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Islam Md Ariful, Oyedeji Shola, Porras Jari

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Sustainable ICT Procurement: Data-Driven Decision-Making in B2B Green ICT Adoption

Md Ariful Islam[1][0000−0002−1596−5580], Shola Oyedeji[2][0000−0003−32023752], and Jari Porras[2][00000003−3669−8503]

[1] Faculty of Information Technology, University of Jyväskylä, Jyväskylä, Finland
ariful.m.islam@jyu.fi
[2] Department of Software Engineering, LUT University, Lappeenranta, Finland
{shola.oyedeji,jari.porras}@lut.fi

Abstract. The rapid growth of the Information and Communication Technology (ICT) sector has led to escalating environmental and social impacts. This study develops and validates the Sustainable ICT Device Acquisition (SIDA) framework and tool, incorporating a Supplier Selection Questionnaire (SSQ) and Sustainability Guidelines to address these challenges. Employing a mixed-methods approach, we identify key barriers and enablers to sustainable ICT procurement. The proposed SIDA tool operationalizes the framework, empowering decision-makers with data-driven insights and comprehensive sustainability information. Workshops with industry practitioners and academic experts validate the tool's potential to raise awareness, streamline supplier evaluation, and enhance decision-making in alignment with sustainability goals. This research contributes a theoretically grounded and empirically validated framework and tool, promoting responsible ICT procurement decisions.

Keywords: green ICT · sustainable decision making · data-based decision making · sustainable ICT procurement · circular economy · B2B

1 Introduction

The modern era is heavily influenced by ICT devices and services, which have significantly altered organizational operations and individual lives through enhanced efficiency and global connectivity. However, this technological growth, partly fueled by advancements in artificial intelligence (AI), is accompanied by substantial environmental and social impacts, such as significant energy usage and waste production. For instance, the global embodied CO2 emissions of the key ICT user devices (laptops, desktops, monitors, smartphones, tablets) were estimated to total 180 Megatonnes, which is very likely to increase as the sector expands [1]. For the scope of this study, these key user ICT devices will be referred to as "ICT products" or "ICT devices".

Life cycle assessment (LCA) research shows that the majority of emissions are attributed to both the embodied phase ranging from 12% to 97% and use-phase emissions varying from 3% to 88%. The increasing production and rapid

innovation cycles within the ICT sector have indeed enhanced ICT device capabilities but have also reduced product lifetimes, resulting in the generation of substantial amounts of e-waste as well as increasing energy consumption annually. In 2019 alone, the global production of electronic waste (e-waste) reached approximately 50 million tons, with a projected annual growth rate of 3-5% [6], and predictions suggesting the ICT sector could account for 14% of the global carbon footprint by 2040 [2], there is an urgent need to address sustainability in ICT procurement.

The importance of procurement in this context cannot be emphasized enough. Scope 3 emissions, primarily arising from purchased goods and services, often constitute over 75% of an industry sector's carbon footprint [4]. The CDP's [3] 2020 report further emphasizes the critical role of procurement in addressing these indirect emissions. This emphasis on supply chain emissions is further supported by recent findings from the same report showing that supply chain emissions are on average 11.4 times higher than operational emissions, more than double previous estimates. Corporate buyers face potential costs of up to US$120 billion from environmental risks in their supply chains within the next five years. Despite these challenges, only 37% of suppliers are engaging their own suppliers to reduce emissions, indicating a significant gap in cascading sustainable practices through the supply chain.

These findings underscore the need for effective procurement frameworks, yet while research has explored various aspects of sustainable ICT, the literature reveals a notable gap in comprehensive frameworks and models for ICT procurement decision-making. This gap is evident in practice, where 75% of Finnish ICT sector organizations report no attempts at green ICT procurement [7], and challenges are further exacerbated by the absence of consistent carbon footprint data for 78% of device models [5]. Both public and private organizations struggle to integrate sustainability due to unreliable data, fragmented practices, and a lack of standardized criteria [9].

