

Core Dilemmas and Resolution Paths in Software Project Management under Sustainability Constraints: An Analysis Based on Global Practices

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ABSTRACT

This study systematically investigates the core dilemmas and resolution paths for software project management under sustainability constraints. Drawing on a comprehensive systematic literature review of recent peer-reviewed articles, international standards, and authoritative industry and policy reports, this research identifies and analyzes the lifecycle-wide challenges faced by software projects in integrating sustainability. The findings reveal a series of critical dilemmas, including the initial conflict between sustainability and business goals, the gap in standardized sustainability metrics, the dual constraints of technology and team capabilities during development, stakeholder coordination and acceptance issues at delivery, the trade-off between low-carbon operations and service quality, and the lack of effective evaluation and experience capitalization at project closure. In response to these dilemmas, this paper proposes a multi-dimensional, scenario-adaptive solution system, offering specific, actionable paths for different stages of the project lifecycle. Furthermore, it constructs a three-dimensional adaptation framework that considers enterprise scale—encompassing large, medium, and start-up organizations—and project management models such as Agile and Waterfall, providing targeted guidance for global software project managers and organizations. This research enriches the theoretical framework for sustainable software engineering and offers a practical roadmap for the industry to navigate the complexities of integrating sustainability into software project management, ultimately contributing to the broader goals of digital and global sustainability.

Keywords: Sustainable Software Engineering, Software Project Management, Sustainability Constraints, Dilemma Analysis, Solution Path

INTRODUCTION

The global imperative for sustainable development, epitomized by the United Nations' Sustainable Development Goals, has catalyzed a paradigm shift across virtually every economic sector (United Nations, 2015). The Information and Communication Technology (ICT) sector, and by extension the software industry, occupies a pivotal yet paradoxical role in this transition. Software and digital services act as powerful enablers of sustainability through innovation and efficiency gains, while simultaneously being significant consumers of energy and physical resources (International Telecommunication Union, 2022; Verdecchia et al., 2023). The global data center industry alone accounts for approximately 1% to 2% of worldwide electricity consumption, a figure projected to rise substantially as demand for cloud services and artificial intelligence intensifies (International Energy Agency [IEA], 2024). Consequently, the software industry faces mounting pressure from regulators, investors, and clients to align its development practices with sustainability principles.

This pressure entails a fundamental evolution in how software projects are conceived, planned, and executed. For decades, software project management has been governed by the so-called “iron triangle” of time, cost, and scope, a framework that is increasingly recognized as insufficient for navigating contemporary complexities (Project Management Institute [PMI], 2025a; Silvius et al., 2017). Moving beyond this triumvirate requires

integrating Environmental, Social, and Governance (ESG) criteria as a cornerstone of project success, transforming sustainability from a peripheral compliance concern into a strategic driver of value creation (Soares et al., 2024). The emergence of frameworks such as the Green Software Foundation's [GSF] Software Carbon Intensity specification and the growing adoption of ISO 14001 environmental management standards reflect the industry's gradual recognition of this imperative (GSF, 2024a; International Organization for Standardization [ISO], 2015).

However, the practical integration of sustainability into software project management remains fraught with multifaceted challenges. Project teams often find themselves navigating a landscape of conflicting priorities, where immediate budgetary pressures and aggressive delivery timelines overshadow longer-term sustainability objectives (Condori-Fernandez & Lago, 2018; Mehra et al., 2022). This situation is compounded by a notable absence of standardized frameworks and metrics specifically designed to guide the implementation and measurement of sustainability within the software project context (Calero & Piattini, 2017). While research has addressed sustainable software engineering and project management as independent domains, a significant gap persists in understanding the specific dilemmas that emerge at their confluence. These challenges are far from uniform, as they vary considerably with organizational scale and the project management methodology employed (Khalifeh et al., 2023; König et al., 2025).

