



Phased Implementation Design of the E-SETGO Framework in Real-World Software Development Projects: A Low Hanging Fruit Strategy for Higher Education Institutions

Filan Firmansyah¹ , Dinar Mutiara Kusumo Nugraheni², Indra Waspada²

¹Postgraduate School, Diponegoro University, Indonesia, 50275

²Faculty of Science and Mathematics, Diponegoro University, Indonesia, 50275

filanfirmansyah@students.undip.ac.id

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Abstract

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The information and communication technology (ICT) sector contributes 4% of greenhouse gas (GHG) emissions, projected to reach 8% by 2030, creating a paradox because software enables all 17 United Nations Sustainable Development Goals (SDGs). The E-SETGO framework, validated by nine experts using Lawshe's Content Validity Ratio (CVR), identifies 16 core and 8 conditional sustainable software development practices across six Software Development Life Cycle (SDLC) phases. However, empirical evidence on organisational adoption remains limited. This study addresses the gap by proposing a phased implementation design based on the low-hanging-fruit principle, prioritising practices with low adoption barriers. Using Design Science Research (DSR), two software projects at Institut Teknologi PLN (ITPLN) are selected: the AMORA management information system and the Distance Learning (PJJ) Learning Management System. A five-dimension Adoption Barrier Score (ABS) matrix identifies P6.Org, P1.Org, and P6.Soc as adoption candidates. The study proposes a 12-month implementation strategy, instruments, and SDG mapping for validation.

Keywords: Sustainable Software Engineering; E-SETGO Framework; Low Hanging Fruit; Phased Implementation; Design Science Research; Sustainable Development Goals

Abstrak

Sektor teknologi informasi dan komunikasi (TIK) berkontribusi sekitar 4% terhadap emisi gas rumah kaca (GRK) global dan diproyeksikan mencapai 8% pada 2030. Kondisi ini menjadi paradoks karena perangkat lunak juga berperan penting dalam mendukung pencapaian 17 Tujuan Pembangunan Berkelanjutan (SDGs) Perserikatan Bangsa-Bangsa. Kerangka E-SETGO yang divalidasi melalui Content Validity Ratio (CVR) Lawshe oleh sembilan ahli menghasilkan 16 praktik inti dan 8 praktik kondisional pengembangan perangkat lunak berkelanjutan yang terintegrasi dalam enam fase Software Development Life Cycle (SDLC). Namun, bukti empiris mengenai penerapan praktik tersebut dalam organisasi masih terbatas. Penelitian ini mengatasi kesenjangan tersebut dengan mengusulkan desain implementasi bertahap berdasarkan prinsip low-hanging fruit, yaitu memprioritaskan praktik dengan hambatan adopsi terendah. Metode Design Science Research (DSR) diterapkan pada dua proyek perangkat lunak di Institut Teknologi PLN (ITPLN), yaitu sistem informasi manajemen AMORA dan Learning Management System (LMS) Pembelajaran Jarak Jauh (PJJ). Matriks Adoption Barrier Score (ABS) mengidentifikasi P6.Org, P1.Org, dan P6.Soc sebagai kandidat prioritas implementasi awal. Penelitian ini menghasilkan strategi implementasi 12 bulan, instrumen pengumpulan data, serta pemetaan kontribusi terhadap SDGs untuk validasi empiris selanjutnya.

Kata-kata kunci: Rekayasa Perangkat Lunak Berkelanjutan; Kerangka Kerja E-SETGO; Low Hanging Fruit; Implementasi Bertahap; Design Science Research; Tujuan Pembangunan Berkelanjutan



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1. Introduction

The global digital transformation has placed the information and communication technology (ICT) sector in a structurally paradoxical position: simultaneously serving as the primary engine of sustainable development enablement and as a significant source of the very environmental pressures that sustainable development seeks to resolve. The ICT sector currently accounts for an estimated 2–4% of global greenhouse gas (GHG) emissions, a share comparable to international aviation with credible projections indicating a potential rise to 8% by 2030 as digital infrastructure scales to meet accelerating global demand [1]. At the same time, the United Nations recognises digital technologies as cross-cutting enablers for all 17 Sustainable Development Goals (SDGs), spanning quality education, clean energy access, reduced inequalities and responsible consumption patterns [2]. This duality creates a systemic imperative: software development processes must be reconceived not merely for functional and economic performance, but for multi-dimensional sustainability that simultaneously reduces environmental footprints and amplifies positive societal contributions.

