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A Framework for Sustainability-Aligned Business Development Across Sectors: A Design Science Approach

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Abstract

A design science framework integrates sustainability into business development across sectors. The framework embeds sustainability, reflected in environmental, social, and governance (ESG) dimensions, within a structured process that links drivers, evaluation components, and outcome indicators. Six principles guide its structure: clarity, integration, adaptability, stakeholder engagement, performance feedback, and scoring consistency. Researchers applied the framework in energy, engineering, and agribusiness cases. Case results show how the framework improves opportunity selection, identifies capability gaps, strengthens prioritization, and structures stakeholder input without adding complexity. Findings confirm that incorporating sustainability factors during the initial stage of business development changes decision patterns, aligns projects with long-term goals, and increases transparency in portfolio planning. This design science approach moves sustainability and its ESG dimensions from a reporting concern to a central element of strategic evaluation and growth planning. Organizations gain a practical structure to align opportunity development with resilience, learning capacity, and sustainability outcomes. In addition, the framework provides a foundation for adaptation, digital tool development, and longitudinal feedback cycles as firms integrate sustainability and ESG dimensions within uncertain policy, market, and stakeholder environments.

Keywords: sustainability strategy; ESG integration; business development; design science; decision framework; stakeholder alignment; strategic evaluation; organizational resilience

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1. Introduction

Climate change, biodiversity loss, social inequality, and governance challenges shape global growth strategies [1,2]. Disclosure requirements and reporting standards reinforce expectations that organizations align development pathways with environmental and social priorities [3,4]. Sustainability serves as a central determinant of opportunity identification, capital allocation, portfolio renewal, and risk management in contemporary contexts [5,6]. Boards, regulators, and investors expect clear integration of sustainability principles reflected through environmental, social, and governance (ESG) dimensions. Many firms emphasize short-term performance while neglecting ecological and social risks [7,8], which reduces innovation effectiveness, fragments resource allocation, and produces incoherent strategies in volatile transition markets.

Sustainability performance influences long-term value creation, capital access, legitimacy, and resilience [9,10]. Firms that adopt stronger practices gain reputational advantages, lower financing costs, and adaptive capacity [11,12]. Despite this, few tools embed sustainability in early business development. Many organizations restrict it to reporting,

which prevents influence on critical choices [13,14]. As a result, managers overlook opportunities to strengthen leadership and continue funding projects misaligned with stakeholder expectations [15,16].

Existing literature advances the field but remains limited. Studies describe sustainable business model patterns, connect sustainability with innovation, and highlight gaps in labor, supply chain, and emissions metrics [17–19]. Reviews confirm the growing relevance of sustainability, while broader frameworks propose alignment pathways [20,21]. Yet most approaches remain conceptual. Few provide modular structures that link sustainability drivers with evaluation logic [22,23]. Transparent scoring appears in limited work. Cross-sector demonstrations remain scarce, and many design principles lack operational clarity [24–26].

Design science research addresses these gaps [27,28]. It develops artifacts that solve organizational problems while contributing to theory. By emphasizing iterative construction and evaluation, design science combines rigor with practical relevance [29,30]. Applied to sustainability, it treats sustainability as a design parameter in business development. Frameworks developed with this method define evaluation flows, create scoring systems, incorporate stakeholder perspectives, and support learning cycles [31,32]. Testing across industries strengthens both generalizability and utility [33,34].

This study introduces the Sustainability-Aligned Business Development Framework (SABDF), created through a design science approach. The framework connects sustainability drivers, decision components, and outcome measures in a modular structure. Six principles guide its design: clarity, integration, feedback readiness, modular adaptability, stakeholder inclusion, and scoring consistency [35,36]. Together, these principles support transparent evaluation, comparability across contexts, and adaptability to industry conditions [37,38]. An energy alliance centered.

Three cases illustrate the framework in practice. One case involves an energy alliance center that pursues decarbonization and grid resilience [39]. Another focuses on a group of multinational manufacturing companies that balances efficiency and innovation under sustainability pressures [40]. A third examines agribusiness initiatives that transform business models to enhance soil health, biodiversity, and smallholder inclusion [41]. Together, these cases show how the framework reshapes opportunity ranking, exposes capability gaps, strengthens prioritization, and structures stakeholder engagement. They highlight the need for data infrastructure, consensus-building, and modular design to embed sustainability into organizational choices.

The research addresses three questions. First, how can sustainability drivers shape business development decisions at the initial stage. Second, which design principles enable a modular and adaptable framework for sustainability-aligned business development. Third, to what extent does the framework demonstrate relevance across industries. These questions connect artifact design with both theoretical foundations and practical application.

This study contributes in four ways. First, it translates sustainability objectives into decision logic through explicit variables, indicators, and scoring methods. Second, stakeholder perspectives integrate with resource-based reasoning as sustainability drivers trigger capability configuration and stakeholder balance. Third, design science for sustainability advances by linking theory with cross-sector demonstrations. Fourth, the framework establishes a basis for validation, digital tool development, and longitudinal analysis of adaptive capacity. Together, these contributions reframe sustainability integration as a proactive strategic process that equips organizations with structured pathways for resilient, transparent, and learning-oriented portfolios aligned with global transitions.

2. Literature Review

2.1. Sustainability Integration

Sustainability shapes how firms pursue growth, manage risk, and define long-term value [42]. ESG factors guide operational choices in environmental protection, social responsibility, and corporate governance [43]. Boards and investors rely on ESG alignment to judge leadership credibility and resilience in unstable markets [44]. Legal requirements and reporting rules compel firms to show that sustainability principles influence strategic decisions [45].

Firms vary in how they treat this challenge. Some reduce ESG to compliance or public messaging, which weakens its influence on innovation and resource planning [46]. Others build internal systems that link ESG drivers to investment logic and organizational capabilities. These firms treat sustainability as a basis for change rather than an external demand [47]. This raises a central concern. Existing frameworks may lack the structure to support firms that treat sustainability as a source of strategic and operational renewal.

