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RESEARCH ARTICLE

Digital Transformation, Government Incentives, and Circular Performance in the E-Waste Sector: A Sri Lankan Study

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Abstract

Digital transformation is widely promoted as a catalyst for circular economy transitions; however, empirical evidence regarding whether digitalisation generates measurable circular performance gains in the e-waste sector remains limited. Drawing on socio-technical systems (STS) theory, this study examines how organisational digital enablers drive digital transformation and under what institutional conditions such transformation translates into circular performance. Survey data collected from 279 employees in Sri Lanka's e-waste sector were analysed using covariance-based structural equation modelling (CB-SEM), moderation analysis, and bootstrapped moderated mediation procedures. The findings indicate that digital resources and digital leadership significantly enable digital transformation. More importantly, digital transformation does not directly affect circular performance. Instead, its effectiveness depends on government incentives, indicating that institutional support functions as a critical boundary condition shaping the performance implications of digitalisation. These findings challenge technology-deterministic assumptions within circular economy and digital transformation literature by positioning digital transformation as a policy-contingent socio-technical capability rather than an inherently performance-enhancing intervention. The study advances STS theory by demonstrating that internally developed digital capabilities require enabling institutional conditions before they can translate into measurable circular outcomes. Practical implications are provided for managers and policymakers designing digitally enabled circular transformation strategies.

Keywords Digital Transformation · Circular Performance · E-waste Sector · Organisation-level · Government Incentives

1. Introduction

The Circular Economy (CE) has emerged as a central paradigm in addressing resource depletion, waste accumulation, and environmental degradation (Liu et al., 2024; Rashid et al., 2024; Cotrina-Teatino & Marquina-Araujo, 2025). Moving beyond the linear "take–make–dispose" model, CE emphasises resource efficiency, lifecycle extension, and regenerative production systems (Clube & Tennant, 2022; Erdiaw-Kwasie et al., 2023). In the waste sector, these principles are increasingly operationalised through advanced recovery, reuse, and recycling practices, often enabled by digital technologies that improve traceability, coordination, and process efficiency (Pan et al., 2022; Haq et al., 2024). Digital transformation (DT) has therefore been

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widely positioned as a key driver of circular performance (CP)[3], enabling organisations to optimise material flows, enhance compliance, and improve environmental outcomes (Goel et al., 2024; Khan & Sayem, 2025). However, despite strong theoretical expectations, empirical evidence on whether DT consistently delivers measurable improvements in CP remains limited and inconclusive (Frank et al., 2019; Lin et al., 2024). This raises a critical but underexplored question: is DT inherently performance-enhancing, or is its effectiveness contingent on broader socio-technical and institutional conditions? This question is not confined to the e-waste sector but extends to digitally enabled sustainability transitions more broadly in the global context.

The need to address this question is particularly evident in the e-waste sector, which represents a highly complex socio-technical system characterised by fragmented value chains, the coexistence of formal and informal actors, heterogeneous capabilities, and uneven technological adoption (Sengupta et al., 2022; Mehra et al., 2023; Schneider et al., 2024). While prior research has examined digital technologies and circular outcomes, these elements are often treated in isolation, with limited integration into a coherent performance-oriented framework (Okorie et al., 2022; Banihashemi et al., 2023; Wankhede et al., 2025). More importantly, the institutional conditions under which digital capabilities translate into circular outcomes remain under-theorised. Government incentives such as financial support, regulatory frameworks, and institutional capacity-building are widely recognised as essential for effective e-waste governance, yet their role in shaping the DT–CP relationship has received limited empirical attention, particularly in developing economies characterised by institutional fragmentation and regulatory variability (Munni et al., 2024; Mohammed & Kaida, 2024; Peng et al., 2025; Singh et al., 2025). To address these gaps, this study draws on socio-technical systems (STS) theory to develop and test an integrated framework linking organisational digital enablers, DT, and CP under varying institutional conditions. STS theory conceptualises organisational outcomes as emerging from the alignment of social and technical subsystems embedded within broader institutional environments (Aulia & Lin, 2024). Building on this perspective, the study examines not only how organisational capabilities drive DT, but also whether DT translates into CP in the presence or absence of enabling policy conditions, contributing to existing literature (Neri et al., 2024; Olawade et al., 2024; Prashar & Chaudhuri, 2024; Wang et al., 2025; Pu & Bai, 2026).

The study is guided by three research questions: RQ1: To what extent do social and technical subsystems influence DT in the e-waste sector (H1-H4)? RQ2: To what extent does DT influence CP (H5)? RQ3: To what extent do government incentives condition the relationship between DT and CP (H6)? Importantly, this study departs from the prevailing assumption that DT directly improves performance outcomes (Du et al., 2024; Zheng et al., 2025). Instead, it conceptualises DT as a latent socio-technical capability, whose value does not automatically translate into CP. Building on this insight, this contribution extends STS theory in two important ways, thought-provoking the recent literature (Ghosh et al., 2025; Van Ta & Hoang, 2025; Yang et al., 2025). First, it moves beyond the traditional focus on internal socio-technical alignment by demonstrating that such alignment is necessary but insufficient for performance gains. Second, it introduces institutional activation as a critical mechanism through which digital capabilities are translated into organisational outcomes. As a result, DT is reframed not as a deterministic driver of performance, but as a contingent capability, whose effectiveness depends on alignment with external policy structures. Importantly, this mechanism is generalisable beyond the e-waste sector and the Sri Lankan context, offering broader implications for digitally enabled sustainability transitions in institutionally complex environments.

The remainder of the paper is structured as follows. Section 2 develops the theoretical framework and hypotheses. Section 3 outlines the research design and methodology. Section 4 presents the empirical results. Section 5 discusses the findings and their implications. Section 6 concludes with limitations and directions for future research.

[3] CP captures the degree to which organisations improve resource efficiency, minimise waste, and foster innovation in production and consumption systems (Ferrante et al., 2025)

2. Literature Review

2.1. Socio-Technical Systems Theory

Socio-technical systems (STS) theory provides a valuable lens for examining how organisational outcomes emerge from the alignment of technological, social, and institutional elements. At its core, STS theory argues that organisational performance cannot be explained by technological capability alone; rather, outcomes depend on the joint optimisation of technical systems, human capabilities, organisational arrangements, and broader institutional structures (Emery & Trist, 1972; Trist, 1981; Yu et al., 2022; Thomas, 2024). Accordingly, technological interventions that are not aligned with social and institutional conditions may fail to generate expected performance improvements. This perspective is particularly relevant in the context of DT, where organisations increasingly rely on digital technologies to restructure operations, decision-making processes, and value creation mechanisms (Ghosh et al., 2025; Yang et al., 2025). While digital technologies enhance traceability, coordination, and information processing, STS scholarship consistently cautions that DT initiatives often underperform when technological investments are not supported by complementary organisational capabilities, workforce readiness, leadership alignment, and institutional support mechanisms (Bayramova et al., 2023). In this sense, DT should not be viewed as an inherently performance-enhancing intervention, but as a socio-technical capability whose effectiveness depends on system-wide alignment.

These dynamics are especially pronounced in the e-waste sector, which represents a highly fragmented socio-technical environment characterised by uneven technological adoption, weak regulatory enforcement, informal operational structures, and heterogeneous workforce capabilities (Sengupta et al., 2022; Schneider et al., 2024). In many developing economies, advanced recovery technologies coexist with labour-intensive informal practices and limited institutional coordination, constraining organisations' ability to convert technological investments into sustained circular outcomes (Naik & Eswari, 2022). As a result, digital systems may improve information visibility or operational monitoring without necessarily enhancing CP. From an STS perspective, improving CP therefore requires more than the deployment of digital technologies alone. It requires alignment between organisational capabilities, digital infrastructures, operational practices, and enabling institutional conditions. Importantly, STS theory recognises that institutional mechanisms, including regulations, policy frameworks, and government incentives, shape the feasibility and economic viability of socio-technical alignment (Molleman & Broekhuis, 2001; Thomas, 2024). This suggests that the performance effects of DT may depend not only on internal organisational readiness, but also on external policy support that reduces implementation barriers and incentivises circular practices. Building on this logic, the present study conceptualises DT as a socio-technical capability whose performance effects are contingent on institutional activation. Rather than assuming a direct relationship between DT and CP, the study argues that digital capabilities generate measurable circular outcomes only when supported by enabling government incentives. STS theory, therefore, provides the theoretical foundation for explaining why DT may fail to improve CP in the absence of supportive institutional conditions.