In response, Sustainable Software Engineering (SSE) has emerged as an interdisciplinary discipline addressing the environmental, social, economic, technical, organizational, and governance dimensions of software systems across their entire lifecycle [3]. The Karlskrona Manifesto established sustainability as a first-class software engineering concern spanning five interrelated dimensions that must be addressed proactively from project inception rather than retrofitted post-deployment [4]. Systematic mapping studies subsequently documented significant fragmentation in the SSE field, with the majority of research historically concentrated on narrow technical dimensions particularly computational energy efficiency without addressing holistic, multi-dimensional sustainability contributions across the full SDLC [5]. More recent systematic literature reviews confirmed the continued absence of comprehensive methodologies capable of measuring and assessing multi-dimensional sustainability contributions across all SDLC phases simultaneously [6].

Among the frameworks developed to address this holistic challenge, the E-SETGO framework represents the most comprehensively validated approach in current SSE literature. E-SETGO integrates six sustainability dimensions Environmental (E), Social (S), Economic (Ec), Technical (T), Organisational (O) and Governance (G) across six standard SDLC phases: Planning, Analysis/Design, Development, Testing, Deployment and Maintenance [7]. Through rigorous expert validation employing Lawshe's Content Validity Ratio (CVR) methodology with nine practitioners and academics, the framework identified 16 core practices ($CVR \geq 0.78$, near-unanimous expert consensus) and 8 conditional practices (75% agreement threshold), yielding a 24-practice catalog comprehensively mapped to all 17 SDGs through direct, enabling and indirect contribution mechanisms [8]. This SDG mapping demonstrated that conservative adoption of the 16 core practices alone addresses at least 12 of 17 SDGs across multiple

contribution pathways.

Despite this theoretical maturity, the practical implementation of SSE frameworks in real organisational contexts remains critically understudied. A persistent implementation gap exists between theoretically validated frameworks and their effective organisational adoption: practitioners acknowledge conceptual awareness of SSE principles but consistently cite unclear starting points, undefined adoption sequencing, lack of practical operationalisation tools, and insufficient organisational enablers as primary obstacles [9]. The E-SETGO framework's own published conclusions explicitly identify this gap, recommending that implementation studies beginning from low-complexity, low-barrier practices the "low hanging fruit" represent the critical empirically necessary next step [7]. Without such foundational implementation evidence, validated frameworks risk following a pattern common in software process research: technically sophisticated artifacts that fail to achieve organisational traction because the bridge from theory to practice was never systematically engineered.

This paper directly addresses that recommendation by designing a phased implementation strategy for E-SETGO core practices grounded in the low hanging fruit principle. Rather than prescribing simultaneous adoption of all 16 core practices an approach SSE adoption research indicates is organisationally unsustainable the proposed strategy systematically identifies, quantifies and sequences practices by their organisational adoption barrier profiles, enabling progressive capacity building. The design is anchored in two complementary real-world software development projects at Institut Teknologi PLN (ITPLN): the AMORA management information system serving as a controlled Learning Laboratory, and the Learning Management System (LMS) for ITPLN's Distance Learning (PJJ) undergraduate program serving as the green-field Main Case Study [14].