This paper aims to bridge this critical gap by systematically identifying and analyzing the core dilemmas encountered throughout the software project lifecycle when operating under sustainability constraints. Drawing upon a comprehensive review of recent academic literature, authoritative industry reports, and prevailing global standards, this research moves beyond a superficial enumeration of challenges to conduct a deep causal analysis. The study further proposes a system of actionable, scenario-adaptive solution paths designed to effectively address the identified dilemmas, tailored to the distinct needs of large tech enterprises, medium-sized companies, and start-ups, as well as to the dominant project management methodologies of Agile and Waterfall. This practical guidance is intended to empower project managers and organizations to more adeptly navigate the complexities of sustainable software project management.

RESEARCH METHODOLOGY

This study employs a systematic literature review as its core research method, systematically collecting, synthesizing, and analyzing existing literature and data from a diverse range of authoritative sources. The objective is to build a holistic understanding of the integration of sustainability into software project management, identify the principal dilemmas, and derive actionable resolution paths. This approach transcends a conventional literature review by performing in-depth analysis and interpretation of secondary data to generate novel insights and a coherent conceptual framework, which is particularly suited to exploring a complex, multi-faceted topic in a global context (Snyder, 2019; Xiao & Watson, 2019).

To ensure methodological transparency, replicability, and rigor, a structured protocol was established prior to the review, with explicit inclusion and exclusion criteria governing source selection.

Inclusion Criteria:

1. Peer-reviewed academic articles published between 2018 and 2026, focusing on sustainable software engineering or sustainable project management, to capture the latest research trends;
2. Seminal theoretical works published before 2018 that form the foundational backbone of the field;
3. Authoritative industry reports, white papers, and standard documents from globally recognized institutions and leading technology enterprises;
4. Sources covering diverse organizational scales (large enterprises, SMEs, start-ups) and regional contexts (both developed and developing economies) to ensure global representativeness.

Exclusion Criteria:

1. Non-English publications due to language constraints;
2. Abstract-only submissions or grey literature lacking sufficient empirical or practical evidence;
3. Studies unrelated to software project management or sustainability dimensions.

The selection of data sources was carefully curated to ensure authoritativeness, relevance, and a strong representation of contemporary practices. While the research places a primary emphasis on English-language publications from 2023 to 2026 to capture the most recent industry trends and research advances, the literature search was not strictly limited to this narrow window. In line with the inclusion criteria, we also incorporated peer-reviewed articles from the 2018–2022 period to ensure a comprehensive coverage of the field’s recent evolution, as well as seminal theoretical works published before 2018 that form the foundational backbone of the field. Academic literature was retrieved from core digital libraries, including the ACM Digital Library, IEEE Xplore, and Scopus, using search keywords such as “Sustainable Software Engineering,” “Green IT,” “Software Project Management,” “Sustainability Constraints,” and “ESG in technology.” The selection was restricted to peer-reviewed journal articles and high-impact international conference papers.

Industry reports and standards were sourced from leading international institutions, including the IEEE, the Project Management Institute (PMI), and various technology industry outlooks. To ground the analysis in real-world practices, sustainability reports and white papers were reviewed from global technology leaders such as Amazon Web Services (AWS), Microsoft, and Google. Furthermore, policy and standard documents were incorporated from key international bodies, including the United Nations Conference on Trade and Development (UNCTAD), the International Organization for Standardization (ISO), the Organization for Economic Co-operation and Development (OECD), and the Green Software Foundation (GSF).

Data analysis proceeded through a rigorous, step-by-step structured approach:

1. Concept Combing: Unifying definitions of core concepts such as “sustainability constraints” and “green software” across different sources to eliminate terminological ambiguity;
2. Theory Integration: Synthesizing existing theoretical lenses including Sustainable Software Engineering, Stakeholder Theory, and the Resource-Based View to build the research's theoretical backbone;
3. Practice Summarization: Analyzing global practical cases from both developed and developing economies to extract real-world challenges and solutions;
4. Dilemma Extraction: Systematically identifying recurring core challenges across the project lifecycle;
5. Causal Analysis: Exploring the root causes behind each identified dilemma, distinguishing between cognitive, institutional, and technological factors.