2.2. Existing Frameworks' Contributions and Limitations

Scholars describe four major approaches to sustainability integration. One group defines business model types and value structures. These concepts offer structural clarity but lack guidance for decision stages [48]. Maturity assessments and reporting tools emphasize readiness while omitting logic that supports initial screening [49]. Thematic reviews compile cross-domain findings but fail to produce actionable design [50]. Sector-based scoring methods highlight measurement gaps and lack transferable structures [51].

Core limitations appear across these directions. Many frameworks disconnect sustainability drivers from structured evaluation [52]. Few explain how firms align stakeholder needs with internal resources. Several concentrate on indicators while ignoring the process structures that support innovation and governance [53]. Lacking modular designs and traceable decision flows, current approaches offer limited value for organizations managing sustainability within volatile conditions.

2.3. Design Science Bridging

Design science offers a structured way to connect theory, practice, and evaluation in complex settings. Theory-driven approaches abstract existing ideas to achieve coherence [54,55]. Design science begins with real-world challenges and develops solutions by iterating design and evaluation [56]. Researchers define objectives by diagnosing problems, create artifacts that address those objectives, and evaluate performance using specific criteria. Each step maintains traceability between goals, actions, and outcomes [57].

Sustainability contexts involve cross-domain pressures, ambiguous signals, and shifting stakeholder demands [58]. Design science supports these conditions by promoting modular thinking, transparent evaluation, and feedback-based adjustment. The method helps organizations align internal capabilities with external constraints [59,60]. While many models focus on compliance or structural consistency, design science supports adaptive planning and problem-based reasoning suited to innovation and governance under uncertainty [61].

2.4. Stakeholder/Resource Theories

Stakeholder theory highlights external demands and legitimacy pressures [62]. The resource-based view explains how internal assets shape performance and support strategic positioning [63]. Together, these perspectives frame governance as a balance between

outside alignment and internal capability. Both clarify how firms protect value under uncertainty and respond to institutional signals [64,65].

However, these approaches offer little guidance for integration. Governance decisions must navigate trade-offs among stakeholder groups, resource constraints, and conflicting priorities [66]. Without explicit design logic, firms struggle to translate stakeholder expectations into structured choices. Few models explain how to assess salience, allocate resources, and manage time horizons within modular governance workflows. This gap limits the ability to support innovation while sustaining legitimacy and operational resilience.

2.5. Data Infrastructure

Information systems determine how organizations allocate resources, define accountability, and evaluate impact [67]. Platform design influences transparency, traceability, and modularity. Decisions on data flows, access rules, and ownership logic shape how firms respond to stakeholder pressure and coordinate across units [68,69]. Digital infrastructure links responsibilities to investment logic and governance outcomes. Architecture serves as a foundation that connects operational signals with strategic direction [69–71].

Many tools prioritize efficiency and control. Few frameworks support sustainability-oriented development [72,73]. Governance depends on structures that convert data into actionable decisions [74]. Strategy formation needs modular tools that filter investments, align stakeholder needs, and direct resources toward long-term goals [75]. In the absence of such architecture, data governance loses alignment with transformation [76].

2.6. Synthesis and Research Gap

Existing frameworks address parts of the sustainability challenge but lack integration across innovation and governance. Some approaches clarify value structures or compliance indicators. Others focus on stakeholder logic or resource alignment. Few explain how sustainability priorities translate into decision flows that guide early-stage evaluation and long-term capability building. Method choices, design logic, and coordination structures remain fragmented across domains.

This gap limits progress toward unified development models. Innovation, governance, and sustainability remain siloed in theory and practice. Research needs clearer logic to connect stakeholder pressures, resource deployment, and infrastructure design. Without this integration, firms struggle to navigate competing demands and to build systems that sustain both adaptability and accountability. Future work must articulate frameworks that link values with decision structure and translate abstract principles into governance design.

3. Materials and Methods

3.1. Overview

This study applies a design-oriented research approach grounded in the design science tradition to construct and examine the Sustainability-Aligned Business Development Framework. The research serves two goals. One goal targets the practical challenge of aligning ESG factors with business development. The other aims to formalize and test an artifact that supports this alignment and contributes to academic discourse.

Method selection follows three core elements. One defines the research paradigm and its rationale. Another links the problem setting with relevant knowledge. A third outlines the design, development, and evaluation strategy for the framework. This structure keeps the SABDF responsive to real-world demands while remaining grounded in theory.

This work marks the first design iteration of a sustainability-oriented business development tool. Following guidance from design science research, the cycle centers on three features: traceable components and information flows, a distinct mechanism layer with modular and rule-based logic, and naturalistic demonstrations using secondary cross-domain cases. The study emphasizes reusable principles and transparent logic over statistical confirmation. It presents no formal hypotheses to avoid unsupported claims.

3.2. Research Paradigm and Justification

This study follows a design science research paradigm. It focuses on artifact creation that addresses organizational needs and contributes to theory. Unlike empirical approaches that prioritize testing or description, design science defines a structured process for building decision frameworks. Such structure supports sustainability work by combining practical alignment with conceptual clarity.

Early-stage projects face sparse data and uncertain patterns. Design science suits these settings by enabling abductive artifact development based on theory-informed mechanisms. The approach delays statistical confirmation until longitudinal patterns emerge, keeping early-stage design grounded without premature claims.

Other methods yield insights through ESG modeling or qualitative exploration. However, they lack a system for artifact construction and structured refinement. Design science addresses both aims of this study: practical framework development and improved methodological clarity in sustainability-centered business design.

3.3. Problem Environment and Knowledge Base

The framework design rests on three streams of knowledge. One stream offers ESG integration models that embed sustainability into strategy. While these models define alignment goals, few include modular architecture or indicators that support adaptation across contexts. Another stream applies strategic theory. Stakeholder models address competing demands, and resource-based logic treats sustainability as a source of capabilities and system renewal. A third stream draws from design science to provide structure for building and evaluating decision frameworks.