The primary scientific contributions are: (1) a multi-dimensional Adoption Barrier Score (ABS) prioritization matrix for all 16 E-SETGO core practices, operationalizing adoption barrier theory as a quantifiable sequencing instrument; (2) a dual pilot implementation design providing complementary maintenance-phase and green-field research contexts; (3) four purpose-built data collection instruments for empirical measurement of adoption rate, barrier identification, SDG contribution assessment, and team perception change; and (4) a pre-mapped SDG contribution framework establishing expected contribution profiles prior to empirical implementation. Collectively, these represent the first evidence-based operationalization strategy for E-SETGO in real organizational contexts.

2. Method

This research employs Design Science Research (DSR) as its overarching methodology, following Hevner et al.'s framework defining DSR as research aimed at creating innovative artifacts constructs, models, methods or instantiations intended to address identified .

organisational problems [10]. DSR is particularly appropriate here because the research objective is constructive rather than purely explanatory: the aim is to engineer a reproducible implementation operationalisation that bridges theory and practice. The research encompasses three primary DSR phases: (1) problem explication and motivation, (2) artifact design and development, and (3) design demonstration through pilot specification [11].

2.1. Structured Literature Review on SSE Adoption Barriers

A structured literature review was conducted to identify empirically grounded barriers to SSE practice adoption. Search terms combined "sustainable software engineering," "adoption barriers," "framework implementation," "green software," and "SDLC integration" across Scopus and Google Scholar, filtered to 2019–2025 publications. Seventeen papers met the inclusion criteria requiring empirical or expert-elicitation findings on SSE adoption barriers in organisational or project settings. Thematic analysis produced five barrier dimensions appearing consistently across independent studies: (1) Tool Availability (TA), availability of specialised measurement or profiling tools; (2) Knowledge and Expertise (KE), prerequisite domain skills and training; (3) Cultural Change Requirements (CCR), degree of behavioural or workflow change required; (4) Management Support Dependency (MSD), level of organisational approval or policy infrastructure needed; and (5) Time and Resource Overhead (TRO), additional time investment relative to standard development activities [9] [12] [13].

2.2. Adoption Barrier Score (ABS) Instrument Development

An Adoption Barrier Score (ABS) was developed for each of the 16 E-SETGO core practices across the five barrier dimensions. Each practice was rated on a three-point ordinal scale: 1 = Low barrier, 2 = Medium barrier, and 3 = High barrier. Evaluations were grounded in: (a) expert commentary from the E-SETGO validation study documenting reasons for lower consensus on certain practices [7]; (b) knowledge and tool prerequisites identifiable from each practice's implementation requirements; and (c) organisational change management and technology adoption literature [15]. The composite ABS was calculated as the unweighted arithmetic mean across five dimensions, producing scores from 1.0 (Very Low, immediately adoptable without preconditions) to 3.0 (High, requires substantial organisational enablers). Classification thresholds: Very Low (1.0–1.4), Low (1.5–1.9), Medium (2.0–2.4), High (2.5–3.0).

2.3. Pilot Project Selection Criteria

Two pilot projects were purposively selected against four pre-specified criteria: (1) active

development or maintenance activity within the 12-month research window; (2) researcher access enabling participant observation; (3) complementary SDLC phase coverage for cross-context comparative analysis; and (4) sufficient project scope for meaningful multi-practice implementation. The AMORA system satisfies criteria 1, 2 and 4 as an actively maintained management information system with the researcher embedded as a full team member in ITPLN's IT and Information Systems unit (PDSI) [14]. The LMS PJJ satisfies criteria 3 and 4 as a green-field project with documented multi-phase development requirements derived from ITPLN's formal distance learning program accreditation preparation, covering all six SDLC phases with diverse stakeholder groups including administration, faculty, students, and PLN Group industry partners [14].

2.4. Implementation Design Process

The phased implementation design was constructed through four sequential steps: (1) ABS-based practice prioritisation to establish evidence-grounded implementation sequencing; (2) SDLC phase alignment to synchronise practice deployment with natural project lifecycle milestones; (3) pre-implementation SDG contribution mapping applying the Direct/Enabling/Indirect three-mechanism framework from Firmansyah et al. [8]; and (4) data collection instrument development drawing on validated constructs from SSE adoption and technology adoption literature [9][15]. The resulting design integrates the ABS matrix, dual pilot specifications, 12-month timeline, four instruments, and evidence collection framework into a coherent, reproducible implementation blueprint.