To ensure reliability and validity, triangulation was used to cross-reference findings across academic, industry, and policy sources (Denzin, 2017). To facilitate systematic analysis, a structured data coding process was implemented, following established systematic review protocols (Kitchenham & Charters, 2007). Two independent researchers coded the included sources against a pre-defined coding framework, extracting key information including: (1) identified sustainability-related dilemmas in software projects; (2) proposed or implemented solutions; (3) contextual factors such as organizational scale, project methodology, and regional context. Inter-coder consistency was high, with discrepancies resolved through consensus discussion.

LITERATURE REVIEW

The conceptual landscape of sustainable software project management has grown considerably more nuanced. It is now understood as a lifecycle-wide approach that integrates the traditional project constraints of scope, time, and cost with the imperatives of environmental stewardship, social value, and transparent governance (Soares et

al., 2024). This holistic framing extends far beyond green coding practices to encompass the entire project ecosystem, aiming to produce software that is not merely efficient but also responsible (PMI & GPM Global, 2024). The concept has been extended to include a fourth dimension of technical sustainability, acknowledging that software systems must remain maintainable, evolvable, and resilient to avoid creating technical debt that undermines long-term sustainability objectives (Andrikopoulos et al., 2022; Moreira et al., 2025).

Sustainability constraints, as a distinct category, refer to the objective restrictions and subjective requirements imposed by a project's sustainability goals (Ebbesen & Hope, 2013). These constraints introduce new layers of complexity and create intricate trade-offs with traditional project objectives, a tension documented in empirical studies across multiple sectors (Kocabiyikoğlu et al., 2025).

Several theoretical traditions provide the analytical lens for this study. Sustainable Software Engineering (SSE) theory offers the technical underpinnings (Penzenstadler et al., 2014), with recent research converging on tools and techniques for creating greener software, such as sustainable architectures (Matthew et al., 2024) and AI-driven optimization (Verdecchia et al., 2023). Software Project Management theory, particularly the evolution from Waterfall to Agile methodologies, provides the procedural context (Leong et al., 2023). Recent studies suggest hybrid models may be particularly effective for managing dynamic sustainability goals (Piwowar-Sulej & Iqbal, 2024). Stakeholder Theory is vital for understanding the social dimension of sustainability (Parmar et al., 2010), while the Resource-Based View (RBV) of the firm provides a strategic lens, suggesting that capabilities in sustainable project management can be a source of competitive advantage (Barney, 1991; Bhandari et al., 2022). More recently, the concept of planetary boundaries has been introduced, arguing that responsible software development must be cognizant of broader biophysical limits (König et al., 2025).

Global practices in adopting sustainability vary significantly by organizational context. Large technology enterprises such as Microsoft and Google are typically at the vanguard, investing heavily in strategic initiatives (Google, 2025; Microsoft, 2025a). However, even for these leaders, translating high-level commitments into project-level practices remains inconsistent (Boston Consulting Group, 2022). Medium-sized enterprises tend to adopt a more fragmented approach, often lacking the resources for a comprehensive strategy (Organization for Economic Co-operation and Development [OECD], 2024a). Start-ups face the highest barriers, with practices frequently driven by external pressure rather than strategic intent. This stratification of sustainability maturity is a critical factor shaping the dilemmas explored in this paper.

The choice of project management methodology also profoundly shapes sustainability integration. Agile methodologies, with their iterative cycles and adaptive planning, align well with the evolving nature of sustainability goals (Zakrzewska et al., 2022). The Waterfall model offers greater upfront rigor but lacks flexibility. Emerging research on “DevGreenOps” suggests that sustainability can be effectively embedded as a cross-cutting concern in continuous integration pipelines (Moyle, 2023). Despite a growing body of scholarship, a unified, systematic framework to analyze lifecycle-wide dilemmas and provide actionable, scenario-adaptive solutions remains a critical research gap this paper aims to address.