However, the possibility for substantial positive transformation is significant [3]. Organizations, regardless of their public or private status, could mitigate the negative impacts of ICT through strategic decision-making processes that prioritize sustainability [11]. As [12] emphasize, the very nature of ICT's impact is shaped by the decision-making process itself.

To address these theoretical and practical gaps we introduce the Sustainable ICT Device Acquisition (SIDA) Framework. The framework advances sustainable ICT procurement theory through an integrated decision support model that systematically connects stakeholder engagement, sustainability criteria, and assessment metrics. Its contribution lies in bridging the research-practice gap through structured supplier evaluation methods and evidence-based decision support mechanisms, providing organizations with a systematic approach to incorporating sustainability in ICT procurement processes.

The remainder of this study is organized as follows: Section 2 reviews existing literature on sustainability in ICT procurement. Section 3 delineates the

[3] https://www.cdp.net/en/research/global-reports/transparency-to-transformation

research methodology employed. Section 4 reports the findings of this study. Section 5 discusses the implications of the findings, linking them to the research questions and broader sustainability goals. Lastly, Section 6 summarizes the key conclusions drawn from this research.

2 Related Works

This section briefly overviews the current state of knowledge regarding sustainable procurement of ICT products. It investigates the environmental impacts of ICT, delves into the idea of sustainable procurement, assesses established frameworks and models, and analyzes pertinent standards, regulations, and policies.

2.1 Environmental Impacts of ICT Products

The aspects of environmental impacts vary depending on the ICT products or services in consideration. The ICT sector's environmental impact extends beyond its carbon footprint, encompassing significant raw material consumption. This impact is exacerbated by continuous technological advancements, potentially leading to global scarcity of essential raw materials including metals, crystals, water and energy. Recent LCA studies reveal that both the embodied and use phases contribute substantially to overall emissions, with the embodied phase accounting for anywhere between 12% to 97% and the use phase for 3% to 88% of the total emissions, depending on factors such as the materials and electrical efficiency [5]. In addition to environmental impacts, the ICT sector also has significant social impacts, including labor practices in manufacturing, digital divide, and the potential for ICT to perpetuate or mitigate social inequalities. These social considerations are also integral to a holistic understanding of sustainability in ICT procurement.

Table 1. Estimated Total Carbon Footprint (kg CO2e) of ICT Devices across Lifecycle Stages (Source: [2])

	Useful Life (years)		Production Energy (kg CO_2-e)		Use Phase Energy (kg CO_2-e/yr)		Lifecycle Annual Footprint (kg CO_2-e/yr)	
	Min	Max	Min	Max	Min	Max	Min	Max
Desktop	5	7	218	628	69	75	100	200
Notebooks	5	7	281	468	20	23	60	117
CRT Displays	5	7	200	200	51	95	79	135
LCD Displays	5	7	95	95	23	43	37	62
Tablets	3	8	80	116	4.5	5.25	14.5	43.9
Smart Phones	2	2	40	80	4.5	5.25	24.5	45.3

Table 1 shows the significant carbon footprint of ICT devices across their lifecycle stages particularly in the production phase. Extending device lifespans can

substantially reduce annual carbon footprints. For instance, increasing a tablet's lifespan from 3 to 8 years can halve its yearly footprint. However, the rapid turnover of ICT devices contributes to the growing e-waste problem, as only 17.4% of the 53.6 million tonnes of e-waste generated was properly recycled in 2019 [13]. These findings highlight the need for sustainable procurement strategies prioritizing energy efficiency, longevity, and responsible end-of-life management in the ICT sector. While these studies provide valuable insights into ICT's environmental impact, they rarely translate into actionable procurement frameworks, creating a gap between impact assessment and practical decision-making.