3. Results and Discussion

3.1. Adoption Barrier Score Analysis and Prioritisation Matrix

Table 1 presents the complete ABS analysis for all 16 E-SETGO core practices. The distribution reveals a structured, non-random pattern corresponding closely to E-SETGO's dimensional validation findings: Social and Technical practices consistently achieve Very Low to Low ABS scores (1.0–1.4), reflecting their alignment with established software engineering best practices and the validation finding that these dimensions achieved 100% expert coverage with the strongest consensus. Conversely, the sole Environmental core practice (P6.Env) scores highest (ABS = 1.9), consistent with the 33.3% expert coverage and high rejection rates observed for Environmental practices in the validation study [7].

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Table 1. Adoption Barrier Score (ABS) Prioritisation Matrix for All 16 E-SETGO Core Practices

No.	Core Practice (Code)	SDLC Phase	Dimension	TA	KE	CCR	MSD	TRO	ABS
1	Knowledge Retention & Documentation (P6.Org)	Maintenance	Organisational	1	1	1	1	1	1.0 [VL]
2	Sustainability Objectives & Champion (P1.Org)	Planning	Organisational	1	1	1	1	1	1.0 [VL]
3	Continuous User Feedback & Engagement (P6.Soc)	Maintenance	Social	1	1	1	1	1.5	1.1 [VL]
4	Usability & User Satisfaction Testing (P4.Soc)	Testing	Social	1	1.5	1	1	1	1.1 [VL]
5	Stakeholder Inclusivity in Requirements (P1.Soc)	Planning	Social	1	1	1.5	1	1	1.1 [VL]
6	Maintainability / Scalability Criteria (P1.Tech)	Planning	Technical	1	1	1	1.5	1	1.1 [VL]
7	Modular, Extensible Architecture (P2.Tech)	Design	Technical	1	1.5	1	1	1.5	1.2 [L]
8	Comprehensive Regression Testing (P4.Tech)	Testing	Technical	1.5	1	1	1.5	1	1.2 [L]
9	QA Aligned with Organisational Standards (P4.Org)	Testing	Organisational	1	1.5	1	2	1	1.3 [L]
10	Maintenance Governance & Sustainability Audits (P6.Gov)	Maintenance	Governance	1	1.5	1.5	2	1	1.4 [L]
11	Planned Technology Upgrade Roadmap (P6.Tech)	Maintenance	Technical	1	1.5	1.5	1.5	1.5	1.4 [L]
12	User Training & Community Feedback Channels (P5.Soc)	Deployment	Social	1.5	1.5	1	2	2	1.6 [M]
13	Life-Cycle Cost-Benefit Analysis (P1.Econ)	Planning	Economic	1	2	1.5	2	2	1.7 [M]
14	DevOps Monitoring for System Reliability (P5.Tech)	Deployment	Technical	2	2	1.5	1.5	1.5	1.7 [M]
15	Team Well-Being & Collaborative Practices (P3.Soc)	Development	Social	1	2	2.5	2	1.5	1.8 [M]

No.	Core Practice (Code)	SDLC Phase	Dimension	TA	KE	CCR	MSD	TRO	ABS
16	Periodic Code Refactoring for Efficiency (P6.Env)	Maintenance	Environmental	2.5	2	1.5	1.5	2	1.9 [H]
Dimensions, TA: Tool Availability; KE: Knowledge & Expertise; CCR: Cultural Change Requirement; MSD: Management Support Dependency; TRO: Time & Resource Overhead. Scale: 1=Low, 2=Medium, 3=High. ABS Tiers: [VL]=Very Low 1.0-1.4 [L]=Low 1.5-1.9 [M]=Medium 2.0-2.4 [H]=High 2.5+.									