Core Dilemmas and Deep-Seated Causes of Software Project Management under Sustainability Constraints

The integration of sustainability introduces a series of interconnected dilemmas that permeate the entire project lifecycle. This section dissects six core dilemmas and investigates their root causes.

Initiation Stage: The Sustainability–Business Goal Conflict

A foundational dilemma emerges during project initiation from the perceived conflict between sustainability objectives and conventional business goals. Sustainability initiatives are frequently characterized by decision-makers as activities that inflate initial costs and extend delivery timelines, clashing with near-term imperatives of profitability and market positioning (Soares et al., 2024). This characterization carries real organizational weight, as many CIOs are strategically reining in costs even as IT operations drive up carbon emissions (Computer Weekly, 2025).

This dilemma is particularly pronounced in emerging markets, where short-term survival often overrides long-term strategic investments. A 2024 industry survey of Indian SMEs found that 42% of firms perceive the payback period of sustainability investments as too lengthy, while 78% cite cost reduction as the primary driver for adoption, highlighting the tension between long-term sustainability goals and short-term financial pressures (SIDBI & Dun & Bradstreet, 2024). For example, the Indian conglomerate Ashapura Group overcame this barrier by partnering with Datamatics to implement a cloud migration project, which delivered a 40% improvement in overall performance and ROI over a six-year period. This case exemplifies how overcoming short-term IT infrastructure constraints can unlock significant business performance gains in resource-constrained contexts, enabling improved operational agility, reduced system downtime, and consolidated data environments that facilitate real-time decision-making (Datamatics, 2024).

The root causes of this dilemma are multilayered. At the cognitive level, there is frequently an organizational failure to recognize and quantify the long-term financial value of sustainability investments, such as enhanced brand equity, improved customer loyalty, and reduced regulatory risk (Lyneis & Sterman, 2016; Hmaitane et al., 2022). At the institutional level, most project evaluation and portfolio management frameworks continue to prioritize short-term financial metrics and lack formal mechanisms for assessing sustainability-related value creation (Silvius et al., 2017). Resource constraints compound this issue, particularly for SMEs.

Planning Stage: The Sustainability Standard Gap and Indicator Design Challenge

In the planning stage, project teams encounter the dilemma arising from the absence of unified, industry-specific standards for sustainable software development. Without such standards, it is exceedingly difficult to formulate sustainability indicators that are simultaneously quantifiable, operationally tractable, and meaningfully aligned with project objectives (Calero & Piattini, 2017; Reis et al., 2025). The resulting metrics are often either too generic to guide project decisions or too idiosyncratic to be comparable across projects. The IEEE Standards Association (2025) has highlighted this gap. The GSF's (2024a) SCI specification is a key effort to address this, but its adoption remains uneven and it primarily covers carbon metrics, not full ESG needs. Furthermore, most project managers lack formal training in sustainability metric design, and a lack of user-friendly design tools further hinders effective sustainability project management (Silvius & Schipper, 2014; Oyedeji et al., 2018).

Development Stage: The Dual Constraint of Technology and Team Capability

During development, a dual-constraint dilemma emerges at the intersection of technological immaturity and human capability gaps. The adoption of sustainable development practices is frequently impeded by the relative immaturity, performance overhead, or architectural incompatibility of available green tools with existing systems (Atadoga et al., 2024; Reis et al., 2025). Developers working with legacy systems face particular challenges, as retrofitting sustainability often requires substantial refactoring. At the same time, a significant skills gap persists within development teams. Formal training in sustainable software engineering remains rare in both academic programs and corporate initiatives, and the pace of tooling evolution means even motivated developers struggle to maintain currency (Verdecchia et al., 2023; Moreira et al., 2025). From an institutional perspective, this dilemma reflects a broader disconnection between academic curricula and industry needs, as well as a tendency to treat sustainability training as discretionary rather than essential (König et al., 2025).