2.2 Sustainability in ICT procurement and Existing frameworks

Sustainable procurement in ICT is crucial for reducing the sector's environmental impact [15]. It integrates economic, environmental, and social considerations into procurement processes, aiming to create value while minimizing negative environmental effects [16]. This approach differs from traditional procurement by focusing on whole-life value rather than just lowest price. The procurement process typically includes needs identification, market analysis, specification development, supplier evaluation and selection, contract management, and performance review [18,17]. Each stage offers opportunities to incorporate sustainability criteria [19]. Ecolabels, such as EU Ecolabel, Energy Star, and EPEAT, provide information on products' environmental performance [20]. LCA evaluates environmental impacts throughout a product's lifecycle. Life Cycle Costing (LCC) considers total costs over a product's lifespan. The Triple Bottom Line framework assesses environmental, social, and economic impacts. Sustainable Supply Chain Management (SSCM) extends these principles across the entire supply chain. Although recent frameworks offer theoretical foundations and incorporate resource optimization and circular economy principles [22], they lack specific guidance for ICT procurement decisions. Current approaches tend to treat sustainability criteria in isolation, without providing integrated decision support mechanisms that procurement professionals require.

2.3 Regulations, Policies and Standards

The regulatory landscape for sustainable ICT procurement is rapidly evolving, driven by global climate commitments and the increasing demand for responsible resource management. Key regulations and standards shaping this field include the EU's Green Public Procurement[4] (GPP) criteria [24] and the Ecodesign for Sustainable Products Regulation (ESPR) [26], which introduces the Digital Product Passport (DPP) to enhance product traceability and promote circular economy principles. Additionally, Germany's Supply Chain Due Diligence Act [27] and the EU's Corporate Sustainability Reporting Directive (CSRD) [25] emphasize increased corporate accountability and transparency. In the standardization domain, ISO 20400 and ISO 14001 [23] provide frameworks for sustainable

[4] https://circabc.europa.eu/ui/group/44278090-3fae-4515-bcc2-44fd57c1d0d1/library/bf592737-c5a8-43ce-99e1-dea61648d3f9/details

procurement and environmental management, while sector-specific guidelines from the International Telecommunication Union (ITU) align with Paris Agreement targets [10].

While these regulations and standards establish comprehensive requirements, organizations face significant challenges in their practical implementation. The complexity of integrating multiple standards, coupled with the rapid evolution of ICT technologies, creates a substantial gap between regulatory compliance and effective procurement practices. This implementation gap is notable in three areas: the translation of standards into actionable procurement criteria, the integration of sustainability requirements with existing procurement processes, and the evaluation of supplier compliance with these standards.

This evolving landscape presents both challenges and opportunities for organizations. Compliance efforts can drive innovation and create competitive advantages, while also influencing organizational behavior and decision-making. However, the lack of structured frameworks for putting these standards into practice often results in fragmented approaches to sustainable procurement, emphasizing the need for integrated decision support systems that can close the gap between regulatory requirements and practical implementation.

Future research should focus on the practical implementation and impact of these regulations, particularly on developing systematic approaches that can help organizations translate complex regulatory requirements into effective procurement decisions, as well as explore the potential of emerging technologies to enhance transparency and traceability in the ICT supply chain.

3 Methodology

This study employs a mixed-methods approach to investigate sustainability integration in ICT procurement processes and develop evidence-based frameworks and tools. The methodology integrates a Systematic Literature Review (SLR), semi-structured interviews, and quantitative survey analysis, enhancing the validity and reliability of the findings [8]. The research process, illustrated in Figure 1, unfolds across three primary phases:

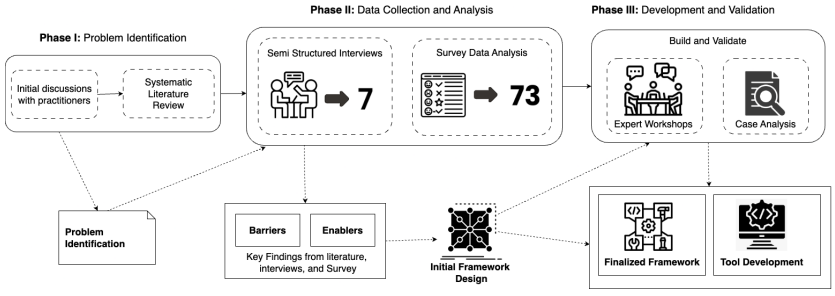

Fig. 1. The research process and design

- **Phase 1 - Problem Identification:** Initial discussions with the industry practitioners shaped the problem formulation, followed by a Systematic Literature Review (SLR)[5] to establish the state of the field and identify knowledge gaps. The SLR addressed specific questions about existing sustainability integration approaches in ICT procurement, barriers encountered, and successful implementation strategies. Findings from the SLR informed the formulation of this study's research questions RQ1 and RQ2 (see 3.1) and guided subsequent data collection.
- **Phase 2 - Data Collection and Analysis:** Semi-structured interviews[6] with 7 industry experts were conducted to gather qualitative insights on existing practices, challenges, and opportunities in sustainable ICT procurement. Additionally, a quantitative survey analysis was performed on data collected from 73 respondents in a separate study by the Green ICT ecosystem [14] offering a broader perspective on barriers and enablers. The respondents represented organizations of varying sizes (48% large, 52% SMEs) across both private (62%) and public (38%) sectors.
- **Phase 3 - Development and Validation:** The analysis findings informed the iterative development of the Sustainable ICT Decision and Acquisition (SIDA) framework and its supporting components: a decision support tool, Supplier Selection Questionnaire (SSQ), and practical sustainability guidelines. This involved 5 expert workshops and stakeholder feedback sessions, and case analysis to ensure alignment with real-world challenges and opportunities, with a particular emphasis on facilitating decision-making and behavior change within procurement teams.

Data analysis involved thematic analysis of interview transcripts using NVivo software,[7] and statistical analysis of survey data using Python and specialized libraries. The iterative evaluation process, incorporating stakeholder engagement and collaboration, ensured that the final framework and tools were both theoretically grounded and practically relevant. This methodology enabled a comprehensive approach to addressing the research questions, integrating insights from literature, industry experts, and quantitative data to develop practical tools for sustainable ICT procurement.

3.1 Research Questions

This research aims to investigate sustainability integration in organizational ICT procurement processes through the following research questions:

- **RQ1:** What are the key barriers and enablers for integrating sustainability criteria into ICT procurement processes in organizations?
- **RQ2:** How can organizations effectively integrate sustainability into the decision-making process of ICT procurement processes?

[5] https://tinyurl.com/SLR-Protocol
[6] https://tinyurl.com/Semi-Interview-protocol
[7] https://lumivero.com/products/nvivo/

4 Results

The section is structured to provide a comprehensive understanding of the results, encompassing the problem identification phase, qualitative analysis of the interview data, quantitative analysis of the survey data, and the iterative design, refinement and validation of the SIDA framework and tools.

4.1 Problem Space and Literature Analysis

Several initial meetings were conducted with practitioners to understand the problem space and potentially identify key challenges in integrating sustainability into ICT procurement. Barriers identified include the absence of **clear sustainability criteria, difficulty in assessing supplier performance, resistance to change, fear of increased costs, and a lack of supportive tools**. Addressing these requires understanding decision-makers' tendencies to overlook sustainability, lowering or removing these barriers, and developing effective support mechanisms to encourage sustainable ICT procurement.

The SLR identified six primary categories of barriers and enablers influencing the integration of sustainability into ICT procurement: Environmental, Economic, Technical, Awareness and Training, Policy and Regulations, and Organizational Dynamics. Environmental barriers include the complexity of eco-labels and the lack of standardized CO2 emission data, creating confusion in product evaluation [5,28]. Economic challenges are rooted in the uncertainty of return on investment and the higher upfront costs associated with sustainable options [29]. Technical barriers arise from the absence of standardized frameworks and inadequate information management systems [5,21]. Awareness and Training obstacles stem from insufficient knowledge and training programs, while unclear policies and fragmented regulations create a challenging landscape for organizations [29,31]. Organizational dynamics, including a lack of senior management commitment and stakeholder resistance, further complicate the adoption of sustainable practices.

Conversely, the SLR identified enablers such as environmental consciousness and the use of eco-labels, long-term financial benefits [32], technical advancements like sustainability assessment frameworks and decision support tools [33], increased awareness and training foster behavioral change within organizations, supportive policies and regulations [34], and organizational dynamics such as pressure from ESG-focused investors [29].