The ABS distribution reveals a critical structural pattern: all six practices achieving Very Low ABS (1.0–1.1) belong exclusively to the Social and Organisational dimensions, sharing the characteristic that they formalise activities which mature development teams already perform informally. This aligns directly with Rogers' innovation diffusion theory, where compatibility with existing values and practices is the most powerful predictor of adoption rate [15]. In contrast, the sole Environmental core practice (P6.Env, ABS = 1.9) reflects the field-wide barrier documented in both E-SETGO's validation and the broader SSE adoption literature: green refactoring measurement and energy efficiency optimisation require specialised profiling tools and domain expertise not yet mainstream in software development education or standard organisational practice environments [6] [7].

3.2. Low Hanging Fruit Identification and Theoretical Justification

Three core practices emerge as universal, context-independent immediate entry points for E-SETGO implementation, achieving composite ABS scores of 1.0 across all five barrier dimensions simultaneously:

P6.Org, Knowledge Retention and Documentation (ABS: 1.0 Very Low). This practice requires no specialised tools internal wikis, runbooks, and knowledge repositories are achievable with standard office productivity platforms available in any organisational context. Zero domain knowledge prerequisites beyond baseline documentation competency, no behavioural culture change, no management approval beyond team-level agreement, and negligible per-cycle time overhead when integrated into standard sprint retrospectives or patch-cycle activities. Its Maintenance phase placement makes it immediately applicable to any active project regardless of development stage. SDG contribution: Enabling for SDG 4 (Quality Education, workforce capacity building) and Enabling for SDG 17 (Partnerships, institutional knowledge transfer) [8].

P1.Org, Sustainability Objectives and Champion (ABS: 1.0 Very Low). Designating a sustainability champion and defining three to five measurable project sustainability objectives

requires only organisational consensus and charter documentation achievable within a single structured team meeting without specialised software, training, or management hierarchy involvement. This practice serves as the organisational anchor legitimising all subsequent E-SETGO practices within the team's project vocabulary and establishing accountability for sustainability outcomes. Its ABS of 1.0 across all five dimensions is unique among all 16 core practices, reflecting the purely organisational-volitional nature of the commitment. SDG contribution: Direct for SDG 8 (Decent Work, organisational capacity building) and Enabling for SDG 17 (Partnerships, cross-stakeholder sustainability alignment) [8].

P6.Soc, Continuous User Feedback and Engagement (ABS: 1.1 Very Low). Establishing structured feedback channels requires only ubiquitous digital survey tools, minimal expertise, no organisational policy infrastructure, and low per-iteration time investment. The practice simultaneously serves project quality objectives and generates recurring documentary SDG contribution evidence. Its marginally higher TRO score (1.5 vs. 1.0) reflects recurring collection cycle investment, minimal in absolute terms. SDG contribution: Indirect for SDG 16 (Strong Institutions public service satisfaction) and Enabling for SDG 10 (Reduced Inequalities inclusive digital service delivery) [8].

These three practices embody the compatibility principle from innovation diffusion theory [15]: the most effective SSE adoption entry point is not introducing sustainability as a new organisational burden, but conducting a sustainability audit of existing informal practices identifying sustainability-relevant behaviours that already occur informally and formalising them as E-SETGO practices to build adoption momentum before introducing practices requiring genuine behavioural or technical change.

3.3. Dual Pilot Strategy Design

The dual pilot strategy is designed to satisfy two simultaneously held research requirements: controlled instrument refinement in a low-risk insider environment and comprehensive high-ecological-validity data generation suitable for academic publication.

Pilot A, AMORA System (Learning Laboratory). The AMORA system an active management information system built on PHP/MySQL architecture, deployed on ITPLN's server infrastructure, and maintained through patch-based iterative cycles by the PDSI unit provides the controlled Learning Laboratory context. Researcher insider access as a full team member minimises access confounds that typically compromise SSE adoption study validity.