2.2. Theoretical Framework

Building on STS theory, this study develops a framework that links organisational digital enablers, DT, and CP across varying institutional conditions. The framework is grounded in the central STS assumption that organisational outcomes emerge through the alignment of social, technical, and institutional subsystems rather than through technological deployment alone. Within this framework, digital resources represent the technical subsystem by capturing the technological infrastructures and digital capabilities required to support transformation initiatives. Digital leadership, employee engagement, and task–technology fit represent the social subsystem by reflecting organisational coordination, behavioural readiness, and the alignment between technologies and operational activities. Government incentives represent the institutional subsystem by shaping the external conditions under which DT becomes economically and operationally viable. Recent studies increasingly recognise that the relationship between digitalisation and sustainability performance is conditional rather than deterministic (Khan et al., 2025; Alshibani et al., 2026; Duong, 2026; Mansouri et al., 2026). Existing evidence suggests that digital technologies contribute to circular and environmental outcomes only when supported by complementary organisational structures, integration capabilities, and enabling conditions. Misalignment between technological systems, organisational processes, and institutional environments can weaken or even negate expected sustainability gains (Duong, 2026). These findings are particularly relevant in the e-waste sector, where fragmented operations and institutional variability constrain the implementation of digitally enabled circular practices.

Accordingly, this study advances a policy-contingent view of DT. Specifically, DT is conceptualised as an intermediate socio-technical capability linking organisational enablers to CP, while government incentives serve as an institutional activation mechanism that determines whether digital capabilities translate into measurable circular outcomes. In this sense, government incentives do not merely support digital adoption; they determine the extent to which DT generates operational improvements associated with CP. Circular performance in this study reflects observable operational outcomes associated with circularity, including improved material recovery, reduced hazardous handling, enhanced resource efficiency, and strengthened environmental compliance. While CP has traditionally been examined using organisation-level indicators, recent studies increasingly rely on employee-level assessments of operational circular practices, particularly in contexts where standardised performance metrics are inconsistent or unavailable (Le et al., 2022; Kampoowale et al., 2025; Kankanamge et al., 2026). In the e-waste sector, employees are directly involved in recovery, sorting, dismantling, and compliance activities, making them well-positioned to assess operational manifestations of CP. The resulting framework therefore integrates organisational capabilities, behavioural mechanisms, DT, and institutional conditions to explain how socio-technical alignment generates circular outcomes in institutionally complex environments, particularly in developing economies (refer to Figure 1).

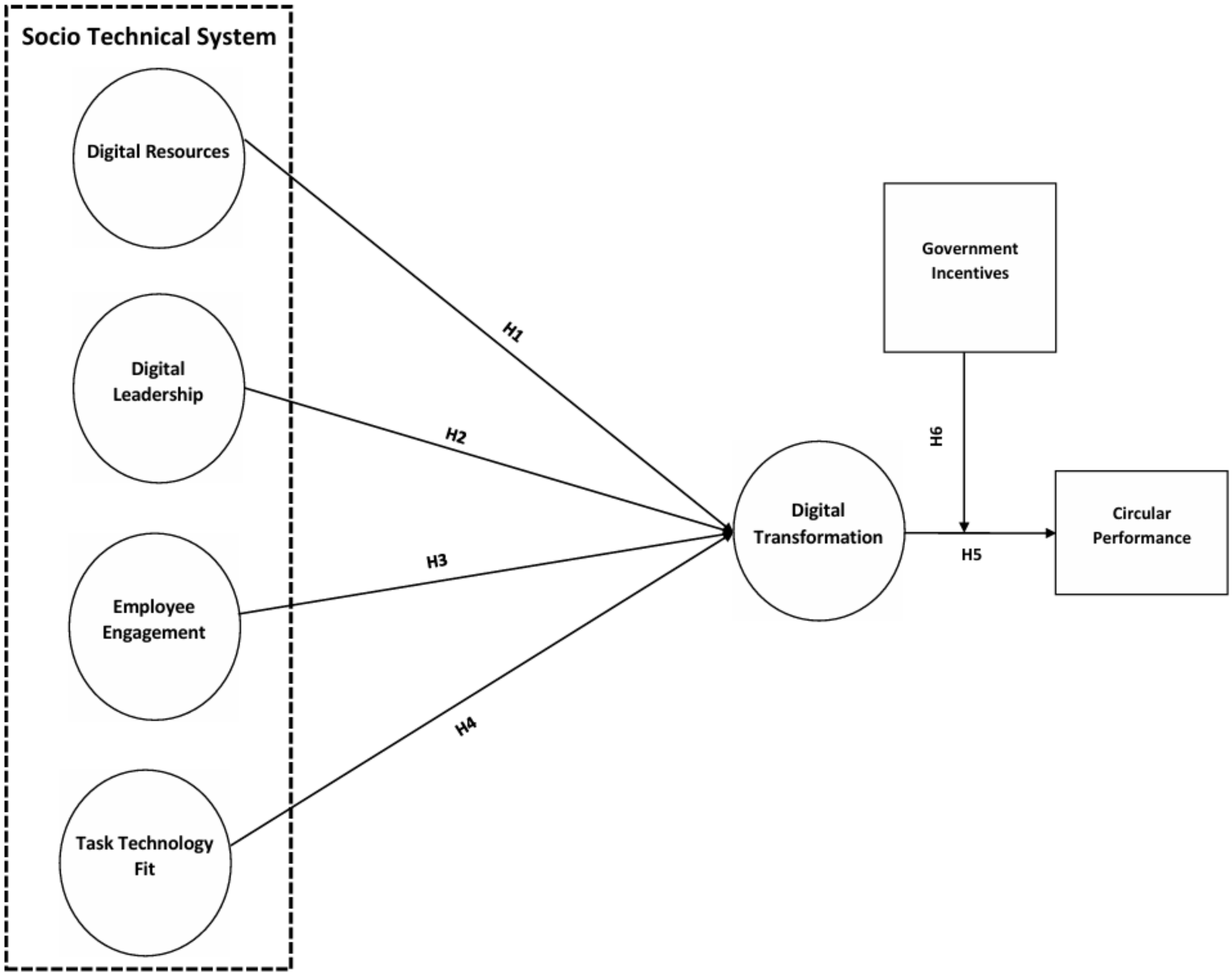

Figure 1. Theoretical Framework

2.3. Hypothesis Development

In line with the study's research questions, the following hypotheses are developed to empirically test the proposed relationships.

2.3.1. Digital Resources and Digital Transformation Digital resources represent the foundational technological infrastructure supporting DT. These resources include hardware systems, digital platforms, data management capabilities, and traceability technologies that enable organisations to integrate information flows and coordinate operational activities (Piccoli et al., 2022, 2024). Within STS theory, digital resources form part of the technical subsystem whose effectiveness depends on their integration with organisational processes and broader socio-technical arrangements. In the e-waste sector, digital resources facilitate material tracking, compliance monitoring, and coordination across fragmented value chains (Kang et al., 2020). Prior research suggests that digital infrastructures improve organisational capacity to manage dispersed actors, increase transparency, and support circular resource management practices (Khan & Ahmad, 2022; Kankanamge et al., 2026). However, digital resources remain unevenly distributed across organisations in developing-country e-waste systems, limiting organisations' capacity to formalise operational processes and implement digitally enabled recovery systems. In such contexts, access to digital infrastructure becomes a critical prerequisite for transformation initiatives. From an STS perspective, digital resources enable organisations to establish the technical foundations necessary for DT by supporting information integration and system visibility. Accordingly, organisations with stronger digital resource capacity are expected to demonstrate greater progress in DT initiatives.

- H1: Digital resources positively influence digital transformation.

2.3.2. Digital Leadership and Digital Transformation STS theory emphasises that technological systems require complementary social coordination mechanisms to generate organisational change. Within this context, digital leadership reflects the ability of organisational leaders to align digital technologies with organisational goals, workforce capabilities, and operational processes (Benitez et al., 2022; Khawaja & Hamdan, 2023). Prior research suggests that DT depends not only on technological sophistication but also on leadership capacity to guide organisational adaptation, coordinate stakeholders, and foster digital readiness (Cheng et al., 2025). These dynamics are particularly relevant in the e-waste sector, where fragmented operational structures and uneven technological maturity increase the need for strategic coordination. Digital traceability systems, monitoring platforms, and blockchain-enabled governance mechanisms require leadership commitment to ensure organisational integration and workforce alignment (Goyal & Gupta, 2024). In developing economies, where digital initiatives are often centralised and resource-constrained, leadership becomes especially important in overcoming organisational resistance and coordinating socio-technical change. From an STS perspective, digital leadership strengthens the social subsystem underpinning technology transformation processes by facilitating organisational alignment between technologies, operational practices, and strategic objectives. Accordingly, stronger digital leadership is expected to enhance organisations' ability to implement DT initiatives effectively.