4.2 Interview and Survey Data Collection and Analysis

Interviews with industry experts and analysis of survey data further validated and expanded upon the identified barriers and enablers. Seven industry experts from Finland and Germany were interviewed (see Table 2). Their insights validated and expanded upon the literature findings, particularly emphasizing practical implementation challenges. The study identified several key barriers to sustainable ICT procurement. Technical barriers emerged as a significant challenge,

Table 2. Interview Participants

Job Title	**Experience (years)**	**Country**	**Company Size**
Senior IT Procurement Manager	15	Finland	Large
Head of Sustainability	12	Finland	Medium
IT Procurement Specialist	10	Finland	Medium
Sustainability Manager	8	Finland	Very Large
IT Operations Manager	14	Finland	Large
Chief Technology Officer	13	Germany	Medium
Procurement Analyst	9	Germany	Small

particularly regarding data management and accessibility. As one sustainability manager explained:

> "We have so much data on different products and suppliers, but it's scattered across multiple spreadsheets. It's difficult to find the information we need, and it's even harder to make sense of it all in a meaningful way."

This highlights the pressing need for improved data management and decision support tools. Organizational resistance was another critical barrier. As one practitioner noted:

> "How can we make ICT sustainable? Like how does it work? They don't really believe in it. They just say it's a buzzword or something."

This highlighted the challenge of establishing organizational commitment to sustainable practices.

Factor analysis of the survey data revealed the average impact of identified barriers and enablers on a scale from 0 to 10, as illustrated in Figure 2. The bar charts presents a comparative view of the most significant barriers and enablers in sustainable ICT products procurement, as perceived by survey respondents. Figure 3 illustrates that the survey responses further validated and expanded upon the barriers identified in the literature review and interviews. The barriers highlighted in yellow indicate convergence across all three data sources - literature review, interviews, and survey data - underscoring their significance and prevalence in the context of sustainable ICT procurement.

In Figure 4, the enablers highlighted in yellow signify convergence of the survey data with the findings from both the literature review and the interviews, underscoring their consistent importance across different data sources. These converged enablers, such as **regulatory pressures, organizational sustainability goals, and the availability of clear sustainability information**, represent key factors that organizations perceive as crucial in facilitating the adoption of sustainable ICT procurement practices. While 'Transparency & Data Availability' and 'Carbon Footprint data availability' appear as separate technical enablers, this distinction is intentional. The former encompasses broad