Implementation targets the three immediate low-hanging-fruit practices (P6.Org, P1.Org, P6.Soc) plus P4.Soc (Usability Testing, ABS 1.1) across an eight-week structured cycle concurrent with ongoing maintenance activities. Pilot A's primary research function is methodological: generating refined ABS weightings, validating instrument operationalisation, producing a preliminary adoption barrier taxonomy, and identifying practice-specific implementation constraints that inform Pilot B's final design.

Pilot B, LMS PJJ ITPLN (Main Case Study). The LMS for ITPLN's Distance Learning undergraduate program represents the ideal main case study: a green-field project with formally documented institutional support, heterogeneous stakeholder groups including administration, faculty, curriculum design teams, students, and PLN Group industry partners, and a multi-phase development timeline exceeding ten months documented in ITPLN's formal accreditation preparation materials [14]. This configuration enables E-SETGO practices to be embedded from the Planning phase the most complete and research-valuable implementation scenario. Pilot B targets ten core practices across five SDLC phases: P1.Org, P1.Soc, P1.Tech, P1.Econ (Planning); P2.Tech (Design); P4.Soc, P4.Tech, P4.Org (Testing); P5.Soc (Deployment); P6.Org, P6.Soc (Maintenance). Environmental practices are explicitly deferred pending organisational readiness assessment at Month 9, embodying the phased low hanging fruit principle in the main case study design itself.

3.4. Data Collection Instruments

Four complementary measurement instruments operationalise the study's four research questions:

Instrument A, Adoption Rate Checklist: A biweekly tripartite checklist (Fully Adopted / Partially Adopted / Not Adopted) assessed at each sprint or maintenance iteration, measuring practice implementation against verifiable documentary evidence. Non-adoption entries require mandatory concurrent barrier documentation to ensure barrier data collection is prospective rather than retrospective.

Instrument B, Adoption Barrier Interview Guide: A six-question semi-structured interview guide administered to all development team members at research months 3 and 9, designed to explore practice-specific barriers using critical incident technique, identify cross-practice adoption patterns, capture perception changes over time, and elicit practitioner-recommended

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implementation sequences. Transcripts will be analyzed using thematic coding with two independent coders to establish inter-rater reliability.

Instrument C, SDG Contribution Assessment Rubric: Adapted from Firmansyah et al.'s three-mechanism framework [8], this rubric evaluates each implemented practice's realized contribution type Direct, Enabling or Indirect to its pre-mapped SDGs using project artifacts as evidence. Direct contributions require artifacts demonstrating immediate measurable SDG indicator impact; Enabling contributions require artifacts demonstrating created conditions for SDG achievement; Indirect contributions require artifacts documenting facilitation of third-party SDG contributions.

Instrument D, Pre-Post Team Perception Survey: A seven-item five-point Likert scale survey administered before implementation commencement and at the six-month mark, measuring sustainability awareness, practice relevance perception, burden perception, team support, long-term adoption willingness, and SDG contribution understanding. Pre-post differences will be analyzed using Wilcoxon signed-rank tests given the ordinal scale and anticipated small sample sizes.

3.5. Pre-Implementation SDG Contribution Mapping

Table 2 presents the pre-implementation SDG contribution mapping for core practices targeted in Pilot B, establishing expected contribution profiles by applying the Direct/Enabling/Indirect classification framework from Firmansyah et al. [8].

Table 2. Pre-Implementation SDG Contribution Mapping for Pilot B Core Practices

Core Practice	Primary SDGs	Mechanism	Contribution Justification
P1.Org: Sustainability Objectives & Champion	SDG 8, 17	Direct	Builds institutional capacity for sustainable organisational practices and cross-stakeholder alignment toward shared development goals.
P1.Soc: Stakeholder Inclusivity in Requirements	SDG 10, 5, 16	Direct	Structured inclusion of marginalised stakeholder groups in requirements ensures digital equity and accessible service design for all demographics.
P1.Tech: Maintainability/Scalability Criteria	SDG 9	Enabling	Non-functional requirements for maintainability create software infrastructure capable of sustained, reliable long-term service delivery.