- H2: Digital leadership positively influences digital transformation.

2.3.3. Employee Engagement and Digital Transformation STS theory conceptualises employees as active participants within socio-technical systems rather than passive recipients of technological change. Employee engagement reflects the extent to which employees are cognitively, emotionally, and behaviourally involved in organisational activities and transformation processes. In DT contexts, engaged employees are more likely to adopt new technologies, participate in organisational learning, and integrate digital systems into operational routines (Thomas, 2024). In the e-waste sector, these dynamics are particularly important given the labour-intensive nature of operations such as collection, sorting, dismantling, and recovery. Prior studies suggest that low workforce awareness, limited technological exposure, and weak organisational engagement can constrain technology adoption and operational improvement within informal and semi-formal waste systems (Sengupta et al., 2022). Conversely, engaged employees may facilitate transformation by supporting digital integration, knowledge-sharing, and adaptive operational practices (Ferreira et al., 2023). From an STS perspective, employee engagement strengthens the social subsystem by supporting interaction between human actors and digital technologies. Accordingly, higher levels of employee engagement are expected to contribute positively to technology transformation initiatives in organisations.

- H3: Employee engagement positively influences digital transformation.

2.3.4. Task–Technology Fit and Digital Transformation Task–Technology Fit (TTF) theory suggests that technologies are more effective when their functionalities align with task requirements (Goodhue & Thompson, 1995). In DT contexts, technologies frequently underperform when digital systems are poorly aligned with operational realities and workflow requirements (Yuce et al., 2019). Although TTF primarily focuses on task–technology alignment, it complements STS theory by explaining how technical systems interact with operational processes within broader socio-technical environments. In the e-waste sector, operational activities such as material collection, dismantling, compliance reporting, and recovery coordination vary across organisations. Technologies that support real-time monitoring, digital documentation, and traceability may improve coordination only when they adequately align with operational requirements (Bhadra & Mishra, 2021; Sudhakar et al., 2024). Misalignment between technological systems and operational tasks may instead constrain implementation and reduce the effectiveness of DT initiatives. Accordingly, from an STS perspective, task–technology alignment supports DT by improving the compatibility between operational activities and digital systems.

- H4: Task–technology fit positively influences digital transformation.

2.3.5. Digital Transformation and Circular Performance Digital transformation has frequently been positioned as a mechanism for improving circular economy outcomes through enhanced traceability, operational monitoring, and resource optimisation (Moller, 2020; Matarneh et al., 2024). Digital technologies may support lifecycle management, material recovery, and compliance visibility, thereby creating conditions conducive to CP improvements. In the e-waste sector, digital systems such as traceability platforms and data-driven monitoring tools may strengthen recovery efficiency and formalise operational processes (Garrido-Hidalgo et al., 2019). However, STS theory suggests that the performance effects of DT are not automatic. Technological deployment alone may not generate meaningful organisational outcomes when digital systems are not aligned with broader organisational and institutional conditions. Prior research also highlights that digitalisation may generate unintended consequences, including implementation costs, operational disruption, and increased resource consumption, potentially weakening sustainability outcomes when broader system alignment is absent (Kunkel & Tyfield, 2021; Serrano et al., 2025). Accordingly, this study conceptualises DT as a socio-technical capability whose performance implications depend on broader organisational and institutional alignment. While DT may provide the technological and informational foundation associated with circular operational practices, the extent to which these capabilities translate into measurable CP is expected to remain contingent on enabling institutional conditions. Nevertheless, a positive association between DT and CP remains theoretically plausible.

- H5: Digital transformation is positively associated with the circular performance.

2.3.6. Government Incentives as a Moderator STS theory emphasises that socio-technical systems are embedded within broader institutional environments that shape organisational outcomes. Government incentives, including subsidies, tax benefits, regulatory support, and institutional assistance, can reduce implementation barriers associated with DT and encourage organisations to adopt digitally enabled circular practices (Lv et al., 2022; Rashid & Kausik, 2024). In the e-waste sector, where organisations frequently operate under financial constraints and fragmented regulatory frameworks, institutional support may be critical in determining whether DT yields measurable CP. Government incentives may reduce implementation risk, enhance compliance capacity, and encourage organisations to align digital investments with circular-economy objectives (Bhatia et al., 2024). Without such support, digital initiatives may remain compliance-oriented, failing to produce substantive improvements in CP. Building on STS theory, this study therefore conceptualises government incentives as an institutional activation mechanism that conditions the extent to which DT translates into CP. In this sense, DT is expected to become more effective under stronger policy support conditions.

- H6: Government incentives positively moderate the relationship between digital transformation and circular performance.

3. Methodology

3.1. Research Design and Instrument Development

This study adopts a quantitative cross-sectional research design (refer to Figure 2) to examine the relationships among organisational digital enablers, DT, government incentives, and CP in the Sri Lankan e-waste sector. A survey-based approach was selected because it enables systematic examination of latent organisational constructs and their interrelationships using structured empirical data, consistent with prior research in DT and sustainability studies (Verma et al., 2025). The research instrument was developed based on the study's theoretical framework and consisted of two sections (refer to Appendix 1). The first section captured demographic and occupational characteristics of respondents, while the second measured the latent constructs included in the conceptual model: Digital Resources (DR), Digital Leadership (DL), Employee Engagement (EE), Task–Technology Fit (TTF), DT, Government Incentives (GI), and CP. All constructs were operationalised using established multi-item scales measured on a five-point Likert scale ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"). Prior to data collection, the questionnaire was reviewed to ensure clarity and appropriateness for participants in the e-waste sector.