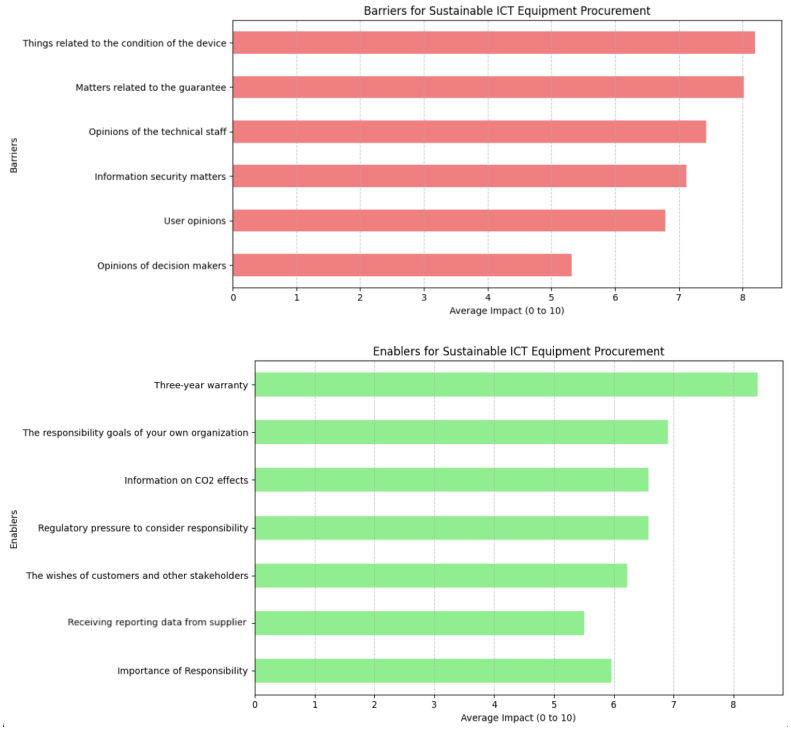

Fig. 2. Average Impact of Barriers and Enablers

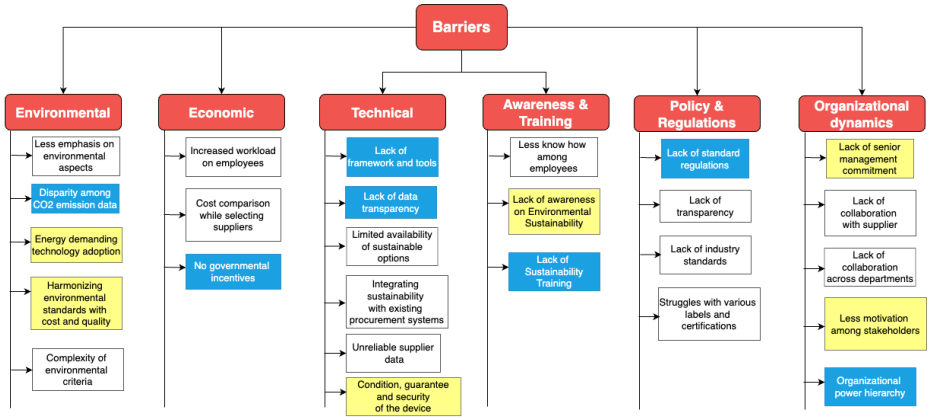

Fig. 3. Merged Barriers supported by Survey data. Highlighted Yellow Barriers indicate convergence across literature review, interviews, and survey data.

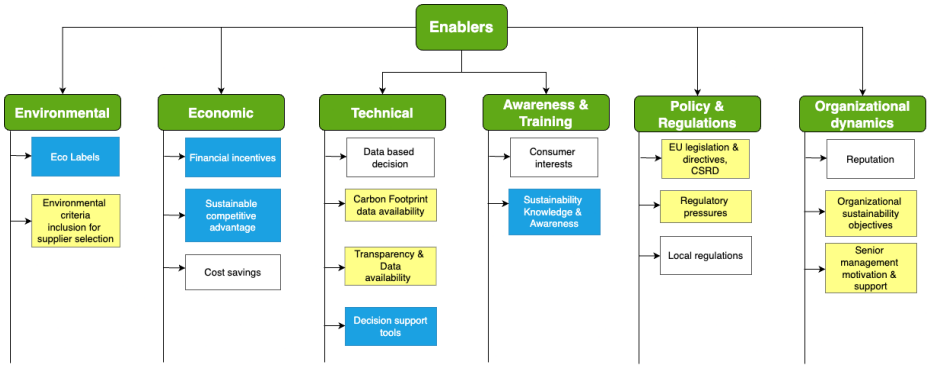

Fig. 4. Merged Enablers supported by Survey data. Highlighted Yellow Enablers indicate convergence across literature review, interviews, and survey data.

product lifecycle and supply chain information, whereas the latter specifically focuses on greenhouse gas emissions metrics—a critical factor in sustainable ICT procurement decisions. This separation ensures dedicated attention to carbon footprint while maintaining comprehensive transparency requirements.

4.3 SIDA Framework Development and Supporting Tools

To address the lack of a comprehensive framework for sustainable ICT procurement, we developed the Sustainable ICT Device Acquisition (SIDA) framework combining theoretical insights from literature with practical knowledge gained through empirical research. The SIDA framework comprises the following components: Policy and regulations compliance, Sustainability criteria, Carbon footprint information, Supplier selection and performance evaluation, Assessment metrics, scoring, and weighting, Measurable KPIs, Stakeholder engagement mechanisms, Decision support, and Awareness and training. The framework was iteratively improved to better reflect practical needs and implementation considerations. Workshops with academic peers and industry experts provided valuable feedback on the initial SIDA framework, leading to its refinement.

