

CHAPTER 1 : INTRODUCTION

1.1. Background

Indonesia faces a major issue in managing their municipal solid waste, and it urgently needs support from digital and software solutions (Kristanto, Kemala and Nandhita, 2022; Kurniawan *et al.*, 2022). The country manufactures approximately 69.9 million tons of waste per year, with projections standing at 82 million tonnes a year in 2045 (Farahdiba *et al.*, 2023; Marešová *et al.*, 2023). Indonesia is the third largest contributor of plastic pollution in the world, releasing more than 3.4 million tons of plastic pollution annually (Soesilo and Alfarizi, 2024). That's because the country produces a lot of waste but lacks the proper infrastructure to manage it, and the environmental, economic, and social ramifications of this crisis extend far beyond waste disposal, encompassing water contamination, greenhouse gas emissions, healthcare costs from waste-related illnesses, and economic losses exceeding \$450 million annually in marine ecosystem damage alone (Li *et al.*, 2023; Yang *et al.*, 2024).



Sources: Indonesian Ministry of Environment and Forestry (2022), World Bank (2022), UNEP (2024)

Figure 1.1. Indonesia Waste Crisis : key statistics (UNEP, 2017; Ministry of Environment and Forestry, 2023).

Compare to the advanced digital systems used in advanced nations, Indonesia's waste management technology is fundamentally lacking. Current operations rely heavily on human labor, Excel-based computing systems, and poorly integrated information architectures, which make it hard to monitor things in real time, evaluate the environmental impact accurately, and follow the rules efficiently (Brasika *et al.*, 2023; Kurniawan *et al.*, 2025), and Indonesia's lack of technology makes it much harder for the country to use advanced carbon tracking systems, participate fully in global carbon markets, due to they follow increasingly strict environmental rules that are necessary for reaching sustainable development goals (Saboor, 2024).

Recent studies highlight that the digitalization of environmental management necessitates advanced technological platforms that can integrate real-time data processing, automated calculation algorithms, comprehensive reporting systems, and facilitate multi-stakeholder collaboration within strong governance frameworks (Antariksa, Angin and Widodo, 2025). Industry 4.0 technologies, such as the Internet of Things (IoT), artificial intelligence, cloud computing, and sophisticated web applications, exhibit considerable potential for the comprehensive digitalization of waste management systems via real-time monitoring, automated carbon accounting, and predictive analytics that facilitate transparent reporting and governance-oriented service development (Kominfo, 2024; Kurniawan *et al.*, 2025). Finally, the breakdown of Indonesia's waste management information systems makes it even harder to fully digitize the country's processes and currently, five different systems work in different government ministries that don't have standard ways of communicating or clear rules for how to run the government systems: SIPSN (Ministry of Environment and Forestry), SI INSAN (Ministry of Public Works and Housing), SIPD (Ministry of Home Affairs), NAWASIS (Ministry of National Development Planning), and AKSARA (Bappenas) (Farahdiba *et al.*, 2023; Kurniawan *et al.*, 2024), and this fragmentation of institutions leads to operational inefficiencies, data duplication, differing reporting standards, and administrative limits that make it harder to manage waste and track carbon offsets in a coordinated way.

WASTE MANAGEMENT REFORM INTERVENTIONS AT THE NATIONAL LEVEL

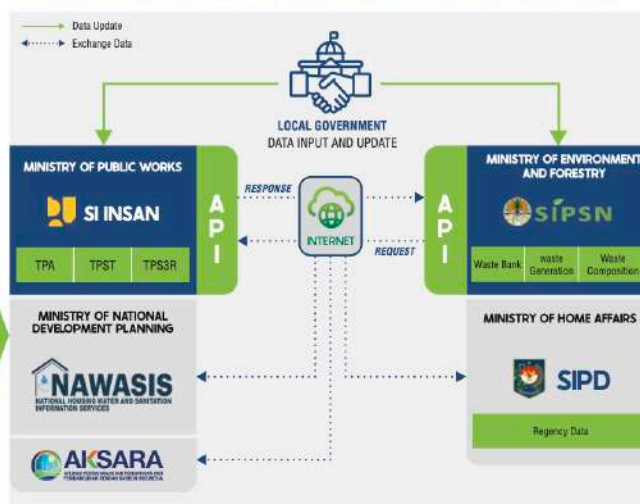
1. INITIATION OF ONE DATA INTEGRATION IN WASTE SECTOR

Currently, there are at least 5 (five) information systems related to waste management in the ministries with different data standards and values, namely: **SIPSN** (Ministry of Environment and Forestry), **SI INSAN** (Ministry of Public Works and Housing), **SIPD** (Ministry of Home Affairs), **NAWASIS** (Ministry of National Development Planning/Bappenas), and **AKSARA** (Ministry of National Development Planning/Bappenas).