These theoretical anchors shape the decomposition of the design problem, define mechanisms for decision alignment, and guide evaluation choices. Rather than applying theory descriptively, the study uses each stream to frame design constraints, enable component traceability, and ensure contextual fit. The SABDF emerges from this logic as a structured response to both practical demands and conceptual gaps.

The integration of Stakeholder Theory, the Resource-Based View (RBV), and Design Science creates a clear causal foundation for the SABDF. Stakeholder Theory identifies external legitimacy pressures that shape governance inputs and stakeholder inclusion, so sustainability expectations inform evaluation criteria. Dynamic capabilities within the RBV explain how firms sense opportunities, align resources to capture them, and reconfigure capabilities as stakeholder priorities evolve. Within the SABDF, these capabilities operate through iterative feedback and modular adaptability that recalibrate weights, thresholds, and indicators as ESG priorities change. Design Science serves as the procedural bridge that converts these mechanisms into structured artifacts, linking stakeholder expectations with capability orchestration through systematic design, evaluation, and refinement.

3.4. Framework Design and Development

The SABDF emerged from a theory-driven design process structured into three steps: conceptualization, formalization, and refinement.

Conceptualization began with a review of literature on ESG integration, stakeholder theory, and the resource-based view. The team extracted ideas that supported sustainability-aligned business development. Each concept passed through functional filters based on modularity, traceability, and decision relevance. Group discussion eliminated constructs that lacked design value. Remaining elements informed the development of sustainability drivers, governance logic, scoring functions, and process modules.

The formalization step assembled these components into a structured framework. The team organized the elements into three layers: input drivers, process modules, and output measures. Each layer aligned with both theoretical constructs and operational needs. To support application, the team developed scoring templates and embedded decision logic across modules. This structure aimed to ensure internal coherence, design clarity, and practical utility.

Refinement tested the framework's internal consistency and contextual fit through case-based simulation. The team applied cross-domain examples to examine the structure's adaptability across industries. During this process, the team adjusted design decisions when components failed to reflect ESG-business alignment or caused ambiguity. This step preserved theoretical grounding while resolving implementation gaps.

Figure 1 presents the design logic using an adapted version of Hevner's three-cycle model. The model anchors the artifact at the intersection of the problem environment, the knowledge base, and the design cycle.

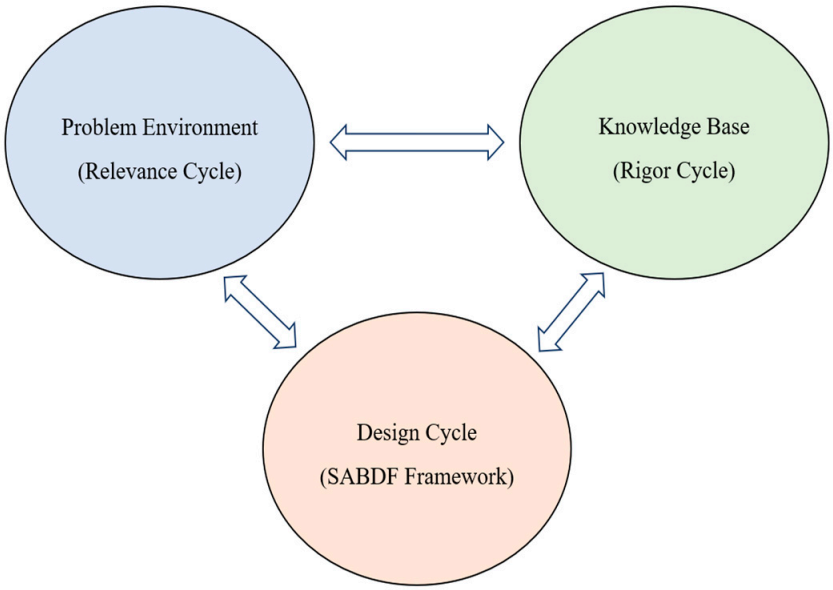


Figure 1. Adapted Three-Cycle Model for the SABDF. Source: adapted from [27].

Table 1 links the Sustainability-Aligned Business Development Framework to its theoretical foundations. Stakeholder Theory provides the normative grounding for legitimacy, inclusion, and transparency within governance structures. The Resource-Based View contributes an analytical basis for dynamic capability, modular adaptability, and sustainable resource configuration. Together, these perspectives explain how the framework aligns stakeholder expectations with organizational capabilities to support sustainability-oriented strategic decision-making.

Table 1. Mapping of Theoretical Foundations to Framework Constructs.

Theoretical Source	Core Concept	Framework Construct	Causal Link/Design Principle Connection
Stakeholder Theory	Legitimacy, salience, and accountability	Governance Inputs	Defines how stakeholder expectations shape governance criteria and evaluation parameters (DP1 Transparency, DP5 Stakeholder Inclusion).
	Participatory alignment of interests	Stakeholder Inclusion Processes	Translates stakeholder perspectives into weight generation and evaluation logic to ensure representative sustainability assessment (DP5).
	Transparency and trust	Audit and Reporting Mechanisms	Embeds traceability and accountability within decision systems (DP1).
Resource-Based View (RBV)	Dynamic capabilities (sensing, seizing, reconfiguring)	Iterative Feedback and Adaptive Learning Loops	Converts ESG outcome variance into recalibration signals that strengthen organizational learning and resilience (DP3 Iterative Feedback).
	Resource orchestration and configurational flexibility	Modular Adaptability Architecture	Enables indicator and module reconfiguration to match changing market and stakeholder conditions (DP4).
	Resource efficiency and strategic value creation	Sustainability Drivers and Capability Linkage	Connects capability deployment to long-term sustainability advantage (DP2 Embedded Integration).
Design Science	Iterative artifact construction and evaluation	Framework Architecture and Refinement Cycle	Provides the procedural mechanism that converts theoretical constructs into testable, auditable decision tools (DP3, DP4).
	Problem–solution traceability	Design Principles and Evaluation Criteria	Ensures traceable alignment between stakeholder inputs, resource capabilities, and measurable ESG outcomes (DP1–DP6).
	Knowledge integration and validation through application	Cross-Sector Demonstration and Feedback Loops	Links theory with empirical adaptation, reinforcing the learning cycle and design validation (DP3, DP6).