Core Practice	Primary SDGs	Mechanism	Contribution Justification
P1.Econ: Life-Cycle Cost-Benefit Analysis	SDG 8, 12	Enabling	Total cost of ownership analysis drives resource efficiency decisions across the full project lifecycle, reducing unnecessary computational consumption.
P2.Tech: Modular, Extensible Architecture	SDG 9, 12	Enabling	Modular architecture extends system longevity, reduces full-system replacement frequency, and minimises computational resource waste.
P4.Soc: Usability & Accessibility Testing	SDG 10, 4	Direct	Usability testing with diverse user groups ensures digital inclusion and WCAG accessibility compliance for all user demographics.
P4.Tech: Comprehensive Regression Testing	SDG 9	Enabling	Rigorous regression testing ensures infrastructure reliability for continuous, uninterrupted digital service provision over time.
P4.Org: QA Aligned with Organisational Standards	SDG 16	Enabling	Standards-aligned quality assurance institutionalises accountability and transparency in software governance processes.
P5.Soc: User Training & Community Feedback	SDG 4, 17	Direct	End-user digital literacy development and structured community feedback loops amplify the educational and social impact of digital services.
P6.Org: Knowledge Retention & Documentation	SDG 4, 17	Enabling	Systematic documentation sustains team competency and enables institutional knowledge transfer across personnel transitions.
P6.Soc: Continuous User Feedback & Engagement	SDG 16, 10	Indirect	Sustained feedback loops incrementally improve satisfaction with digital public services and promote inclusive digital access over time.

The pre-implementation mapping reveals that a low-barrier-driven selection of ten core practices addresses six SDGs with a substantial proportion of Direct contributions—countering the intuition that low-barrier practices necessarily produce lower-quality SDG contributions. Social and Organizational practices with the lowest ABS scores tend to generate Direct contributions because they involve immediate human-centred actions with outcomes traceable to specific SDG indicators, while higher-barrier Environmental practices more often produce Enabling contributions requiring additional tooling infrastructure to generate measurable evidence [8].

3.6. Phased 6-Month Implementation Timeline

The 6-month implementation timeline organizes deployment in four progressive adoption waves aligned with ABS priority tiers and natural project milestones. Wave 1 (Months 1–2) activates the AMORA Learning Laboratory, implementing P6.Org, P1.Org and P6.Soc with concurrent Instruments A and B data collection, alongside LMS PJJ stakeholder identification. Wave 2 (Months 2–3) deploys Low-ABS practices aligned with LMS PJJ Planning and Design phases: P1.Soc, P1.Tech, P1.Econ, and P2.Tech. Wave 3 (Months 4–5) implements Medium-ABS practices during LMS PJJ Testing and Deployment phases P4.Soc, P4.Tech, P4.Org, and P5.Soc with Instrument D mid-survey at Month 6. Wave 4 (Months 4–6) addresses the Maintenance phase entry, with P6.Gov and P6.Env conditional on organizational readiness assessment at Month 9, followed by comprehensive cross-instrument data analysis, barrier taxonomy development, SDG contribution evidence compilation, and manuscript preparation.

3.6. Discussion: Theoretical and Practical Implications

The ABS instrument contributes theoretically to SSE adoption research by providing the first reproducible, multi-dimensional, quantitative barrier assessment tool calibrated specifically for E-SETGO practices. Prior SSE adoption research has described barriers primarily in qualitative or categorical terms [9] [12] [13]; ABS operationalizes these descriptions into a continuous scoring instrument enabling systematic comparative prioritization, a methodological advance enabling the field to move from barrier description to evidence-based implementation sequencing.