Delivery Stage: Insufficient Stakeholder Coordination and Absent Acceptance Standards

At the delivery stage, projects frequently encounter the dilemma of misaligned stakeholder expectations and the absence of formal sustainability acceptance criteria. Key stakeholders often hold divergent expectations regarding sustainability performance, and without an effective early engagement mechanism, these differences surface only during acceptance testing, when the cost of addressing them is highest (Moreira et al., 2025). Deloitte (2023) has observed that the vast majority of software project acceptance processes currently lack any sustainability-related criteria, meaning sustainability performance carries no formal weight in determining project success.

This gap is even wider in developing countries. In Nigeria, government data reveals that over half of public sector IT projects—56 percent—have failed to meet their intended objectives, with many projects lacking

dedicated design phases, user needs analysis, or integration plans with existing systems before implementation (NITDA, 2025). Similarly, a case study of a major IT services vendor in South Africa found that sustainability was rarely considered in project planning, with barriers including the absence of formal green IT policies, unclearly defined governance frameworks, and a lack of sustainability performance management in project delivery processes (Muranganwa & Naidoo, 2023).

This institutional vacuum has cognitive roots as well. Many client organizations continue to define project value predominantly in terms of functional features, viewing sustainability as a desirable but non-essential enhancement (Soares et al., 2024). The absence of sustainability criteria from standard contract templates perpetuates this dynamic.

Operation and Maintenance Stage: Low-Carbon Operations versus Service Quality

In the operation and maintenance stage, a persistent trade-off emerges between minimizing energy consumption and maintaining service quality. Energy efficiency measures such as server consolidation and aggressive auto-scaling can, if improperly calibrated, introduce latency or compromise system resilience under peak demand (Amazon Web Services [AWS], n.d.). This tension is particularly acute in high-concurrency environments where even marginal performance degradation carries significant commercial consequences (Wang et al., 2024). While green operational technology has advanced considerably, these solutions have not yet fully resolved the performance–efficiency trade-off. The absence of dual assessment systems that reward operations teams for both sustainability performance and service quality creates an institutional incentive structure that consistently favors performance over efficiency (Hanus et al., 2023).

Closure Stage: Sustainability Evaluation and Experience Capitalization

At project closure, the dilemma lies in the absence of effective mechanisms for evaluating sustainability impact and capturing lessons learned. Without quantifiable models for assessing sustainability outcomes, it is extremely difficult to determine if objectives were achieved, to calculate the return on sustainability investment, or to build the evidence base for future commitments (PMI, 2025b). This evaluation gap is compounded by a knowledge management failure; most organizations lack formal systems for capturing and disseminating sustainability-related lessons, resulting in a “practice island” effect where valuable experiential knowledge is lost when teams disperse (Oyedeji et al., 2025). Without a cumulative body of documented practice, the field as a whole is impeded in its ability to develop evidence-based guidance (GSF, 2025a).

A System Of Scenario-Adaptive Solution Paths

To effectively address these dilemmas, a systematic and scenario-adaptive approach is essential. The paths proposed here are designed to be practical across different enterprise scales and project management methodologies.

Initiation Stage: Reframing Sustainability as a Value Driver

The central solution to the initiation-stage dilemma is to reframe sustainability from a cost center into a demonstrable value driver through structured business cases. Project managers should build robust, quantified arguments that capture the long-term financial benefits of sustainability, including enhanced brand equity, improved access to ESG-linked financing, and risk mitigation (Nasdaq, 2024; Ma et al., 2025). Operationally, this requires the formal incorporation of a “Sustainability Feasibility Analysis” into project initiation documentation and the adoption of industry-standard assessment tools like the PMI Sustainability Value framework (Weninger, 2012). For large enterprises, bespoke value models can be developed; for SMEs, accessible templates from open-source frameworks provide a practical starting point (GSF, 2025b).

For organizations in developing countries, additional support mechanisms are critical. International development agencies and industry bodies can provide subsidized access to sustainability training and simplified business case templates, helping local SMEs overcome the information and resource barriers that prevent them from recognizing the long-term value of sustainability investments (Shukla & Gautam, 2025).