This process required no inductive coding or empirical concept derivation. Instead, the framework design followed explicit reasoning paths that linked literature insights to design outputs. This approach enabled reproducibility and reduced ambiguity in component justification.

3.5. Evaluation Strategy

Evaluation assessed the framework's alignment with practical challenges in sustainability-driven business development. The research applied the SABDF across three distinct cases to examine the structure's support for diagnosis, strategy formulation, and trade-off resolution. Each case involved real organizational contexts and served as a boundary test for the artifact.

To confirm that the six design principles appeared in practice, we used a structured rubric. Two analysts applied the criteria to case data and resolved discrepancies through

discussion. This procedure checked the clarity and presence of each principle rather than generating new insights. Appendices provide rubric details and illustrative examples.

The evaluation process followed the logic of design science. Application exposed conditions where the artifact required adjustment, including gaps in modular integration and scoring thresholds. These feedback points informed minor revisions but did not affect core constructs. Observations confirmed that the framework enabled cross-role alignment, supported ESG-strategy linkage, and maintained consistency across sectors. This phase validated both the logic and flexibility of the design.

Python 3.13, along with the NumPy and pandas libraries, supports all data processing, normalization, and stability analyses, including Kendall's τ and coefficient of variation computations.

3.6. Summary

This methodology links ESG-business challenges to theoretical insights from sustainability and strategy. It applies a design science paradigm, separates the problem environment from the knowledge base, and follows a structured process for framework development and evaluation. These choices ensure that the SABDF balances academic rigor with practical application.

4. Design and Construction of the Sustainability-Aligned Business Development Framework (SABDF)

4.1. Design Objectives and Requirements

The SABDF builds on existing sustainability integration frameworks and expands their scope. A concise comparison includes the Sustainable Business Model Canvas [77,78] and ESG Maturity Models [79,80], which address selected sustainability dimensions. Table 2 presents the main differences in focus and design logic. Previous models emphasize value creation or single-dimension maturity, while the SABDF combines ESG, capability, and feedback readiness within a unified modular structure.

Table 2. Comparison of the SABDF with Existing Sustainability-Integration Frameworks.

Framework	Main Focus	Dimensions Covered	Iterative Feedback	Modularity	SABDF Advancement
Sustainable Business Model Canvas	Business value creation	Environmental, limited social	No	No	Adds governance and capability layers
ESG Maturity Models	Reporting and compliance	ESG	Partial	No	Adds adaptive modular structure
SABDF (this study)	Business-development integration	ESG + Capability + Feedback	Yes	Yes	Unified multi-dimension artifact

The Sustainability Aligned Business Development Framework responds to five deficiencies identified in research and practice. (R1) Early business development choices overlook sustainability drivers such as environmental, social, and governance factors. (R2) Existing frameworks lack modular structures that transfer across sectors without structural rewrites. (R3) Frameworks lack mechanisms for iterative learning and recalibration. (R4) Stakeholder preferences do not enter transparent and computable weight systems. (R5) Score-based comparability varies across portfolios and time horizons.

Table 3 illustrates how the framework's design objectives address significant deficiencies identified in previous research.

Table 3. Research Deficiencies Identified (R1–R5) and Corresponding Design Principles.

Deficiency ID (R#)	Deficiency in Existing Research	How it is Addressed in SABDF	Corresponding Design Principle(s)
R1	Limited transparency and traceability of sustainability evidence	Introduces explicit transparency mechanisms and data-based assessment logic	DP1—Transparency
R2	Insufficient stakeholder inclusion in framework evaluation	Incorporates stakeholder weighting and participatory input processes	DP5—Stakeholder Inclusion
R3	Lack of modular adaptability across sectors	Embeds modular sub-frameworks for sectoral customization	DP4—Modularity
R4	Absence of feedback and iterative learning in existing models	Establishes iterative recalibration through feedback readiness	DP3—Iterative Feedback
R5	Weak comparability and benchmarking across organizations	Introduces standardized scoring and normalization mechanisms	DP6—Score-Based Comparability

These deficiencies establish the requirements that shape SABDF. To meet them, the framework sets five objectives: link sustainability drivers to early-stage prioritization, enable modular use across sectors, embed mechanisms for feedback and recalibration, formalize stakeholder inputs into weight systems, and stabilize score comparability across time.

4.2. Design Principles (DP1 to DP6)

Six design principles shape the architecture, procedures, and data logic of the SABDF. Each principle draws on sustainability governance, systems design, and management research to ensure conceptual rigor and practical relevance.

- DP1 Transparency:

A transparent framework governs version control for indicators, weights, and gating rules. Each element carries metadata that explains its rationale, proxy logic, and audit trail. This principle reflects accountable sustainability reporting and verifiable decision systems supported by prior work in sustainability accounting [81,82].

- DP2 Embedded Integration:

Embedded integration aligns ESG, strategic, market, and capability criteria inside a single hierarchical evaluation structure. Integrating sustainability within strategic analysis allows business development to consider impact and opportunity at the same time, consistent with integrated-thinking models [83,84].

- DP3 Iterative Feedback:

Iterative feedback enables real-time refinement by capturing variance between projected and observed sustainability outcomes, analyzing the deviation, and feeding the results into the next evaluation cycle. This process ensures adaptive learning and maintains continuous alignment of stakeholder priorities with resource configurations [85,86].

- DP4 Modular Adaptability:

Modular adaptability separates indicator groups and thresholds from aggregation and gating logic. Analysts can add or replace modules without altering the system's foundation. This configuration draws from modular-system theory, which supports flexibility across diverse sectors [87].

- DP5 Stakeholder Inclusion:

Stakeholder inclusion gathers perspectives through point allocation or pairwise comparison. The framework reconciles results with consensus metrics such as Kendall's W. This principle builds on stakeholder and participatory-governance theory, ensuring plural input while limiting bias [88,89].