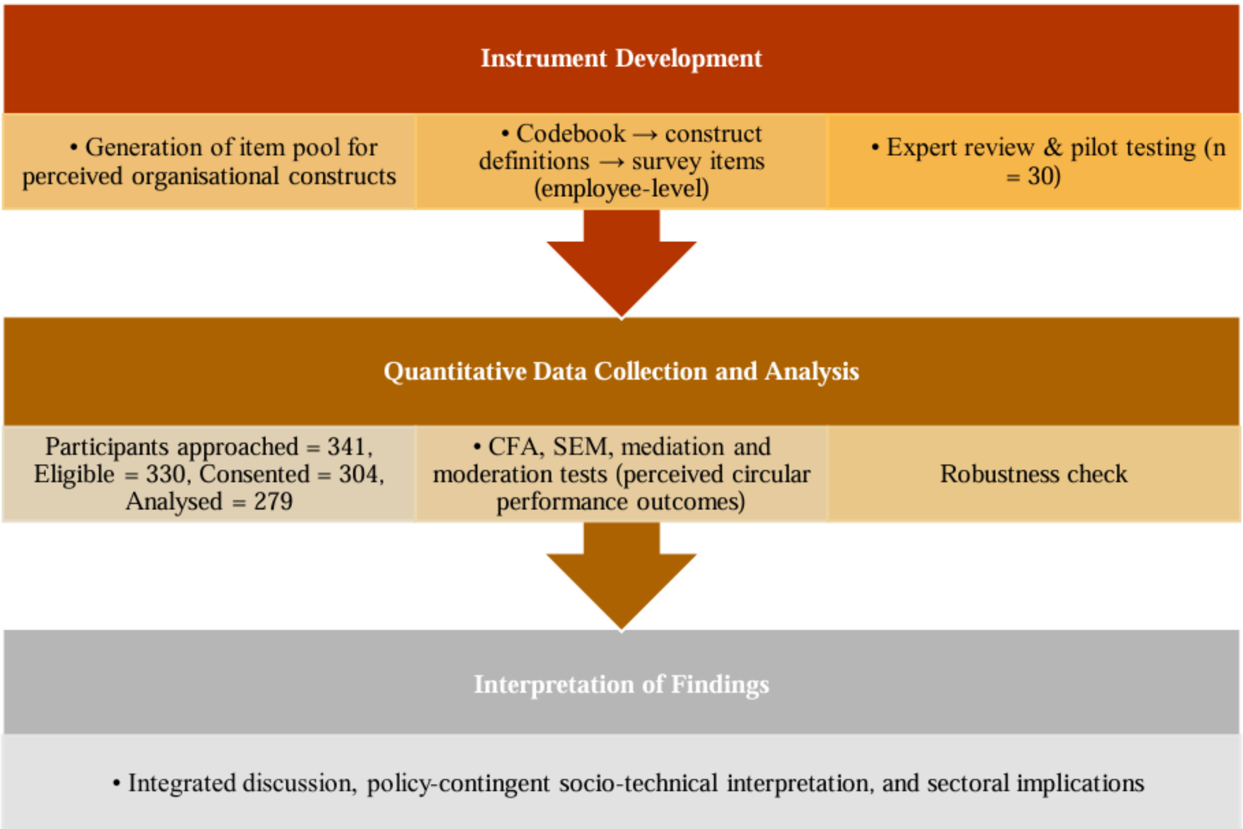

Figure 2. Research Design

3.2. Study Context, Sampling, and Data Collection

The Sri Lankan e-waste sector provides an analytically relevant setting for examining digitally enabled circular transitions under institutionally constrained conditions. The sector is characterised by fragmented supply chains, uneven technological adoption, limited coordination, and the coexistence of formal and informal operational structures (Ranasinghe & Athapattu, 2019; Widanapathirana et al., 2023; Kankanamge et al., 2025a). Although Sri Lanka has introduced regulatory initiatives and policy mechanisms to strengthen e-waste governance, technology adoption remains inconsistent across organisations due to organisational, financial, and institutional constraints (Tripathy et al., 2022; Kankanamge et al., 2025b). These conditions make the sector particularly suitable for examining whether DT translates into CP only under enabling institutional conditions. Importantly, many e-waste organisations operate with limited managerial formalisation and rely heavily on operational activities such as collection, dismantling, sorting, and material recovery. As a result, employees and supervisors are directly involved in operational practices associated with CP, including material recovery efficiency, reduced hazardous handling, and compliance-related activities (Kankanamge et al., 2025b; Kankanamge et al., 2026). In this context, employee-level assessments provide operationally grounded insights into observable circular practices, particularly where standardised organisation-level CP indicators are limited or inconsistently recorded. Accordingly, the use of perceptual CP measures is considered contextually appropriate for capturing transitional circular operational outcomes within the sector, in line with the previous studies (Amin et al., 2025; Masudin et al., 2026).

Data were collected from employees working across collection, dismantling, recycling, and recovery activities in Sri Lanka's e-waste sector. A cross-sectional survey design was employed to capture relationships among constructs at a single point in time. Data collection was conducted between December 2024 and March 2025 following ethics approval from the Human Research Ethics Committee of Charles Darwin University. Participation was voluntary, and informed consent was obtained from all respondents. A mixed sampling strategy combining purposive sampling and industry referrals was used to recruit participants with relevant sectoral knowledge and operational experience. First, online surveys were distributed via email to business owners and managers identified through the Central Environmental Authority (CEA) database and previous industry engagement activities. Participants were asked to circulate the survey among eligible employees. Second, in-person survey administration was conducted to improve participation among less formalised organisations where digital survey participation was limited. Respondents were required to have at least 1 year of experience in e-waste operations and familiarity with technology-related processes in the sector. A total of 341 employees from 121 organisations were invited to participate. Of these, 304 responses were received from 106 organisations, representing a response rate of 89%. Following data screening, 25 incomplete responses were removed, resulting in 279 valid responses for analysis. Because respondents were recruited through organisational referrals and industry networks, multiple participants originated from the same organisation. However, organisation identifiers were not collected in order to preserve anonymity and encourage participation, particularly among less formalised sector participants. Consequently, clustering effects could not be modelled statistically. This limitation should be considered when interpreting the findings, as within-organisation response dependence may reduce estimation precision. Nevertheless, the study incorporates several robustness procedures to strengthen inference and reduce threats to validity.

3.3. Data Preparation, Screening, and Measurement Model Assessment

Prior to estimation, the dataset was screened for missing data, incomplete responses, and distributional suitability. Cases containing no substantive information across study variables were removed. The remaining missing observations were handled using Full Information Maximum Likelihood (FIML), which is appropriate under missing-at-random assumptions and widely recommended for covariance-based structural equation modelling (CB-SEM). Construct-level descriptive statistics, including mean, median, standard deviation, skewness, and kurtosis, were examined to assess variability and distributional characteristics. The results indicated acceptable variability and no substantial deviations from normality, supporting the suitability of SEM estimation and bootstrapped inference procedures.

A Confirmatory Factor Analysis (CFA) was conducted to evaluate the psychometric adequacy of the measurement model prior to hypothesis testing. All constructs were specified as reflective latent variables, with indicators loading only on their intended constructs. Model estimation employed the robust maximum likelihood estimator (MLR), and model fit was assessed using χ^2, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Square Residual (SRMR), consistent with established SEM reporting standards. Reliability was assessed using Cronbach's alpha and composite reliability (CR). Convergent validity was evaluated using Average Variance Extracted (AVE), while discriminant validity was assessed using the HTMT. HTMT values below the conservative threshold of 0.85 indicated satisfactory construct distinctiveness. Given the use of self-reported cross-sectional survey data, several procedures were implemented to reduce potential common-method bias (CMB). First, construct items were adapted from established scales and reviewed for contextual clarity to reduce ambiguity. Second, respondents were assured anonymity and confidentiality to minimise evaluation apprehension and socially desirable responses. Third, discriminant validity was assessed using HTMT, which indicated strong construct separation, reducing concerns about substantial common-method contamination.

3.4. Structural Model Estimation and Robustness Checks

Following measurement validation, the structural model was estimated using CB-SEM to examine the hypothesised relationships among constructs. Standardised path coefficients, robust standard errors, z-statistics, and p-values were reported for all structural paths. Model fit was again assessed using χ^2, CFI, TLI, RMSEA, and SRMR. To examine the study's central proposition that government incentives condition the DT–CP relationship, moderation analysis was conducted using a composite-score interaction approach as a robustness procedure complementing the latent SEM estimation. Construct composites were mean-centred prior to calculating the DT × GI interaction term. Heteroskedasticity-consistent HC3 robust standard errors were used to improve robustness. Nested model comparison was used to assess whether including the interaction term significantly improved the model's explanatory power. The moderation effect was further examined using simple slope analysis at low (−1 SD), mean, and high (+1 SD) levels of government incentives. In addition, a second-stage moderated mediation analysis was conducted using the Index of Moderated Mediation (IMM). Bias-corrected and accelerated (BCa) bootstrapping with 5,000 resamples was employed to estimate confidence intervals for conditional indirect effects and IMM estimates. Several additional robustness procedures were undertaken to strengthen confidence in the findings. Dominance analysis using the Lindeman–Merenda–Gold (LMG) metric was conducted to compare the relative explanatory contribution of DT, GI, and the DT × GI interaction in predicting CP. Collectively, these procedures enhanced the robustness of the analysis and supported examination of the conditional nature of the DT–CP relationship. In addition, Harman's single-factor test and a single-factor CFA model comparison were conducted as post hoc diagnostic procedures to assess potential common method bias (CMB).

4. Results

4.1. Demographic Profile

Table 1 summarises the demographic characteristics of the study respondents by age, education, gender, occupational role, and geographic location. The sample was drawn primarily from urban and semi-urban areas, with 55.6% of respondents residing in urban locations, 38.7% in semi-urban areas, and only 5.7% in rural areas. This distribution reflects the concentration of e-waste activities within urban and peri-urban centres in Sri Lanka. The gender composition indicates a highly male-dominated workforce, with male respondents accounting for 88.9% of the sample. Educational attainment across the sector remains relatively limited. Most respondents reported secondary education (56.3%), while 19% possessed only primary education. Vocational qualifications accounted for 18.3% of the sample, indicating the presence of skills-based technical training within the sector. Only 6.4% of respondents possessed bachelor's degrees, all of whom were employed within formal-sector organisations and concentrated largely in managerial positions. In contrast, frontline operational roles were predominantly occupied by workers without tertiary education. Regarding occupational roles, supervisors and operational workers accounted for the largest category (60.6%), followed by business owners (28.3%) and managers (11.1%). This distribution reflects the labour-intensive and operationally driven nature of the e-waste sector in Sri Lanka. Collectively, the demographic profile highlights the socio-structural characteristics of Sri Lanka's e-waste industry, which is characterised by operationally intensive activities, limited formal education, and relatively low managerial formalisation.