Key suggestions included consolidating certain components (e.g., merging "Carbon Footprint Information" with "Sustainability Criteria"), emphasizing active stakeholder engagement in defining metrics and KPIs, and improving the visual representation of the framework's interactions. Additionally, the need for supporting tools, such as a Supplier Selection Questionnaire and Sustainability Guidelines, was identified to facilitate practical implementation.

Incorporating feedback from workshops, the SIDA framework was refined to enhance its usability and effectiveness (see Figure 5). The revised framework emphasizes decision support, stakeholder engagement, and the crucial role of defining clear sustainability criteria, assessment metrics, and KPIs. Each framework component serves a specific purpose: Carbon Information guides emissions-

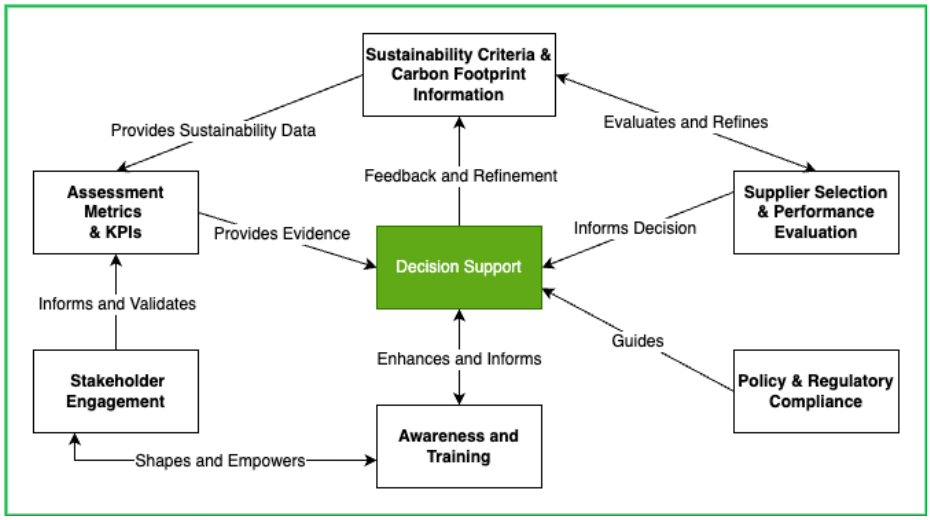

Fig. 5. Sustainable ICT Decision and Acquisition (SIDA) Framework

related decisions, Policy & Regulatory Compliance ensures adherence to sustainability standards, and Stakeholder Engagement facilitates collaborative decision-making. Detailed specifications of framework elements and their relationships are available in the supplementary documentation.[8] To support the framework, we developed a Supplier Selection Questionnaire (SSQ)[9] and Sustainability Guidelines[10]. The SSQ evaluates potential suppliers based on environmental, social, and economic criteria, while the guidelines provide step-by-step recommendations for integrating sustainability into ICT procurement. However, the workshop also highlighted the need for a dedicated SIDA Tool to translate the theoretical concepts of the framework into actionable steps, further supporting its practical application.

Due to time constraints, we were unable to fully develop the SIDA Tool. However, we outlined its proposed design, features, and functionalities, focusing on sustainable software development practices. The SIDA Tool[11] aims to bridge the gap between theory and practice by providing a platform that operationalizes the SIDA framework. It will offer features such as:

- **Sustainability Data Repository:** Centralized access to sustainability data for ICT products.
- **Supplier Evaluation:** Interactive module for assessing supplier sustainability performance.

[8] https://tinyurl.com/SIDA-Framework
[9] https://bit.ly/Supplier_Selection_Questionnaire
[10] https://bit.ly/SustainabilityGuidelines
[11] https://tinyurl.com/SIDA-dashboard

- **Assessment Metrics and KPIs:** Platform for defining, tracking, and visualizing KPIs.
- **Stakeholder Engagement:** Features for fostering collaboration and communication.
- **Decision Support:** Tools for analysis, comparison, and visualization of sustainability data.
- **Awareness and Training:** Gamified modules for enhancing understanding and promoting sustainable procurement.
- **Policy and Regulatory Compliance:** Repository of relevant information and a compliance checker.