- DP6 Score-Based Comparability:

Score-based comparability standardizes normalization and stability metrics to preserve interpretability across cases and time. The method supports longitudinal benchmarking and quantitative accountability in sustainability performance [90].

Table 4 summarizes how the six principles correspond to the five requirements identified in Section 4.1, demonstrating how each design response addresses a specific framework deficiency.

Table 4. Mapping of Design Principles (DP) to Addressed Requirements (R).

Design Principle (DP)	Description	Addresses Requirement(s)
DP1: Transparency	Version control, metadata, audit trail for indicators, thresholds, weights.	R1, R5
DP2: Embedded Integration	ESG logic embedded with strategic and operational metrics.	R1, R2
DP3: Iterative Feedback	Variance triggers initiate recalibration; adaptive design.	R3, R5
DP4: Modular Adaptability	Cluster-level modularity and substitution without redesign.	R2, R3
DP5: Stakeholder Inclusion	Weight generation from participatory processes with consensus metrics.	R4
DP6: Score-Based Comparability	Normalization, dispersion, and time-series comparability safeguards.	R5

The six design principles illustrate how Stakeholder Theory, the Resource-Based View (RBV), and Design Science interact within the framework. Stakeholder Theory grounds the principles of transparency and inclusion by linking governance inputs to legitimacy and participatory alignment. Dynamic capabilities within the RBV explain how firms sense opportunities, align resources, and reconfigure capabilities as stakeholder priorities evolve. These capabilities appear in iterative feedback and modular adaptability, which enable recalibration of weights, thresholds, and indicators when ESG priorities change. Design Science connects these mechanisms through systematic design, evaluation, and refinement, translating theoretical relationships into a structured and traceable decision system.

4.3. Layered Conceptual Architecture

The SABDF builds on three integrated layers that provide traceability, modularity, and learning. Figure 2 illustrates this layered architecture, showing vertical traceability from indicators to outcomes, feedback loops, and modular interfaces linking the layers.

1. Layer 1: Sustainability Drivers and Strategic Factors This layer captures both external and internal signals relevant to sustainability and strategic positioning. It includes environmental readiness (e.g., emissions reduction potential, resilience contribution),

social alignment (e.g., labor practices, community engagement), governance maturity (e.g., transparency, audit structures), internal capabilities, and market opportunities.

2. Layer 2: Decision Components This layer operationalizes the evaluation logic through opportunity mapping, internal capability assessment, and multi-criteria analysis. The latter includes indicator normalization, hierarchical weighting (group and intra-group), composite score generation, and threshold-based gating.
3. Layer 3: Development Outcomes The final outputs of the framework include a Strategic Fit Score (aggregated opportunity suitability), a Sustainability Impact Index (disaggregated ESG contribution), and Adaptive Capability Signals (e.g., ranking stability, trigger activations).

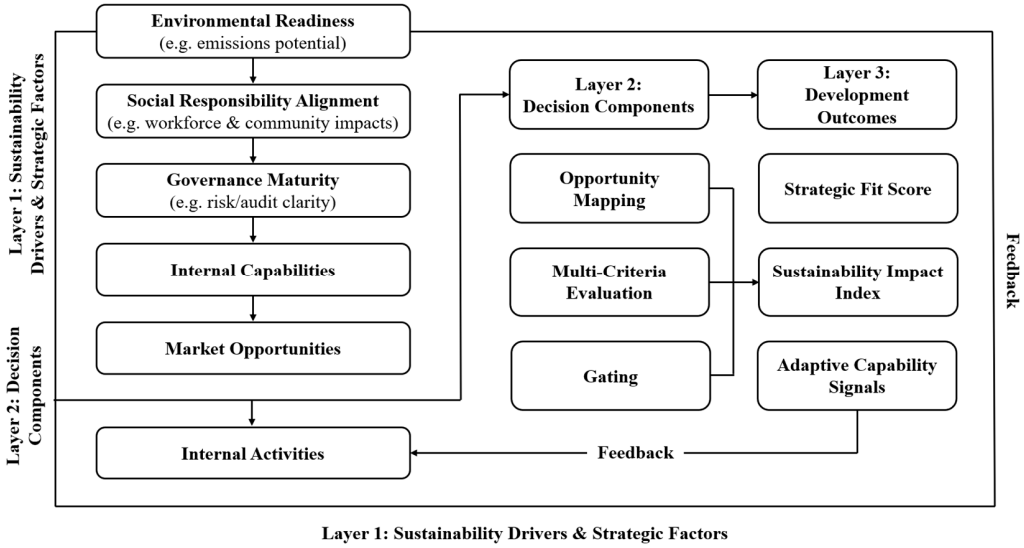


Figure 2. The Sustainability-Aligned Business Development Framework (SABDF).

Feedback paths run throughout the framework. Vertical traceability links every outcome to its originating indicators and weights. Horizontal modularity lets users add new indicator clusters (e.g., biodiversity) without destabilizing the core logic. Stakeholder mediation interfaces support participatory weight calibration, and consistent normalization with stored ranking vectors preserves baseline comparability.

Appendix A presents a complete list of indicators, definitions, and scoring criteria used in SABDF.

4.4. Conceptual Indicator and Scoring Design

The framework uses a structured set of indicators that link data, evaluation, and improvement. Each indicator includes an identifier, ESG or strategic dimension, definition, source type, collection frequency, confidence level, normalization method, weight group, and version record. Managers may add proxy indicators when they document rationale and confidence level. This structure keeps transparency and comparability across applications.

Weighting follows a hierarchical multi-criteria process. At the group level, environmental, social, governance, and capability categories receive normalized group weights (GW) that reflect stakeholder priorities. Within each group, intra-group weights (IRW) come from structured methods such as point allocation or pairwise comparison under Analytic Hierarchy Process logic. Analysts test consensus with Kendall's W and entropy dispersion metrics. When $W < 0.70$ or entropy > 0.30, stakeholders reconvene to adjust preferences. The framework reweights when either the Forecast–Realized Error (FRE) for sustainability outcomes exceeds 15 percent or the Stability Deviation Index (SDI) exceeds 12 percent. Each recalibration logs a new weight version for traceability.