EXISTING CONDITION OF WASTE-RELATED DATA MANAGEMENT



DATA INTEROPERABILITY - ONE DATA INTEGRATION IN WASTE SECTOR



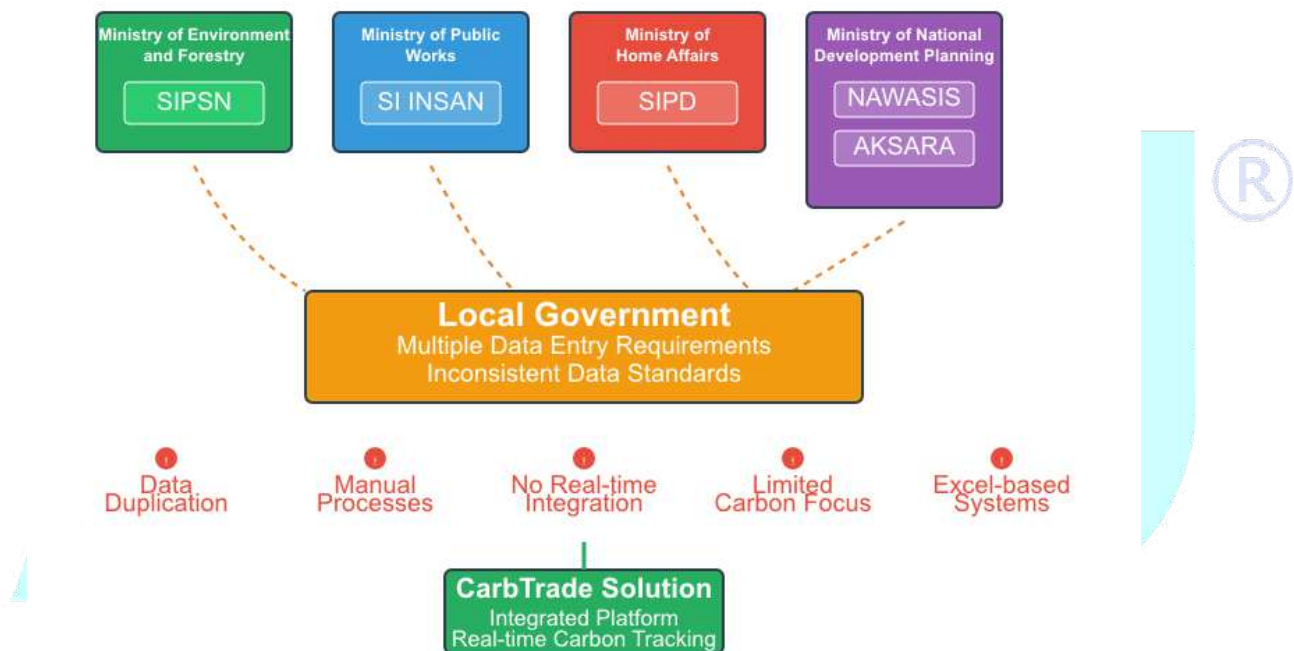
- The implementation of data interoperability in the waste sector enables more efficient input data so that cities/districts only need to input one type of data into one reporting platform.
- This concept will encourage the integration of data in waste sector that is more accurate, actual for the basis of planning, and can be shared.

Figure 1.2. Fragmented Information Systems in Indonesian Waste Management (Eric DKTI, 2024).

Current research indicates that fragmented environmental information systems result in insufficient real-time integration essential for accurate carbon tracking, inadequate governance frameworks that ensure data quality and security across platforms, and a restricted capacity for comprehensive ecosystem management required by contemporary sustainability standards (Putra, Dewi and Sunarya, 2023; Antariksa, Angin and Widodo, 2025), and Local governments face complex reporting systems that increase administrative burdens and hinder cohesive environmental management, necessitating integrated platforms that can address institutional gaps through advanced technological architecture and comprehensive governance frameworks (Bagja *et al.*, 2024). On the other hand CarbTrade platform is an advanced digital solution tailored to tackle these complex difficulties using contemporary web application architecture combined with

the COBIT 2019 governance framework, and the platform employs modern full-stack technologies, specifically Next.js 15 with TypeScript for frontend development to ensure improved code reliability and performance optimization, Laravel 10 with PHP 8.2 for robust backend services and extensive API development, and PostgreSQL 17 enhanced with TimescaleDB extensions for efficient environmental time-series data management and real-time analytics (Lambert *et al.*, 2025; SurekhaTech, 2025).