Table 1. Demographic profile of the Study Participants

Variable	Groups	Proportion	Count
Age Group	18-25	7.9%	22
	26-35	37.3%	104
	36-45	25.5%	72
	46-60	29%	81
Education Level	Primary education	19%	53
	Secondary education	56.3%	157
	Vocational Qualification	18.3%	51
	Bachelors Degree	6.4%	18
Gender	Female	11.1%	31
	Male	88.9%	248
Designation	Owner	28.3%	79
	Manager	11.1%	31
	Supervisor/worker	60.6%	169
Geographical location	Urban	55.6%	155
	Semi urban	38.7%	108
	Rural	5.7%	16

4.2. Measurement Model Assessment

Table 2 presents the descriptive statistics for the study constructs based on composite scores. DR, DL, DT, EE, and TTF exhibit relatively high mean values, suggesting that respondents generally perceive strong internal digital and organisational capabilities within e-waste sector organisations. In contrast, GI and CP display comparatively lower mean values and greater variability, indicating heterogeneity in institutional support and circular operational outcomes across organisations. Standard deviations across constructs indicate sufficient variability for multivariate analysis. Furthermore, skewness and kurtosis values remain within acceptable thresholds, indicating no substantial deviations from normality and supporting the suitability of CB-SEM estimation and bootstrapped inference procedures.

Table 2. Descriptive Statistics

Construct	Mean	Median	SD	Skewness	Kurtosis
DR	4.68	4.8	0.41	−1.04	−0.36
DL	4.66	4.75	0.43	−1.02	−0.35
EE	4.27	4	0.52	−0.12	0.07
TTF	3.98	4	0.51	−0.36	0.55
DT	4.66	5	0.44	−1.05	−0.09
GI	2.99	3	0.71	−0.26	−0.03
CP	2.97	3	0.78	0.05	−0.34

Prior to hypothesis testing, confirmatory factor analysis (CFA) was conducted to assess the adequacy of the measurement model. The results indicate an excellent model fit ($\chi^2 = 354.92$, df = 329, $p = 0.156$; CFI = 0.993; TLI = 0.992; RMSEA = 0.017; SRMR = 0.037). All standardised factor loadings are statistically significant and exceed recommended thresholds.

As shown in Table 3, internal consistency reliability was well established, with Cronbach's alpha values ranging from 0.808 to 0.905 and CR values ranging from 0.812 to 0.905. Convergent validity was supported, as all AVE values exceeded the recommended threshold of 0.50. Collectively, these findings confirm the reliability and convergent validity of the constructs.

Table 3. Reliability and Convergent Validity

Instrument	Instrument Items	Cronbach's Alpha	CR	AVE
DR	5	0.854	0.855	0.544
DL	4	0.830	0.831	0.552
EE	4	0.856	0.858	0.602
TTF	4	0.861	0.86	0.607
DT	3	0.808	0.812	0.589
GI	4	0.885	0.886	0.659
CP	4	0.905	0.905	0.705

Table 4 reports the HTMT values used to assess discriminant validity. All HTMT values remain substantially below the conservative threshold of 0.85, with the highest observed value being 0.521. These findings provide strong evidence of discriminant validity and indicate satisfactory construct distinctiveness across the measurement model.

Table 4. HTMT Matrix

Construct	DR	DL	DT	EE	TTF	GI	CP
DR	—	0.519	0.521	0.158	0.143	0.158	0.07
DL	0.519	—	0.485	0.144	0.14	0.3	0.058
DT	0.521	0.485	—	0.201	0.083	0.106	0.062
EE	0.158	0.144	0.201	—	0.07	0.049	0.077
TTF	0.143	0.14	0.083	0.07	—	0.204	0.107
GI	0.158	0.3	0.106	0.049	0.204	—	0.125
CP	0.07	0.058	0.062	0.077	0.107	0.125	—

4.2.1. Common Method Bias Assessment Given the use of self-reported cross-sectional survey data, additional diagnostic procedures were conducted to assess potential CMB. First, Harman's single-factor test indicated that the first unrotated factor explained only 17.33% of the total variance, substantially below the recommended 50% threshold. This suggests that no single factor accounted for the majority of the covariance among the measurement items. Second, a single-factor CFA model was estimated and compared with the proposed measurement model. The single-factor model demonstrated poor fit to the data ($\chi^2 = 2996.653$, df = 350, $p < 0.001$; CFI = 0.281; TLI = 0.223; RMSEA = 0.165; SRMR = 0.159) relative to the proposed measurement model ($\chi^2 = 354.920$, df = 329, $p = 0.156$; CFI = 0.993; TLI = 0.992; RMSEA = 0.017; SRMR = 0.037). Collectively, these findings provide strong evidence that substantial CMB is unlikely to materially threaten the validity of the study's measurement and structural interferences.

4.3. Structural Model Assessment

Table 5 presents the structural model results. DR has a positive and statistically significant effect on DT ($\beta = 0.371$, $p < 0.001$), supporting H1, while DL also positively influences DT ($\beta = 0.274$, $p < 0.01$), supporting H2. These findings indicate that organisational technological resources and leadership capabilities constitute important socio-technical enablers of DT in the e-waste sector. In contrast, EE ($\beta = 0.084$, $p = 0.217$) and TTF ($\beta = -0.004$, $p = 0.954$) do not exhibit statistically significant effects on DT, leading to the rejection of H3 and H4. This pattern suggests that DT in the current context is primarily driven by organisational-level capabilities rather than by employee-level engagement or task-level alignment mechanisms. Importantly, DT does not exhibit a significant direct association with CP ($\beta = 0.061$, $p = 0.374$), thereby rejecting H5. Rather than weakening the model, this finding supports the study's central theoretical argument that DT alone is insufficient to generate CP improvements. Consistent with the socio-technical systems perspective advanced in this study, the findings suggest that digital capabilities require enabling institutional conditions before they translate into measurable circular outcomes. This proposition is examined further through the moderation and moderated mediation analyses.

Table 5. Hypothesis Testing

Hypothesis	Path	Coefficient (β)	Std. Error	z-Statistic	p-Value	Decision
H1	DR → DT	0.371	0.126	3.623	<0.001	Supported
H2	DL → DT	0.274	0.124	2.723	<0.01	Supported
H3	EE → DT	0.084	0.084	1.234	0.217	Not Supported
H4	TTF → DT	−0.004	0.080	−0.058	0.954	Not Supported
H5	DT → CP	0.061	0.056	0.889	0.374	Not Supported

The structural equation model exhibits an excellent fit to the data ($\chi^2 = 360.89$, df = 335, $p = 0.158$). The structural model demonstrates excellent fit to the data (CFI = 0.993; TLI = 0.992; RMSEA = 0.017; SRMR = 0.043), indicating that the hypothesised structural relationships are well supported by the data.

4.4. Moderation and Moderated Mediation Analysis

To examine the study's central proposition that government incentives condition the effectiveness of DT, moderation and moderated mediation analyses were conducted using HC3 estimation procedures. The mediator model indicates that DR ($\beta = 0.336$, $p < 0.001$) and DL ($\beta = 0.262$, $p < 0.001$) exert strong positive effects on DT, reinforcing their roles as key socio-technical enablers of DT (refer to Table 6). In contrast, EE and TTF remain statistically non-significant. In the baseline outcome model, neither DT nor GI demonstrates a statistically significant direct association with CP. However, once the interaction term is introduced, the DT × GI interaction becomes statistically significant ($\beta = 0.266$, $p < 0.05$). This finding indicates that the performance implications of DT vary systematically across levels of institutional support. Specifically, the results suggest that DT contributes to CP only when supported by sufficiently strong government incentives, consistent with the study's policy-contingent capability activation argument.

Table 6. Moderation and Mediated Path Estimates

Model	Predictor	Coefficient (β)	Std. Error	t-value	p-value
Mediator Model (DT)	DR → DT	0.336	0.079	4.27	<0.001
	DL → DT	0.262	0.073	3.58	<0.001
	EE→ DT	0.079	0.047	1.68	0.093
	TTF→ DT	0.003	0.048	0.07	0.945
Outcome Model (CP)	DT → CP	0.065	0.109	0.60	0.551
	GI → CP	0.118	0.070	1.68	0.093
Moderated Outcome Model	DT → CP	0.096	0.107	0.90	0.368
	GI → CP	0.126	0.070	1.80	0.073
	DT × GI → CP	0.266	0.137	1.94	<0.05

Table 7 presents the results of the Index of Moderated Mediation (IMM). The IMM is statistically significant for DR and DL, indicating that the indirect effects of these organisational capabilities on CP through DT vary systematically across levels of government incentives. In contrast, the IMM is not significant for EE and TTF. Although the conditional indirect effects at specific levels of government incentives are not statistically significant (refer to Appendix 3), the significant IMM values indicate that the magnitude of the indirect effects varies systematically with institutional support conditions. These findings provide evidence of second-stage moderated mediation, reinforcing the argument that government incentives condition the extent to which DT translates organisational capabilities into CP outcomes.