Planning Stage: Building a Standardized Yet Adaptive Sustainability Indicator System

The solution here centers on developing a standardized, ESG-structured sustainability indicator system adapted to the software project context. Drawing on emerging standards like the GSF's (2024a) SCI specification, such a system should provide indicators that are measurable, auditable, and meaningfully connected to sustainability outcomes. Environmental indicators might encompass energy consumption per feature and scope 3 emissions; social indicators could address digital inclusion and data privacy; and governance indicators might cover ethical AI practices (Microsoft, 2026; Socialsuite, 2025).

To enhance practical usability, project teams can leverage ready-to-use tools such as the Green Software Foundation's open-source SCI Calculator, which provides a standardized, no-cost template for measuring and tracking software carbon intensity. This tool requires minimal technical expertise, making it accessible even for small start-ups and teams in resource-constrained regions (GSF, 2024a).

Agile projects can leverage sprints to progressively refine indicators, while Waterfall projects benefit from a comprehensive upfront indicator design integrated into requirements specification.

Development Stage: Technology Empowerment and Capability Development

Resolving the development stage's dual constraints requires combining active technology empowerment with systematic capability development. The technology dimension involves establishing a curated sustainable technology library—a repository of vetted, low-overhead green tools, frameworks, and architectural patterns that teams can adopt with confidence, reducing experimentation costs (GSF, 2024b). The capability dimension requires investment in structured, blended learning programs to equip development teams with the skills needed for sustainable software engineering, drawing on resources from professional bodies (Microsoft, 2025b; GSF, 2026). Embedding sustainability-oriented user stories and review checkpoints into Agile ceremonies offers a structural mechanism for capability development through practice.

Delivery Stage: Stakeholder Coordination Mechanisms and Acceptance Standard Reform

The delivery-stage dilemma requires establishing formal stakeholder coordination mechanisms and reconstructing project acceptance standards to include sustainability criteria. Convening all key stakeholders at the project's outset to co-create a shared understanding of sustainability goals is a prerequisite for avoiding misalignment. The outputs of this process should be formalized in project contracts through a dedicated "Sustainability Acceptance" section, with weighted metrics that carry real contractual weight, providing the institutional legitimacy to sustain commitments under delivery pressure (FasterCapital, 2025). This can be implemented iteratively in Agile contexts or comprehensively upfront in Waterfall projects.

Operation and Maintenance Stage: Dynamic Balancing Through Technology and Organizational Design

Addressing the operation-stage trade-off requires a combination of advanced operational technology and organizational design innovation. On the technology side, adopting intelligent workload scheduling, AI-driven energy optimization, and real-time energy monitoring tools enables more sophisticated management of the performance–efficiency frontier (AWS, n.d.; Microsoft, 2025a). On the organizational side, redesigning operations team performance management frameworks to include dual KPIs covering both sustainability performance and service quality creates the institutional incentive structure needed to drive continuous improvement on both dimensions (Kaplan & Norton, 2005).

Closure Stage: Quantitative Evaluation and Institutional Knowledge Capitalization

The closure-stage dilemma demands a dual response combining rigorous quantitative sustainability impact evaluation with institutional mechanisms for knowledge capitalization. The evaluation dimension involves applying structured, quantifiable assessment methodologies—such as multi-criteria analysis or adapted balanced scorecards—to generate defensible scores of project sustainability performance (Sarker et al., 2021). The knowledge capitalization dimension requires establishing corporate knowledge management systems to capture, curate, and disseminate sustainability lessons learned, creating a "sustainability practice case library" that

prevents the dissipation of experiential knowledge (Caricola & Grimaldi, 2011). This dual path enables organizations to build the evidence base and institutional memory for continuous improvement (Nicoletti Junior et al., 2022).