Current Indonesian Waste Management Information Systems



Source: Analysis of Indonesian Waste Management Information Systems (2024)

Figure 1.3. Current Technology Infrastructure vs. CarbTrade Platform Integration Capabilities (Eric DKTI, 2024)

Recent studies on environmental web applications underscore the considerable benefits of React-based frameworks utilizing Server-Side Rendering (SSR), which enhance performance for data-intensive, real-time interfaces crucial for platforms overseeing live emissions tracking and intricate reporting workflows (Gkamas, Karaiskos and Kontogiannis, 2022; Domínguez-Bolaño *et al.*, 2024), furthermore, the TypeScript implementation improves platform reliability by utilizing static

type checking and error detection, in accordance with COBIT control objectives for software quality assurance and security implementation (ISACA, 2019a), finally the platform utilizes a microservices architecture for modular scalability, adopts API-first development strategies for seamless third-party integrations, implements Docker containerization for consistent deployment, and incorporates Progressive Web App features to ensure offline functionality during field operations with limited connectivity (Gkamas, Karaiskos and Kontogiannis, 2022). In this demanding technological and regulatory landscape, Jangjo Technology Indonesia represents a new wave of waste management companies striving to integrate traditional methods with contemporary sustainability standards via the deployment of novel technologies. Established in 2019, Jangjo utilizes the proprietary JOWI (Jangjo Zero Waste Integrated) system, which processes 200 tons of mixed waste daily within a mere 3,000 m², realizing an impressive 70% reduction in land use compared to traditional systems, thereby advancing sustainable urban development goals (Jangjo Technology, 2025), also the company caters to prominent commercial clients such as Plaza Indonesia, FX Mall, Hotel Aston Pluit, and DBS Bank, managing various waste streams throughout Jakarta's commercial, hospitality, and financial industries, but nevertheless, akin to 86% of Indonesian environmental services firms, Jangjo predominantly depends on Excel-based data management systems, which impose considerable constraints on precise carbon footprint assessment, regulatory adherence, and transparent client reporting (Carbon Trust, 2025), and this reliance on manual spreadsheet systems illustrates wider issues within Indonesia's environmental sector, where firms encounter elevated error rates, absence of audit trails, challenges in annual data reconciliation, and incapacity to produce real-time reports necessary for contemporary environmental compliance and participation in carbon markets.

The convergence of Indonesia's waste crisis with the United Nations Sustainable Development Goals necessitates robust digital transformation projects utilizing advanced technological platforms. SDG 13 (Climate Action) underscores the necessity for immediate measures to address the effects of climate change, with waste management being an essential element of national climate strategy (United Nations, 2025), and Indonesia's Enhanced Nationally Determined Contribution under the Paris Agreement pledges to decrease greenhouse gas emissions by 31.89% by 2030, with the waste sector offering substantial opportunities for climate action through

enhanced management practices and carbon offset mechanisms facilitated by advanced digital platforms (UNFCCC, 2022), SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production) underscore the interrelation of waste management with urban sustainability and circular economy principles, necessitating advanced digital platforms for efficient implementation and monitoring (Sachs *et al.*, 2021). Recent studies indicate that integrated strategies targeting multiple Sustainable Development Goals (SDGs) via technology-driven solutions yield synergistic advantages that surpass those of isolated interventions, especially in developing nations where resource limitations necessitate efficient multi-objective approaches (Pradhan *et al.*, 2017; Irianto, Adiatma and Rachman, 2025). The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) frameworks offer critical theoretical foundations for comprehending the successful implementation of environmental management platforms in Indonesia, while also advancing sustainable development goals (Al-Emran and Granić, 2021), and recent extensive research indicate that combined TAM-UTAUT models account for 39-57% of the variance in technology adoption intention, with performance expectancy, effort expectancy, cultural characteristics, and governance quality as the principal predictors of acceptance, on the other hand, cultural and organizational issues considerably hinder technology adoption in Indonesia, with substantial power distance influencing decision-making processes and collectivist tendencies necessitating group consensus for platform implementation (Hofstede, 2024).