Table 7. Index of Moderated Mediation (IMM)

IMM	Estimate	BCa 95% CI Lower	BCa 95% CI Upper	Significance
IMM_DR	0.089	0.004	0.209	Yes
IMM_DL	0.070	0.002	0.176	Yes
IMM_EE	0.021	−0.002	0.068	No
IMM_TTF	0.001	−0.023	0.033	No

4.5. Robustness Checks

Several robustness checks were undertaken to strengthen confidence in the moderation findings. Nested model comparison indicates that inclusion of the DT × GI interaction term significantly improves model fit ($\Delta F = 3.83$, $p < 0.05$). In addition, multicollinearity diagnostics indicate that variance inflation factors remain well below conventional thresholds. Figure 3 illustrates the moderating effect of government incentives on the DT–CP relationship. The simple slopes analysis demonstrates that the effect of DT on CP is conditional rather than universally positive. At low levels of government incentives (−1 SD), DT shows a negative, non-significant association with CP ($\beta = -0.094$, $p = 0.48$). At average levels of institutional support, the relationship becomes weakly positive but remains statistically insignificant ($\beta = 0.096$, $p = 0.36$). In contrast, under high levels of government incentives (+1 SD), DT demonstrates a substantially stronger positive association with CP ($\beta = 0.286$, $p < 0.1$). Collectively, these findings indicate that DT alone does not inherently improve CP. Rather, digital capabilities generate measurable circular outcomes only when activated by sufficiently strong institutional support mechanisms.

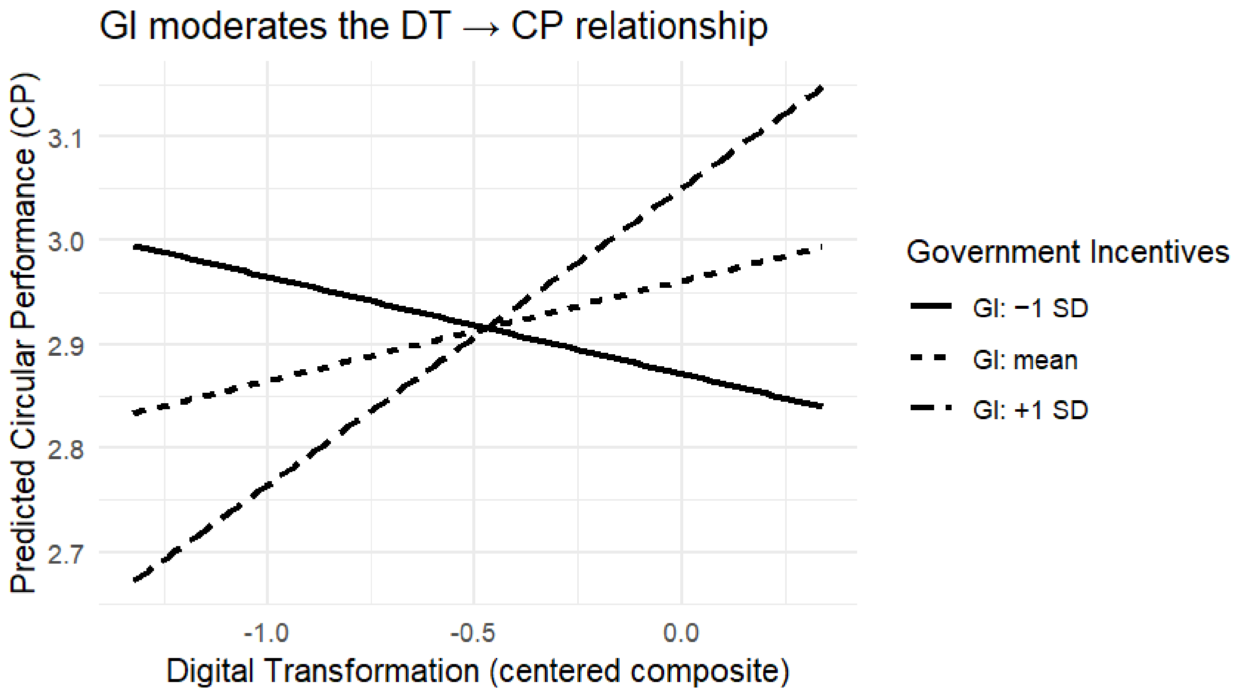

Figure 3. Moderation Effect of Government Incentives

To further assess the relative explanatory contribution of each predictor, dominance analysis using the Lindeman–Merenda–Gold (LMG) metric was conducted. The results indicate that the DT × GI interaction explains the largest proportion of variance in CP (LMG = 0.492), followed by GI as a main effect (LMG = 0.443). In contrast, DT alone accounts for a substantially smaller proportion of explained variance (LMG = 0.065). These findings strongly reinforce the study's central argument that government incentives operate as institutional activation mechanisms rather than merely additive predictors of CP in the Sri Lankan e-waste context. Nevertheless, given the cross-sectional nature of the data, the findings should be interpreted as evidence of systematic associations rather than definitive causal effects.

5. Discussion

This study examined how organisational digital enablers facilitate DT and how DT, in turn, influences CP in the e-waste sector through the lens of STS theory. By explicitly modelling government incentives as a moderating mechanism, the study responds to persistent calls for more context-sensitive explanations of why digital investments generate uneven sustainability outcomes, particularly in institutionally constrained developing-economy settings (Guo et al., 2023; Zhao et al., 2023; Zhang et al., 2025). The findings yield three interrelated insights, with the conditional role of government incentives emerging as the study's central contribution. First, the findings indicate that DT in the e-waste sector is primarily driven by organisational-level enablers, namely DR and DL, rather than by employee-level factors such as EE and TTF. This suggests that the initiation and coordination of DT depend more heavily on organisational capabilities, strategic direction, and access to technological infrastructure than on individual-level behavioural mechanisms. From an STS perspective, this finding reinforces the importance of aligning the technical subsystem (digital infrastructure, platforms, and data systems) with the organisational subsystem (leadership coordination, strategic direction, and decision-making structures) in enabling transformation processes (Yang et al., 2025; Van Ta et al., 2025). While prior information systems research emphasises the importance of employee engagement and task–technology alignment in facilitating transformation (Hernik et al., 2025; Boussaidi & Korbi, 2025; Sun & Yoon, 2025), these mechanisms may become less influential in operationally constrained environments where technology adoption decisions remain highly centralised.

In the Sri Lankan e-waste sector, transformation initiatives are largely determined by owners, managers, and organisational resource availability, while workers primarily execute predefined operational routines. Under such conditions, employee engagement and perceived task–technology alignment may not meaningfully influence transformation decisions, even though they remain theoretically relevant to broader socio-technical functioning. Rather than suggesting that micro-level social mechanisms are unimportant, the findings indicate that their influence may be structurally constrained in contexts characterised by limited organisational decentralisation and operational informality. Accordingly, the study refines STS theory by demonstrating that the relative influence of social subsystem components varies across analytical levels, with meso-level organisational capabilities exerting stronger influence than micro-level behavioural factors in structurally constrained environments. Second, the study demonstrates that DT does not exert a direct effect on CP. This finding challenges the increasingly dominant assumption that digitalisation inherently generates sustainability and circular economy benefits (Yin et al., 2024; Rajpal et al., 2025). Instead, the results indicate that digital technologies alone are insufficient to produce measurable circular outcomes in the absence of enabling institutional conditions. Although DT may improve operational visibility, traceability, monitoring, and information processing, these capabilities do not automatically translate into improvements in resource recovery, waste reduction, or circular operational performance. In institutionally constrained settings, organisations may adopt digital systems primarily for administrative coordination, compliance visibility, or operational efficiency, without fundamentally reconfiguring production and recovery processes to align with circular objectives. This finding is particularly important because it challenges technology-deterministic assumptions embedded within portions of the DT and sustainability literature (Maiurova et al., 2022; Sharma et al., 2024). Consistent with STS theory, the results suggest that organisational outcomes emerge through broader system alignment rather than through technological deployment in isolation. Accordingly, the DT–CP relationship appears to be conditional, non-linear, and institutionally embedded rather than universally positive. This finding strengthens the argument that the CP implications of digitalisation cannot be evaluated independently of the institutional environments within which technologies are implemented.