Normalization converts indicators to a 0–1 scale. Analysts apply z-score adjustments for longitudinal tracking and winsorize extreme values. They check skewness and kurtosis before inclusion.

Figure 3 illustrates this scoring structure. The model aggregates indicators through hierarchical weighting:

$$A = \sum_{g=1}^{G} GW_g \left(\sum_{i=1}^{n_g} IRW_i N_i \right) \quad (1)$$

where A is the aggregate score, GW_g the group weight, IRW_i the intra-group weight, and N_i the normalized indicator value. Normalization preserves proportional integrity within and across groups. Analysts verified the internal consistency of weights, and all updates remain version-controlled and auditable. Figure 3 shows how indicator scores flow from the case evidence base through normalization and weighting into the final composite evaluation. Appendix C lists all constructs, indicators, and proxy variables shown in Figure 3. Appendix E provides a worked example of the coding and normalization process for the construct Environmental Readiness.

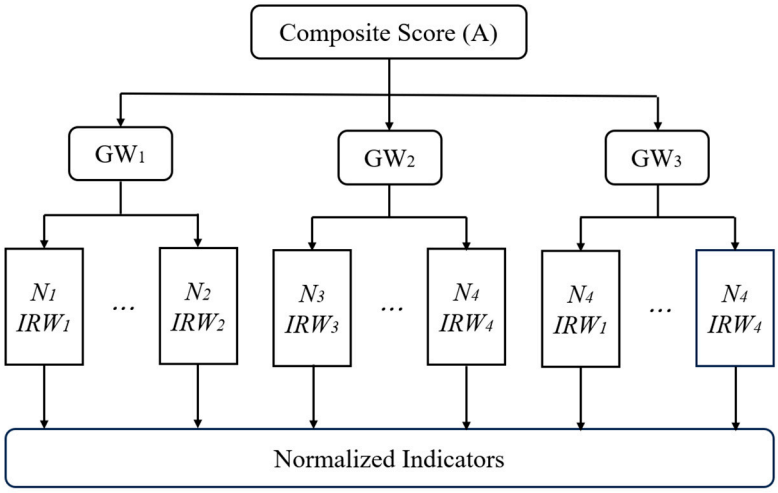


Figure 3. Weighting Structure and Indicator Hierarchy.

4.5. Decision Flow and Gating Mechanism

The SABDF operationalizes its evaluation logic through a six-stage decision process (Figure 4). The process begins with initiation, during which managers capture opportunity metadata, apply exclusion filters, and conduct minimal ESG profiling. The second stage, qualification, populates indicators, enforces completeness checks, and applies preliminary normalization.

The evaluation stage follows, applying hierarchical weighting to generate composite scores while testing scenario sensitivity. In the fourth stage, stakeholder review, the framework decomposes scores, conducts consensus diagnostics, and finalizes weight vectors. Decision and logging occur in the fifth stage, where opportunities are classified as "Go," "Hold," or "Refine" and each decision links to documented justifications. The final stage, post-period update, records realized impacts, computes forecast deviations, and evaluates whether trigger conditions call for recalibration.

The gating mechanism strengthens this flow by combining composite thresholds with mandatory ESG minimums. This safeguard prevents compensatory trade-offs, such as allowing a high environmental score to offset weak governance. Any threshold revision requires justification and version tracking to ensure transparency and accountability.

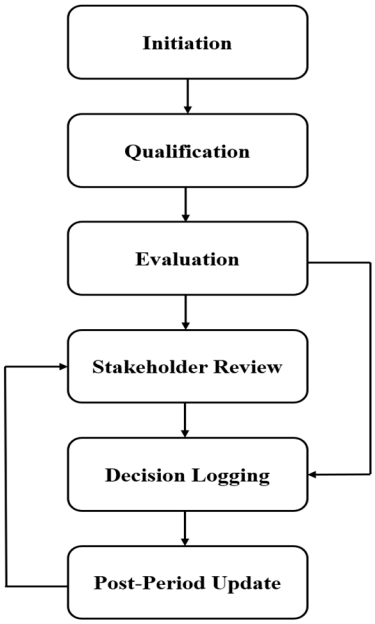


Figure 4. Decision Flow Process in SABDF.

4.6. Operational Mechanisms

The Sustainability-Aligned Business Development Framework applies its six design principles through operational mechanisms that connect data processing, stakeholder input, and strategic evaluation. These mechanisms turn the framework's conceptual architecture into repeatable decision processes.

- Transparency and Traceability (DP1):

Audit logs record opportunity identifiers, indicator values, weight versions, gating outcomes, and their rationale. Each entry includes metadata for verification. This record system ensures transparency and supports internal and external audits. By maintaining traceable documentation, the framework reinforces accountability in sustainability-related decisions.

- Embedded Integration (DP2):

An integrated API enables managers to register, update, or retire indicators without disrupting existing evaluations. The same interface links ESG, market, and strategic data, supporting unified analysis and modular substitution. This mechanism allows sustainability factors to influence business planning rather than operate as a parallel assessment.

- Iterative Feedback (DP3):

Feedback mechanisms strengthen learning across evaluation cycles. The framework monitors the Forecast–Realized Error (FRE) and Stability Deviation Index (SDI) to detect variance in projections versus outcomes. When deviations exceed thresholds, recalibration adjusts weights and thresholds. These steps keep model assumptions aligned with evolving conditions, turning feedback into continuous improvement.

- Modular Adaptability (DP4):

Each indicator cluster functions as an independent module. Analysts replace or expand modules without redesigning the system. This modular structure supports sector-specific adaptation and enables testing of new sustainability indicators under controlled conditions.