1.2. Problem Statement

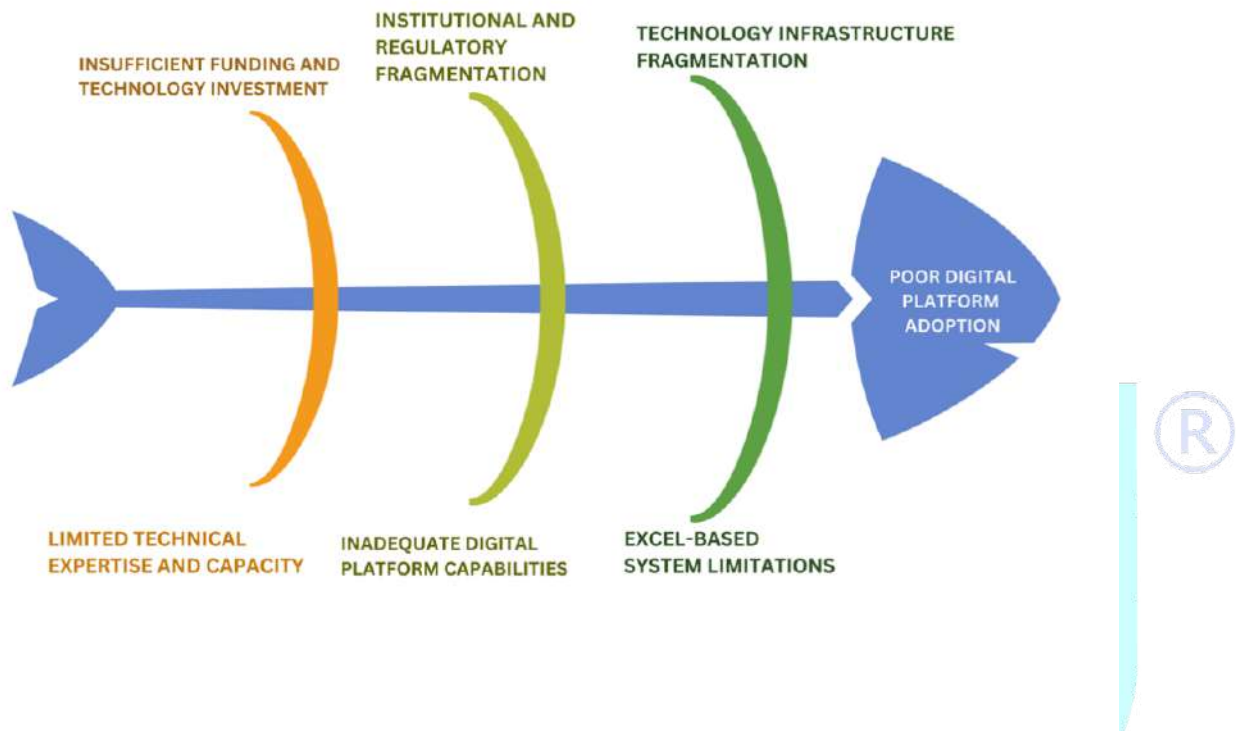


Figure 1.4. Research Problem Fishbone Diagram

Notwithstanding increasing environmental awareness, regulatory pressures, and global commitments to sustainable development, has made Indonesian waste management firms persist in utilizing outdated Excel-based data management systems and disjointed technological infrastructures, which fundamentally hinder precise carbon footprint assessments, regulatory compliance, and transparent environmental reporting, and this technology disparity constitutes a significant obstacle to Indonesia's waste management goals, corporate sustainability aims, and which contributions to global Sustainable Development Goals, while also constraining digital transformation opportunities in the environmental services industry.

Core Problems Identified:

- **Fragmentation of Technological Infrastructure:** Disparate, non-integrated information systems across various ministries result in data redundancy, inconsistent standards, and intricate reporting obligations that encumber both government entities and private enterprises, hindering effective platform integration and comprehensive environmental management.
- **Limitations of Excel-Based Systems:** The prevalent dependence on manual spreadsheet systems for carbon footprint calculations leads to significant error rates nearing 1% of all formulas, absence of audit trails, inability to produce real-time reports, and inherent scalability limitations which that hinder effective regulatory compliance and client transparency (Turner & Watson, 2024).
- **Insufficient Digital Platform Capabilities:** Existing systems are deficient in real-time data processing, automated calculation engines, comprehensive analytics, API integration capabilities, and the security standards necessary for contemporary environmental compliance and carbon market engagement, hindering organizations from utilizing advanced carbon management functionalities.
- **Restricted Technical Proficiency and Capability:** Inadequate technical acumen and digital literacy within waste management organizations hinder the adoption of advanced environmental technologies, especially among SMEs, which constitute the majority of Indonesian enterprises and encounter considerable capacity limitations for technology implementation.
- **Institutional and Regulatory- Fragmentation:** Inadequate institutional structures and policy frameworks impede integrated waste management strategies, which is constraining the capacity for holistic carbon tracking and environmental effect evaluation via cohesive technological platforms.
- **Inadequate Funding and Technological Investment:** Deficient financial models and funding mechanisms for the adoption of environmental technology, especially among SMEs, hinder investment in digital platforms that could improve operational efficiency and environmental compliance while promoting sustainable development goals.

The convergence of technological, organizational, economic, and regulatory challenges creates a complex adoption environment necessitating a comprehensive understanding through integrated theoretical analysis, augmented by technology architecture considerations and sustainable development frameworks.

1.3. Research Objectives

This research seeks to establish a thorough understanding of the CarbTrade platform's technological architecture, governance implementation, and user acceptance in Indonesia's, in the waste management sector through an integrated theoretical analysis that will incorporate the COBIT 2019 governance framework, Software Development Life Cycle methodologies, and empirical investigation based on sustainable development principles.

Objective 1: To design a COBIT 2019-based CarbTrade platform architecture for Indonesian waste management organizations.

Objective 2: To examine factors influencing CarbTrade platform adoption using TAM-UTAUT-COBIT framework in Indonesian companies.

Objective 3: To assess how governance quality moderates the relationship between adoption intention and actual platform usage.

1.4. Research Questions

RQ1: How can COBIT 2019 framework improve CarbTrade platform design to meet Indonesian waste management needs while ensuring security, compliance, and stakeholder trust?

RQ2: What factors influence Indonesian waste management companies' adoption of CarbTrade platforms using TAM-UTAUT-COBIT models, including governance quality, performance expectations, and cultural factors?

RQ3: How does platform governance quality affect the relationship between adoption intention and actual usage among Indonesian waste management companies, and how do COBIT maturity levels influence sustained platform use?

1.5. Hypothesis

H1: Technology Acceptance and Four-Tier Platform Governance Quality Integration

H1a: Performance expectancy positively affects adoption intention across all four user types, with stronger effects for environmentally-conscious companies with mature governance.

H1b: Effort expectancy negatively influences adoption intention across all user groups, but this effect is moderated by user role complexity, organizational size, technical capabilities, and governance support availability.

H1c: COBIT governance framework quality positively moderates the relationship between performance expectancy and adoption intention across all user groups, with stronger effects for administrative users.

H2: Social Influence and Cultural Moderation Effects Enhanced by Four-Tier Governance Credibility

H2a: Social influence positively affects adoption intention and usage across all user types, stronger in Indonesian collectivist contexts.

H2b: Indonesian cultural dimensions moderate effort expectancy-adoption relationships differently across user categories.

H2c: Facilitating conditions moderate intention-usage relationships across user categories with different requirements per user type.

H3: Platform Governance and Sustainable Development Integration Effects

H3a: COBIT implementation improves platform reliability and trust across all users, stronger for Admin/Superadmin.

H3b: Sustainability alignment enhances adoption motivation across all user types, varying by role.

H3c: Governance quality mediates sustainability-adoption relationships, stronger for decision-making roles.

1.6. Research Scope and Limitations

Industry and Geography Focusing on commercial and institutional waste generators such as shopping malls, lodging facilities, financial institutions, and apartment buildings, the Jakarta metropolitan area is Indonesia's most technologically advanced urban center with the highest

concentration of waste management firms and sufficient technology infrastructure for platform deployment and comprehensive governance implementation.

On the other hand the scope of technology development includes a thorough web application architecture that uses Next.js 15 with TypeScript implementation, Laravel 10 with PHP 8.2 for backend services, PostgreSQL 17 with TimescaleDB extensions for optimizing environmental data, and COBIT 2019 governance framework integration for environmental management platforms that guarantee security, compliance, and scalability.