Third, the findings provide strong evidence that government incentives function as a critical boundary condition shaping the DT–CP relationship. The significant DT × GI interaction and crossover pattern observed in the simple slopes analysis indicate that DT contributes to improved CP only under conditions of strong institutional support. At low levels of government incentives, DT is associated with weak or even negative performance implications, suggesting that organisations may incur digitalisation costs without achieving corresponding CP gains. At moderate levels of institutional support, the relationship remains limited. Only under strong government incentives does DT demonstrate a positive and substantively meaningful relationship with CP. The dominance analysis further reinforces this conclusion by demonstrating that the interaction between DT and government incentives explains a substantially greater proportion of variance in CP than DT or government incentives considered independently. From an STS perspective, government incentives operate as institutional activation mechanisms that enable digital capabilities to translate into measurable organisational outcomes. Rather than functioning as merely additive policy instruments, incentives reduce implementation risk, strengthen compliance motivations, and encourage organisations to align digital initiatives with circular operational objectives. In this sense, the findings extend STS theory by demonstrating that socio-technical alignment alone may be insufficient to generate sustainability-oriented organisational outcomes. Instead, digitally enabled CP emerges through the interaction between internal socio-technical capabilities and enabling institutional conditions. Accordingly, the study advances a policy-contingent view of socio-technical capability. While conventional STS approaches emphasise the joint optimisation of social and technical subsystems, the present findings demonstrate that the effectiveness of such alignment depends on whether institutional environments activate or constrain the performance potential of digital capabilities. This contribution extends beyond the Sri Lankan e-waste sector by suggesting that digitally enabled sustainability transitions in institutionally constrained contexts may depend less on technology adoption itself and more on the extent to which policy environments support the translation of digital capabilities into sustainability outcomes.

Finally, although CP is conceptualised as an organisation-level outcome, this study operationalises CP through employee-reported assessments of observable operational practices. In the Sri Lankan e-waste sector, where organisations frequently operate within fragmented and partially informal structures, standardised organisation-level performance metrics are not consistently available. Accordingly, employee-level assessments of material recovery efficiency, operational compliance, and resource management practices provide a contextually appropriate proxy for capturing transitional circular operational outcomes. While this approach aligns with prior sustainability and organisational research using perceptual performance measures, the findings should nevertheless be interpreted with appropriate caution, given the cross-sectional and perceptual nature of the data.

5.1. Theoretical Implications

This study makes several important theoretical contributions to STS theory, DT literature, and CE scholarship. First, the study advances STS theory by demonstrating that internal socio-technical alignment alone may be insufficient to generate organisational performance outcomes such as CP. While conventional STS perspectives emphasise the joint optimisation of social and technical subsystems within organisational boundaries (Cardoso et al., 2023; Yang et al., 2025; Van Ta et al., 2025), the findings indicate that the performance implications of such alignment remain contingent on enabling institutional conditions. Specifically, government incentives function as institutional activation mechanisms that determine whether internally developed digital capabilities translate into measurable circular outcomes. In this sense, the study extends STS theory beyond internal organisational alignment by empirically demonstrating the importance of institutional embedding as a boundary condition for digitally enabled sustainability performance in structurally fragmented sectors such as e-waste. Second, the study contributes to DT literature by challenging technology-deterministic assumptions regarding the relationship between digitalisation and sustainability performance (Maiurova et al., 2022; Sharma et al., 2024). The absence of a direct DT–CP relationship indicates that DT should not be conceptualised as an inherently performance-enhancing intervention. Instead, DT operates as a contingent organisational capability whose effectiveness depends on broader institutional support structures. Although digital technologies may enhance traceability, monitoring, and operational visibility, these capabilities do not automatically produce improvements in circular operational outcomes. Accordingly, the findings reposition DT as a latent socio-technical capability whose performance effects emerge only when supported by enabling policy conditions, particularly in developing economies.

Third, the study contributes to CE scholarship by providing organisation-level empirical evidence from the underexplored e-waste sector in a developing-economy context (Sengupta et al., 2022; Gaur et al., 2023; Nguyen et al., 2024). Existing CE performance research often assumes that technological adoption directly enhances circular outcomes by improving efficiency, traceability, and recovery practices (Khan et al., 2025; Alshibani et al., 2026; Duong, 2026). However, the present findings challenge this linear capability–performance logic by demonstrating that DT alone does not improve CP. Instead, CP improvements emerge only when digital capabilities are coupled with enabling institutional incentives. This introduces a conditional performance perspective in which digital capabilities operate as contingent rather than universally effective drivers of circular outcomes. In doing so, the study extends CE performance scholarship by integrating institutional and policy conditions into organisation-level CP frameworks, particularly within contexts characterised by regulatory fragmentation and uneven technological adoption (Ramani & De Giovanni, 2025). Finally, the non-significant effects of EE and TTF contribute to ongoing debates regarding the role of human agency within socio-technical transformation processes (Koskela & Paloniemi, 2022; Malik et al., 2025). Rather than suggesting that employee-level mechanisms are unimportant, the findings indicate that their influence may be structurally constrained in sectors characterised by operational informality, centralised decision-making, and uneven digital maturity. This refines existing socio-technical perspectives by demonstrating that the relative influence of social subsystem components may vary across analytical levels and institutional contexts.

5.2. Managerial Implications

The findings generate several important implications for managers operating in the e-waste sector. First, DT should be approached as a strategic organisational capability rather than as a stand-alone technological intervention. The strong effects of DR and DL on DT indicate that organisations should prioritise investments in digital infrastructure, traceability systems, data management platforms, and digitally oriented leadership capabilities that integrate technology into organisational decision-making and operational coordination. Second, managers should avoid assuming that digitalisation alone will automatically improve CP. Although digital technologies may strengthen compliance visibility, reporting efficiency, and operational monitoring, such improvements may not necessarily translate into higher recovery rates or broader circular outcomes in the absence of enabling institutional support. Managers operating in weak incentive environments should therefore adopt phased digitalisation strategies that initially focus on operational standardisation, compliance readiness, and process integration, rather than expecting immediate CP gains. Third, the non-significant effects of EE and TTF suggest that DT in the e-waste sector currently remains highly centralised and leadership-driven. Accordingly, managers should recognise that workforce engagement and task-level alignment may become more influential only after foundational organisational digital capabilities and governance structures are established. This highlights the importance of sequencing digital capability development, leadership coordination, and workforce adaptation processes rather than relying solely on employee-driven transformation initiatives in emerging sectors like e-waste.

5.3. Policy Implications

The findings generate several important implications for policymakers and development agencies seeking to support digitally enabled circular transitions in developing economies. Most importantly, the results indicate that government incentives function not merely as adoption stimuli but as institutional activation mechanisms that determine whether DT generates meaningful circular outcomes. This suggests that policy interventions should move beyond generic digitalisation subsidies toward outcome-oriented incentive structures explicitly linked to measurable CP indicators such as recovery rates, traceability completeness, reuse volumes, and environmentally compliant processing practices. The findings further suggest that weak or fragmented incentive schemes may be insufficient to generate meaningful circular outcomes. Policymakers should therefore consider threshold-based or performance-linked incentive structures that encourage organisations in developing economies to align their digital investments with broader circular-economy objectives. Without such alignment, digital technologies risk remaining administrative or compliance-oriented tools rather than functioning as transformation mechanisms within national circular economy systems. At the system level, the study highlights the importance of integrating digitalisation strategies with broader institutional and regulatory reforms. Investments in digital traceability systems, reporting platforms, and monitoring infrastructures should be coordinated with formalisation policies, regulatory simplification, and performance-based support mechanisms. In the e-waste sector, where formal organisations frequently depend on informal actors for collection and pre-processing, policies that support the integration of informal workers into formal digital systems through training, registration, and digital identification mechanisms may improve both traceability and social inclusion outcomes. Collectively, the findings indicate that digitally enabled circular transitions require coordinated socio-technical governance rather than isolated technological adoption initiatives. Effective circular transformation in the e-waste sector, therefore, depends on alignment among organisational capabilities, leadership structures, and institutional support mechanisms that collectively enable digital technologies to generate measurable CP outcomes.