- Stakeholder Inclusion (DP5):

Stakeholder translation processes convert qualitative judgments into numerical data through pairwise comparison or point allocation. Analysts assess consensus using Kendall's W and lock finalized weights to prevent bias in subsequent evaluations. These procedures embed participatory legitimacy in each evaluation and align decision weighting with stakeholder priorities.

- Score-Based Comparability (DP6):

Comparability safeguards preserve measurement stability over time. Freeze windows, baseline vector snapshots, and perturbation metrics (e.g., Kendall tau distance) constrain dispersion across evaluations. New indicators remain at zero weight until validated through pilot application. These mechanisms enable reliable benchmarking while allowing incremental system growth.

Together, these mechanisms operationalize the six design principles. The framework integrates governance, transparency, and learning into a single evaluative process that links data to strategic decision-making. Figure 5 illustrates the relationships between feedback triggers, recalibration procedures, and governance reviews.

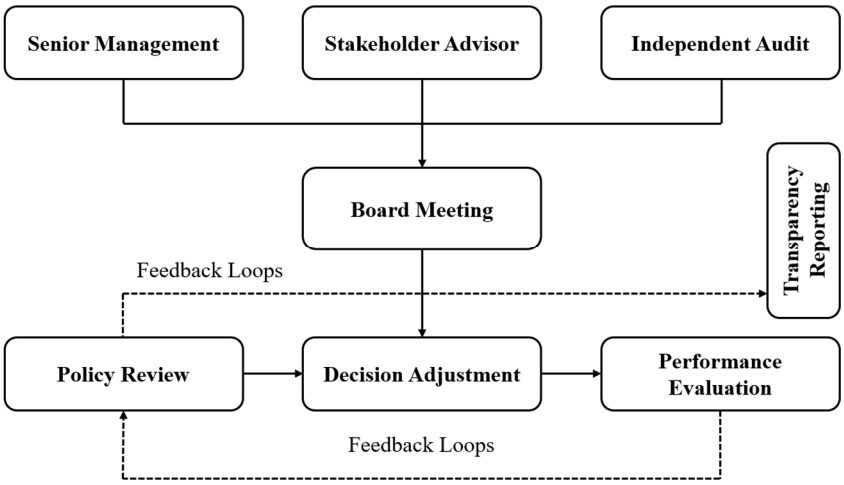


Figure 5. Feedback and Governance Mechanisms.

4.7. Extensibility, Governance, and Summary

The SABDF supports extensibility through structured patterns that govern indicators, clusters, stakeholders, and regulatory thresholds. Managers retire outdated indicators, substitute them within the same group, and run stability checks such as Kendall tau analysis. New clusters enter the system as weight groups with an initial value of zero, and pilot testing determines readiness for full inclusion. Additional stakeholder groups expand the framework through consensus diagnostics and reconciliation that resolve misalignments. Regulatory thresholds change through updates that managers archive for audit purposes.

Governance operates through quarterly reviews that monitor recalibration events, indicator lifecycle changes, and shifts in stakeholder consensus. Each change enters a Change Impact Matrix that classifies its scope and significance. High-impact revisions require dual approval from both strategic and sustainability leads, ensuring accountability across functions.

Together, these mechanisms confirm that SABDF delivers a traceable, modular, and feedback-ready architecture that operationalizes six core design principles. The framework establishes a foundation for empirical validation of strategic integration, cross-context comparability, and adaptive learning performance, which the following chapters explore in greater depth.

5. Evaluation and Case Validation

5.1. Purpose of Evaluation

This evaluation assesses the applicability and robustness of the proposed SABDF through case-based validation. In Design Science Research, evaluation plays a critical role in demonstrating an artifact's logical consistency, practical utility, and contextual relevance. The study applies the framework to three sustainability-oriented cases across different industries, providing a structured analysis of how the model performs in diverse real-world contexts.

5.2. Cases and Data Sources

To test the portability of the SABDF across diverse operating environments, the study adapts three heterogeneous cases from published research [39–41], each representing distinct materiality profiles and governance patterns. Case data come from public secondary sources.

- Case A: An energy alliance centered on decarbonization infrastructure and grid resilience [39].
- Case B: A group of multinational manufacturing companies of innovation and efficiency initiatives [40].
- Case C: An agribusiness value chain program emphasizing soil health, water efficiency, biodiversity, and smallholder inclusion [41].

This selection spans infrastructure intensity (Case A), capability transformation (Case B), and socio-environmental complexity (Case C), thereby enabling a rigorous assessment of indicator grouping, weighting hierarchy, and gating logic across contrasting domains.

Data were drawn from multiple organizational artifacts, including strategic plans; initiative or project screening sheets; stage-gate summaries; sustainability and ESG reports covering three- to five-year horizons; supplier or stakeholder engagement summaries; feasibility or pilot briefs; governance and risk allocation documents; and disclosed or inferred indicator values. Each item was abstracted into a standardized evaluation sheet, which mapped sustainability driver references, capability constructs, decision components employed, and rationales documented for "go," "hold," or "refine" outcomes.

In cases where primary data were unavailable or redacted, proxy indicators were introduced. These were explicitly flagged with rationale statements and assigned confidence-level tags, thereby preserving the principle of transparency (DP1).

Case-specific coverage and mapping statistics were as follows:

- Case A: proposals mapped N = 27, with indicator coverage of 82%;
- Case B: initiatives mapped N = 34, with indicator coverage of 77%;
- Case C: pilot briefs mapped N = 21, with indicator coverage of 88%.

These counts and coverage rates are based on the available documentation and stakeholder disclosures. In some instances, redacted or missing data required the use of proxies, which were explicitly flagged with associated confidence levels. As such, the reported figures should be interpreted as best-available representations rather than exhaustive enumerations.

Appendix D lists all initiatives and indicators and shows how each case contributes to testing individual design principles and the framework's scoring consistency.

Table 5 presents the document types and their application in the SABDF analysis.

Table 5. Document Types and Their Application in the SABDF Analysis.