The dual pilot design advances SSE case study methodology beyond the predominant single-project design that limits external validity in existing implementation literature [13] [15]. By pairing a controlled insider Learning Laboratory with a high-ecological-validity green-field Main Case Study within the same institution, the design enables within-institution comparison of adoption dynamics across SDLC entry points while controlling for organisational culture and management context. This complementary design is directly replicable by other institutions initiating E-SETGO or similar SSE framework adoption.

A critical practical implication from the ABS analysis is that effective SSE implementation should not begin with environmental metrics, carbon accounting, or energy profiling despite the Environmental dimension having the most direct climate-action relevance. The Environmental dimension's consistently high barrier scores confirm the field's diagnosis that green coding and energy efficiency testing require tooling, standards, and educational infrastructure not yet

mainstream in organisational software development practice [6] [12]. Attempting to initiate E-SETGO with Environmental practices risks early adoption failure, creating negative organisational associations with the entire framework. The phased, low-hanging-fruit approach buffers against this risk by building demonstrated organisational value through Social and Technical practices first creating a positive reinforcement cycle where early adoption success motivates investment in progressively more complex practices.

The pre-mapped SDG contribution analysis reveals that low-barrier practices are not merely convenient starting points they produce among the most traceable and documentable SDG contributions. P1.Soc (Stakeholder Inclusivity) directly addresses SDG 10 and SDG 5 through verifiable stakeholder representation artifacts; P4.Soc (Usability Testing) directly addresses SDG 10 through WCAG compliance documentation. This suggests that low-barrier practices can serve as high-quality SDG reporting foundations for organisational sustainability disclosures, providing immediate value that motivates continued investment in higher-barrier practices.

4. Conclusion

This paper presents the first evidence-based phased implementation design for E-SETGO core practices in real-world software development projects, directly addressing the implementation gap between framework validation and organisational adoption. The central scientific contribution is the Adoption Barrier Score (ABS) prioritisation instrument a five-dimension, 16-practice quantitative barrier assessment producing reproducible composite scores that enable evidence-grounded implementation sequencing decisions rather than reliance on intuition or wholesale adoption attempts.

The ABS analysis identifies three practices as universal, context-independent immediate low-hanging fruit: P6.Org (Knowledge Retention), P1.Org (Sustainability Objectives and Champion), and P6.Soc (Continuous User Feedback) all achieving ABS of 1.0 across all five barrier dimensions, indicating adoptability without specialised tools, training, management approval, or cultural change preconditions. The dual pilot design at ITPLN pairs a maintenance-phase Learning Laboratory (AMORA) with a green-field Main Case Study (LMS PJJ), generating complementary data streams for instrument refinement and empirical publication. The pre-implementation SDG mapping establishes that ten low-barrier core practices collectively address

six SDGs, SDG 4, 8, 9, 10, 16, and 17 with predominantly Direct and Enabling contribution mechanisms, providing organisational sustainability communication value proportionate to the modest adoption investment required.

Current limitations as a design study include: ABS scores represent pre-implementation analytical estimates rather than multi-organisational empirical measurements; SDG contribution classifications are prospective mappings rather than documented implementation outcomes; and the single-institution pilot design limits external generalisability. These limitations define the research agenda for subsequent phases: empirical implementation and measurement across both pilots, cross-institutional ABS validation through expert panel assessment, and expansion to additional organisational contexts for external validity testing.

Future research directions include: (1) full empirical implementation generating the first empirical E-SETGO adoption dataset; (2) development of an evidence-based E-SETGO Practitioner's Implementation Guide incorporating quantified adoption patterns and barrier taxonomies; (3) multi-organisational ABS validation across diverse organisational types, scales, and national contexts; (4) longitudinal E-SETGO Maturity Model development enabling organisations to systematically assess and advance sustainable software engineering capabilities; and (5) investigation of organisational enabler packages reducing barrier scores for high-ABS practices through targeted tool development, training curricula, and policy standards. Together, these constitute a research programme transforming the E-SETGO framework from a theoretically validated artifact into an empirically supported, practically adopted standard contributing to the ICT sector's role as a net positive contributor to global sustainable development.

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