DISCUSSION

A central insight from this research is that sustainability in software project management must be embedded as a strategic imperative throughout the project lifecycle. The identified dilemmas are not superficial; they are deeply rooted in prevailing cognitive frameworks and institutional structures that have historically governed project management. This finding reinforces the contemporary push to move beyond the “iron triangle” toward a more holistic, value-driven conception of project success (Atkinson, 1999; Silvius & Schipper, 2014). It also adds analytical depth to the arguments of SSE scholars who have called for an integrated approach to technical and organizational sustainability (Venters et al., 2018; König et al., 2025).

The highly contingent nature of the challenges and solutions identified also carries important theoretical implications. This research demonstrates that the viability of different solution paths varies significantly with organizational scale and project methodology. This finding challenges the tendency in normative frameworks to prescribe universal solutions and affirms the value of scenario-adaptive approaches (Fernandes & Araújo, 2019). It also underscores the need for sustainability capability to be conceptualized, within an RBV framework, as a dynamic capability that must be continuously adapted to evolving technological and stakeholder landscapes (Teece et al., 1997).

For software project managers, this study provides a structured roadmap for evolving into sustainability champions. For software enterprises, the imperative is a strategic, top-down commitment to sustainability embedded in corporate governance and performance management. For industry associations and standard-setting bodies, the research highlights a critical role in accelerating industry-specific sustainability standards (Venters et al., 2023). For policymakers, the findings suggest that incentive structures can catalyze the adoption of sustainable practices (Pirozzi et al., 2023).

Notably, for policymakers in developing countries, targeted subsidies for green technology adoption and simplified ESG reporting requirements for SMEs can significantly lower the barrier to entry, helping local software firms integrate sustainability without overburdening their limited resources (Durrani et al., 2024).

To illustrate the viability of these solutions in emerging market contexts, leading IT services firms in Bangalore, India, have demonstrated that large organizations in developing countries can successfully embed sustainability into project management. These firms have integrated SCI metrics into their project delivery processes, established a centralized library of green software patterns, and trained over 100,000 employees in sustainable development practices, achieving a 34% reduction in the carbon intensity of their software delivery operations between 2020 and 2025 (Shukla, & Gautam, 2025).

It is important to note that the current study is a conceptual paper, with the primary goal of establishing the theoretical framework and identifying the core dilemmas and solution paths. Empirical validation, including large-scale surveys with software project managers, in-depth case studies, and quantitative analysis of variable relationships using Partial Least Squares Structural Equation Modeling (PLS-SEM), is reserved for subsequent research. This sequential research design allows the current work to lay the conceptual foundation, while the follow-up study will systematically test the validity and practical applicability of the proposed framework in real-world settings.

Furthermore, the research landscape also tends to over-represent the experience of organizations in advanced economies; to address this gap, the current study has explicitly incorporated case studies and evidence from emerging markets including India, Nigeria, and South Africa highlighting the unique challenges and opportunities for software organizations in developing countries and enhancing the global relevance of the findings. Nevertheless, the distinctive challenges facing software organizations in low-income developing countries merit further dedicated investigation. Additionally, the rapid pace of technological change means that aspects of this analysis will require updating.

CONCLUSION

This study has systematically investigated the core dilemmas and resolution paths in software project management under sustainability constraints. By tracing the specific dilemmas that arise at each stage of the project lifecycle and probing their deep-seated causal roots, this research has constructed a structured and nuanced understanding of the challenges facing the field. The six core dilemmas identified are not isolated phenomena but form an interconnected system of challenges that demand an equally systematic and integrated response.

The scenario-adaptive solution path system proposed in this paper offers practical, evidence-grounded guidance for navigating these challenges, tailored to the heterogeneous landscape of enterprise scales and project management methodologies. The framework advocates for an integrated approach in which sustainability is embedded as a driver of long-term value and innovation throughout the project management process. The path toward a truly sustainable software industry is neither simple nor linear. It demands simultaneous progress on technological, organizational, institutional, and cultural fronts. This research aims to support that coalition by providing a more complete and practically oriented map of the terrain—one that acknowledges the genuine complexity of the challenges ahead while affirming the tractability of meaningful progress.

Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript.

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