The SIDA Tool's development is guided by sustainable software principles, including **energy efficiency, resource optimization, modularity, data minimization, and ethical considerations**. These principles ensure the tool itself aligns with the sustainability goals it promotes.

While full implementation was not feasible within the project timeframe, validation workshops with practitioners and academic peers confirmed the framework's effectiveness in improving decision-making and raising sustainability awareness. Participants particularly valued the structured approach to supplier evaluation and the practical guidance provided by the supporting tools. The final validation phase demonstrated the framework's significant potential in multiple areas. It provides a systematic approach to sustainable ICT procurement while enhancing stakeholder awareness and engagement throughout the process. The framework effectively supports evidence-based decision-making and facilitates comprehensive supplier evaluation and selection. Additionally, it promotes continuous improvement through measurable KPIs. Moving forward, future work will focus on full implementation of the SIDA Tool and continued refinement based on practical application feedback.

5 Discussion

This study addresses the pressing need for sustainable ICT procurement in the B2B sector by developing and validating the SIDA framework and conceptualizing the SIDA tool. The identified challenges, such as the lack of carbon footprint data transparency [5] and the perceived higher costs of sustainable options [29], echo concerns raised in previous research. The SIDA framework, developed through rigorous mixed-methods research, offers a structured approach to overcome these barriers and facilitate the integration of sustainability into ICT procurement decisions. The SIDA framework goes beyond existing models by explicitly incorporating behavioral and organizational factors crucial for successful implementation. This aligns with calls in the literature for a more holistic approach to sustainable procurement that considers not only technical aspects but also the human and organizational dimensions [19]. By integrating stakeholder engagement, decision support tools, and awareness-building mechanisms, SIDA empowers decision-makers to navigate the complexities of sustainable ICT procurement, addressing a key gap identified in previous research [21,30,5].

An important consideration in sustainable ICT procurement is the potential for rebound effects, where efficiency improvements may lead to increased consumption that partially offsets the intended environmental benefits. This is particularly relevant in the context of energy-efficient ICT devices, where cost savings might drive increased device acquisition or usage. The SIDA framework's comprehensive approach, particularly through its Assessment Metrics and Decision Support components, helps organizations recognize and account for these potential rebound effects in their procurement strategies, though this remains an area for further investigation and refinement.

Furthermore, the conceptualization of the SIDA tool demonstrates the potential to bridge the gap between theory and practice. While not fully implemented in this study, workshops with industry practitioners and academic experts validated its potential to enhance decision-making, raise awareness, and facilitate sustainable procurement. This resonates with the literature's emphasis on the need for practical tools and decision support systems to enable sustainable procurement [33].

The alignment of the SIDA framework with specific SDG targets, such as 12.5 (waste reduction), 12.8 (awareness raising), 9.1 (resilient infrastructure), 8.4 (decoupling growth from environmental degradation), and 8.5 (decent work and economic growth), highlights its potential for broader societal impact.

The SIDA framework and tool hold significant implications for both research and practice. For practitioners, they offer a practical and effective solution for integrating sustainability into ICT procurement, potentially leading to improved environmental and economic outcomes. For researchers, this study opens avenues for further investigation into the framework's effectiveness across various industries, its long-term impact on organizational behavior and sustainability performance, the quantification and mitigation of rebound effects, and the exploration of diverse methods for organizing sustainability criteria.

6 Conclusion

This study addressed the pressing need for sustainable ICT procurement in the B2B sector by developing the SIDA framework and conceptualizing the SIDA tool. The SIDA framework provides a structured approach for integrating sustainability into procurement decisions, while the SIDA tool offers a practical platform for implementation. By adopting the SIDA framework and tool, organizations can expect significant benefits, including reduced environmental impact, enhanced social responsibility, and cost savings. While the SIDA tool shows promise, further research is needed to assess its long-term efficacy and explore scalability challenges. This research contributes a valuable solution for organizations striving to align ICT procurement with sustainability goals. By addressing current limitations and pursuing future research directions, we can continue advancing sustainable ICT procurement practices.

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