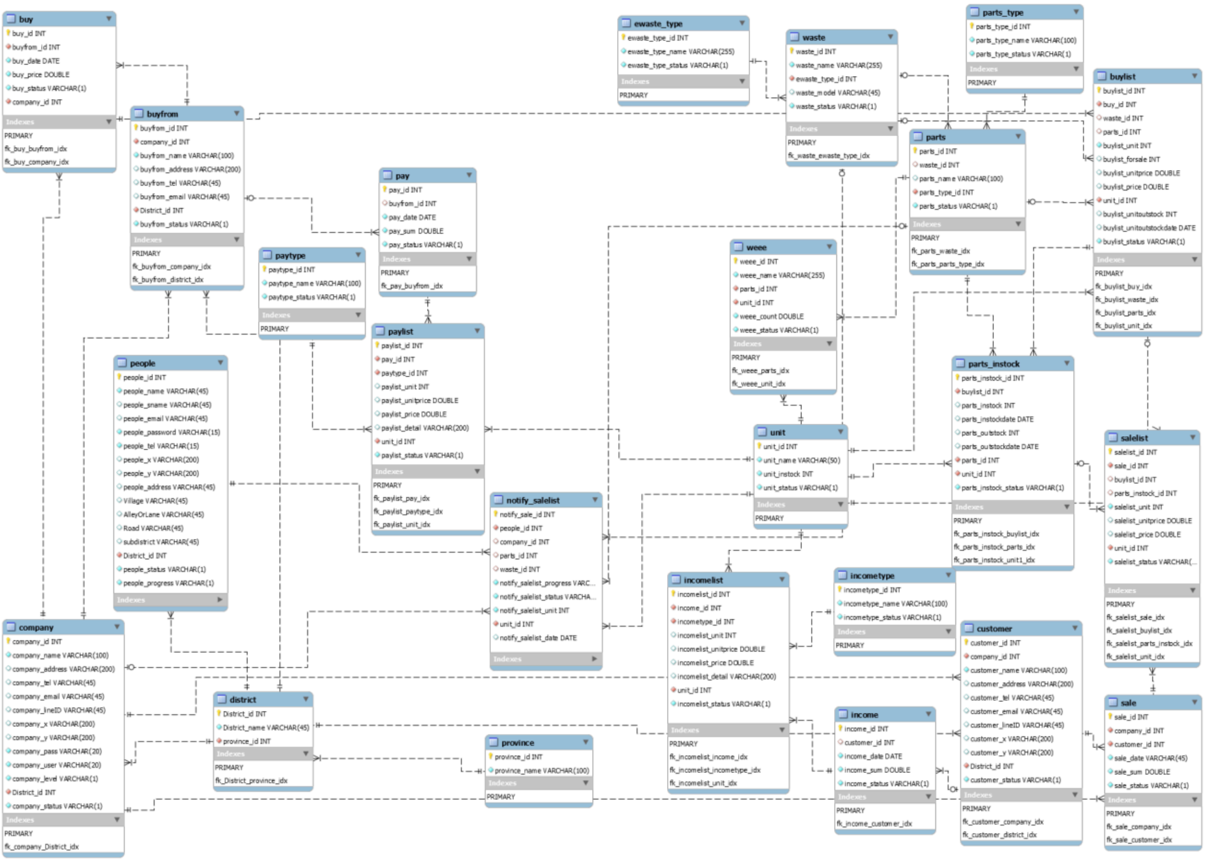


Figure 1: ER diagram for E-waste information management system

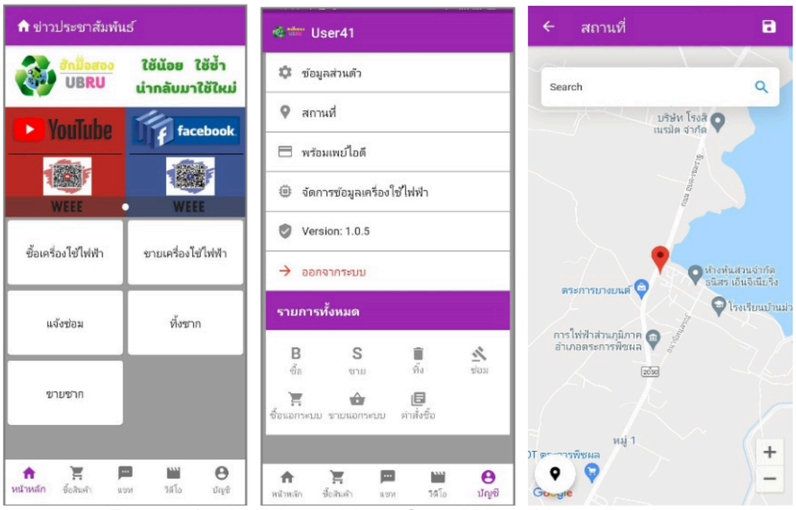

Figure 2: dashboard interface WeeeU application

## Discussion and Conclusion

This study proposed a SCOR Digital Standard–based Circular E-waste Supply Chain Framework for Thailand, integrating global best practices and localized operational insights. By synthesizing Japan's policy experience and technological innovation with Thailand's community-driven initiatives, the framework provides a scalable and participatory model that addresses systemic inefficiencies in E-waste management. The integration of the SCOR DS processes—from Orchestrate to Return—enables traceability, accountability, and collaboration across multiple stakeholders, bridging the gap between formal and informal systems. Moreover, Thailand's adaptation of the SCOR DS framework must localize these elements via municipal orchestration and low-cost technologies.

In term of policy implications, this framework creates benefits to local community includes.

1. **Localized EPR mechanisms:** Empower LAOs as Orchestrators of circular operations supported by national data platforms.
2. **Digital traceability:** Embed QR codes, open dashboards, and data integrity protocols (OE4) in municipal systems.
3. **Public participation:** Implement incentive-based programs and education campaigns through schools and temples.

The framework demonstrates that integrating SCOR DS processes with CSC logic enhances efficiency, ESG compliance, and community participation. It establishes a governance pathway for Thailand's transition toward a digitally enabled, locally managed circular economy.

The findings suggest that Thailand's transition toward a sustainable circular economy requires hybrid governance—combining national policy direction with local action networks led by municipalities, schools, and informal collectors. Applying digital tools, community awareness, and transparent performance tracking can transform E-waste from an environmental liability into a resource for inclusive economic growth. Ultimately, the framework advances both the practical and policy dimensions of circular logistics in developing economies, contributing to regional sustainability and the achievement of SDGs 11, 12, and 13

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