5.4. Limitations and Future Research Directions

Despite its contributions, this study has several limitations that create opportunities for future research. First, the use of a cross-sectional research design limits strong causal inference regarding the temporal relationship between DT and CP. Digital transformation is inherently dynamic and path-dependent, and its performance implications may emerge only over extended periods. Accordingly, future research should employ longitudinal or panel data designs to examine how digital capabilities, institutional support mechanisms, and circular outcomes evolve over time. Second, the study relies on self-reported perceptual measures of organisational practices and performance, which may introduce CMB and social desirability concerns despite the procedural and statistical remedies implemented. In particular, CP was operationalised using employee-level assessments of observable operational practices rather than objective organisation-level indicators. Although this approach is contextually appropriate in fragmented, partially informal e-waste settings, future studies could strengthen external validity by incorporating objective performance indicators, such as certified recovery rates, compliance audit outcomes, or digital traceability records. Third, the empirical context is limited to Sri Lanka's e-waste sector, which is characterised by institutional fragmentation, operational informality, and evolving regulatory structures. While this context provides important insights into digitally enabled circular transitions in developing economies, the findings may not be fully generalisable to highly formalised waste management systems or developed-economy contexts. Comparative cross-country studies would therefore be valuable for examining how variations in regulatory environments, institutional maturity, and market structures influence the socio-technical mechanisms identified in this study.

Fourth, government incentives were operationalised as a composite construct capturing general perceptions of institutional support. Future studies could disaggregate specific policy mechanisms, such as subsidies, tax incentives, digital compliance mandates, or EPR schemes, to examine their differential effects on DT and CP outcomes. Fifth, multiple respondents originated from some organisations, which may introduce within-organisation response dependence. Although the unit of analysis was the individual employee and anonymity constraints prevented the collection of organisation identifiers, future research using multilevel or nested data structures would allow more precise examination of organisational-level effects and clustering dynamics. Finally, the non-significant effects of EE and TTF suggest the need for deeper theorisation of human agency within institutionally constrained socio-technical systems. Future qualitative or mixed-method studies could explore how workers, supervisors, and informal actors negotiate, resist, or adapt to digital systems in operational practice, and how such micro-level processes interact with leadership structures and institutional pressures during digitally enabled circular transitions.

6. Conclusion

This study examined how organisational digital enablers shape DT and under what conditions DT contributes to CP in the e-waste sector. Drawing on STS theory, the findings demonstrate that DT is primarily driven by organisational-level capabilities, particularly DR and DL, whereas employee-level mechanisms, such as EE and TTF, do not significantly influence transformation processes in this context. More importantly, the study reveals that DT does not directly improve CP. Instead, the effectiveness of DT depends on enabling government incentives that unleash the performance potential of digital capabilities. These findings challenge technology-deterministic assumptions in parts of the DT and CE literature by demonstrating that digitalisation alone is insufficient to yield measurable circular outcomes. Rather, the DT–CP relationship is conditional, institutionally embedded, and dependent on broader socio-technical alignment. Government incentives, therefore, emerge not merely as supportive policy instruments but as mechanisms for institutional activation that determine whether digital capabilities translate into substantive improvements in CP. The study advances STS theory by extending the notion of socio-technical optimisation beyond internal organisational alignment to include enabling institutional conditions. In doing so, it advances a policy-contingent perspective on digitally enabled circular transformation, in which organisational outcomes emerge from the interaction among digital capabilities, leadership structures, and institutional support mechanisms. The findings also contribute to CE scholarship by shifting attention from technology-centred assumptions toward more context-sensitive and institutionally embedded explanations of CP in developing-economy e-waste sectors. Overall, the study demonstrates that successful circular transitions in institutionally constrained sectors cannot be achieved solely through technological adoption. Instead, meaningful circular outcomes require coordinated alignment among organisational capabilities, strategic leadership, and supportive policy environments that can translate digital investments into operational sustainability performance.

Data availability Data will be made available on reasonable request.

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Declarations

Competing Interests The authors declare no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee.

Informed consent Informed consent was obtained from all participants included in the study.

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Appendix

Appendix 1 – Measurement Scale

Instrument Items	Source	Items	Factor Loadings
Digital Resources	Wang and Esperança (2023)	• DR1: Our organisation maintains adequate digital hardware infrastructure to support the implementation of digital initiatives.	0.743
		• DR2: Our organisation has consistent access to large-scale digital data required to support the e-waste urban mining process.	0.776
		• DR3: Our organisation is equipped with appropriate software systems to enable the execution of digital initiatives.	0.721
		• DR4: Our organisation possesses the technical expertise required to implement, manage, and maintain digital systems	0.633
		• DR5: Our organisation has sufficient financial and technical capacity to support sustainability-oriented digital initiatives.	0.797
Digital Leadership	Shin et al. (2023)	• DL1: Leaders in our organisation actively promote practical digital solutions to improve circular economy processes.	0.729
		• DL2: Leaders engage employees to reduce resistance to digital transformation initiatives.	0.696
		• DL3: Leaders share their own experiences with digital technologies to support organisational learning.	0.776
		• DL4: Leaders clearly communicate the potential risks and benefits associated with digital technologies.	0.768
Employee engagement	Pobee (2021) and Tavitiyaman et al. (2023)	• EE1: I consistently invest high levels of effort when working with digital technologies in my role in the e-waste urban mining process.	0.726
		• EE2: I actively seek opportunities to enhance my knowledge and skills related to digital technologies in the process.	0.799
		• EE3: I feel encouraged and supported to apply digital technologies in my work activities.	0.774
		• EE4: I am given opportunities to experiment with digital technologies before their full implementation in my job.	0.796
Task-technology fit	Koh et al. (2023)	• TTF1: The functionalities of our digital technologies adequately support the completion of e-waste urban mining tasks.	0.810
		• TTF2: The features of our digital technologies are appropriate for performing e-waste urban mining processes.	0.762
		• TTF3: The digital technologies we use enhance the effectiveness of completing e-waste urban mining activities.	0.789
		• TTF4: The capabilities of our digital technologies fully align with the circularity requirements of e-waste urban mining.	0.757
Digital Transformation	Nasiri et al. (2020); Singh et al. (2021)	• DT1: Our e-waste urban mining practices are being systematically digitalised wherever feasible.	0.772
		• DT2: Digital systems are increasingly integrated into our organisation's formal operational and managerial processes.	0.709
		• DT3: Daily work activities within our organisation are progressively dependent on digital technologies.	0.815

Instrument Items	**Source**	**Items**	**Factor Loadings**
Government incentives	Own development	• GI1: Our organisation receives financial incentives (e.g., subsidies, grants, or tax benefits) that support investments in digital technologies for e-waste management.	0.823
		• GI2: Government policies and regulations encourage our organisation to adopt digital systems that improve environmental compliance and traceability.	0.813
		• GI3: Access to government-supported programmes reduces the financial and operational risks associated with implementing digital technologies in our e-waste urban mining process.	0.806
		• GI4: Government agencies provide institutional support (e.g., technical guidance, training, or certification schemes) that facilitates the effective use of digital technologies for circular practices.	0.805
Circular performance	Agyabeng-Mensah et al. (2022)	As a result of DT initiatives in our organisation… • CP1: Our organisation has improved its ability to recover valuable materials and enhance resource efficiency.	0.844
		• CP1: Our organisation has improved its ability to recover valuable materials and enhance resource efficiency.	0.863
		• CP2: Our organisation has reduced operational defects, hazardous conditions, and avoidable material losses.	0.840
		• CP3: Our organisation has decreased energy and water consumption across production and processing activities.	0.811

Appendix 2 - Conditional Indirect Effects at GI Levels

Effect	Estimate	BCa 95% CI Lower	BCa 95% CI Upper	Significance
Indirect DR at GI −1 SD	−0.031	−0.124	0.042	No
Indirect DR at GI Mean	0.032	−0.035	0.115	No
Indirect DR at GI +1 SD	0.096	−0.004	0.244	No
Indirect DL at GI −1 SD	−0.024	−0.104	0.031	No
Indirect DL at GI Mean	0.025	−0.025	0.092	No
Indirect DL at GI +1 SD	0.075	−0.002	0.207	No
Indirect EE at GI −1 SD	−0.007	−0.048	0.007	No
Indirect EE at GI Mean	0.008	−0.006	0.038	No
Indirect EE at GI +1 SD	0.023	−0.002	0.078	No
Indirect TTF at GI −1 SD	−0.000	−0.018	0.012	No
Indirect TTF at GI Mean	0	−0.011	0.019	No
Indirect TTF at GI +1 SD	0.001	−0.025	0.039	No