Framework of Time and Theory: Utilizing integrated TAM-UTAUT frameworks enhanced with COBIT governance principles, Indonesian cultural dimensions, and sustainable development theory considerations, the 2020–2025 period covers recent developments in environmental technology adoption, regulatory changes impacting Indonesian waste management, and the emergence of sustainable development frameworks during accelerated digital transformation.

Methodological limitations include: framework-specific limitations affecting platform performance under extreme conditions; infrastructure limitations, such as variable internet connectivity and diverse device capabilities; budgetary constraints limiting extensive third-party integration evaluation with government systems and international carbon registries; and geographic focus, which may limit generalizability to rural areas with different technological capabilities.

1.7. Significance of Study

While incorporating sustainable development frameworks, advanced technology architecture principles, and comprehensive governance frameworks—all crucial for advancing sustainability digitalization in Indonesia and other emerging economies that are witnessing rapid growth in the adoption of carbon management platforms and the implementation of governance frameworks—this research fills important knowledge gaps regarding the adoption of environmental technologies in developing country contexts.

The contributions of software engineering and technology development include: comprehensive governance integration, performance optimization strategies for Indonesian infrastructure conditions, user interface design principles for multi-stakeholder environmental applications, and empirical analysis of environmental management platform architecture requirements enhanced by COBIT governance framework implementation. These advancements increase knowledge of current web development approaches for complex environmental data processing, and while guaranteeing security, compliance, and stakeholder trust.

Also, the integration of TAM-UTAUT frameworks with COBIT governance principles, cultural aspects unique to Indonesian contexts, in considerations of sustainable development theory, and technology architecture features that impact adoption decisions in environmental management contexts are one of the examples of theoretic advancement and academic contributions. This will extend technology acceptance theory to environmental compliance scenarios where adoption motivations include corporate social responsibility commitments, including regulatory requirements, and sustainable development objectives, and

Relevance in Practice and Use in Industry: contributions from the environmental services sector that address pressing issues in Indonesia's environmental services sector, whereas the adoption of technology bolstered by thorough governance frameworks could significantly improve the accuracy of carbon calculations, the ability to comply with regulations, the quality of environmental impact reporting, the development of stakeholder trust, and the contribution to national and international sustainable development goals.

On the other hand Regulatory Implications and Policy Development: Contributions to policy development that address supportive regulatory frameworks that promote the adoption of environmental technologies while upholding data security, privacy protection, system interoperability standards, and comprehensive governance implementation all crucial for stakeholder trust and regulatory compliance offer empirical support to legislators creating laws governing environmental technology and incentives for digital transformation.

Global Environmental Technology Development Impact: In order to support global environmental objectives through locally appropriate approaches that respect cultural values and foster international cooperation, a thorough analysis of platform architecture requirements, governance framework integration, user acceptance factors, and implementation challenges unique to developing country contexts can be used to inform international environmental technology transfer, capacity building initiatives, and governance framework adoption.

1.8. Thesis Structure

This thesis is organized into five chapters that systematically examine the CarbTrade platform's technology architecture and user acceptance within Indonesian waste management contexts.

Chapter 1 establishes the research foundation by presenting Indonesia's waste management crisis and the need for digital transformation solutions. It outlines research objectives, questions, hypotheses, scope, and limitations while highlighting gaps in current literature regarding environmental platform adoption in developing countries.

Chapter 2 provides a comprehensive literature review synthesizing key theoretical frameworks including Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Digital Platform Economics Theory, COBIT 2019 governance framework, Cultural Adoption Theory, and Environmental Technology Adoption models. The chapter examines Jangjo Technology Indonesia's operational context and establishes the conceptual foundation for hypothesis development.

Chapter 3 presents the integrated research methodology combining quantitative survey analysis with qualitative focus group discussions and technology development documentation. It details the Agile SDLC implementation with COBIT governance integration, four-tier user category analysis, questionnaire development, sampling strategies, and statistical analysis frameworks using SPSS and AMOS.

Chapter 4 analyzes empirical findings from 48 respondents across 15 Indonesian waste management companies through comprehensive statistical analysis including structural equation

modeling. The chapter presents hypothesis testing results revealing the significant influence of performance expectancy, governance quality, and waste management hierarchy on adoption intentions, complemented by expert feedback analysis.

Chapter 5 synthesizes research findings within environmental technology adoption theory, discussing theoretical contributions, practical implementation recommendations, and governance framework integration insights. The chapter acknowledges research limitations and proposes future research directions for advancing environmental platform adoption understanding in developing countries.