Document Type	Key Information Extracted	Framework Use
Strategic plans/project briefs	Business objectives, investment logic	Identify sustainability drivers
ESG/sustainability reports	Emission, labor, and governance data	Populate ESG indicator values
Supplier/stakeholder summaries	Engagement frequency, feedback themes	Inform DP5 Stakeholder Inclusion
Feasibility/pilot briefs	Technical readiness, financial metrics	Capability indicators
Governance and risk disclosures	Audit structures, transparency metrics	DP1 Transparency and DP6 Comparability

5.3. Evaluation Procedures and Metrics

Procedure comprised four main steps applied consistently.

Step 1: Structural Checklist Review (24-item traceability and completeness list) verifying glossary coverage, version control, source provenance, gating rule articulation, normalization reproducibility, and dependency decoupling.

Step 2: Indicator and Weight Reconstruction mapping available data to repository schema and computing normalized values (default bounded min-max, α = 5% unless outlier conditions required adjustment).

Step 3: Weighted Scoring and Gating Simulation applying hierarchical weighting (group weights GW and intra-group relative weights IRW) with original or reconstructed stakeholder emphasis.

Step 4: Stability and sensitivity evaluation uses weight shifts, indicator substitution, and ranking tests with Kendall's τ. Weight adjustments of ten percent tested each major group. Indicator replacement examined structural resilience. Rank order remained stable across varied inputs. Coefficient of variation compared raw scores and normalized scores to examine dispersion. Together, these procedures confirm comparability safeguards defined in DP6.

The analysis team assigned four qualitative codes: Absent, Emerging, Moderate, and Strong. Each design principle in each case received one classification based on observed alignment. Coding anchors: for DP1, Strong requires complete indicator definitions, versioned weights, and explicit source or proxy rationale; for DP4, Strong requires at least one successful indicator addition or substitution without structural code or schema change; for DP5, Strong requires documented stakeholder preference translation with consensus metric computed; for DP6, Strong requires both dispersion control (CV within target band [0.10, 0.25]) and ranking stability above τ threshold ($\tau \geq 0.70$) under perturbation. DP3 underwent conceptual examination, since the study covered early-cycle procedures and left full variance recalibration outside its scope. Resulting evidence highlights trigger definition and baseline variance capture as indicators of readiness.

5.4. Simulation of the Iterative Feedback Function (DP3)

The simulation illustrates the operation of the iterative feedback loop (DP3) within the SABDF. Variance between projected and observed ESG indicator values initiates the recalibration of decision parameters and structural configurations. Each evaluation cycle integrates its outputs into the subsequent configuration to enhance organizational learning and strengthen alignment with sustainability objectives.

Table 6 presents simulation results illustrating the recalibration process across five evaluation cycles. Variance between expected and observed performance values prompts adjustments to indicator weights and procedural parameters. These modifications progres-

sively reduce variance, demonstrating that the feedback mechanism operates as an adaptive evaluation system aligned with the iterative evaluation principle of Design Science.

Table 6. Simulation of Iterative Feedback Function (DP3).

Iteration	Key ESG Indicator	Expected Value (Initial Model)	Observed Value (Cycle *n*)	Variance (%)	System Adjustment	Revised Weight (Cycle *n* + 1)
1	Stakeholder Engagement Index	0.80	0.65	−18.8	Increase stakeholder input frequency	0.25 → 0.30
2	Carbon Efficiency Ratio	0.70	0.76	+8.6	Reduce emission reduction target slope	0.20 → 0.18
3	Circular Resource Utilization	0.60	0.63	+5.0	Maintain configuration	0.15 → 0.15
4	Social Inclusion Score	0.75	0.70	−6.7	Revise supplier audit process	0.25 → 0.28
5	Innovation Readiness Index	0.65	0.68	+4.6	Reinforce learning cycle metrics	0.15 → 0.17

Note: The figures represent simulation values generated to demonstrate how the SABDF's feedback loop (DP3) recalibrates ESG indicators and weights across iterative evaluation cycles. They illustrate the operational behavior of the framework's feedback mechanism in alignment with the iterative evaluation principle of Design Science.

Figure 6 visualizes the iterative feedback mechanism (DP3) within the SABDF. Evaluation outcomes generate variance data that inform the reconfiguration of weights, thresholds, and indicators. The revised configuration becomes the input for the next assessment cycle, forming a continuous feedback loop aligned with the iterative evaluation principle of Design Science.

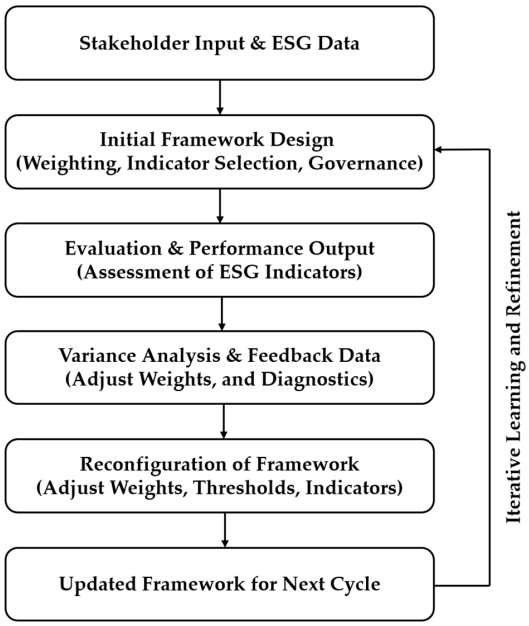


Figure 6. Conceptual Representation of the SABDF Feedback Loop (DP3).

5.5. Case Findings

Case A, energy alliance. Historical infrastructure proposals (N = 27) were re-scored under SABDF. Data sufficiency allowed population of 85% environmental, 62% social, 74% governance, and 80% capability indicators. Social data gaps created partial transparency (DP1 rated Moderate). Reconstructed weights with resilience focus increased score separation. Aggregate spread rose to 0.21 from 0.12. Four historically funded proposals stayed among top ranks, producing a concordance ratio near 0.80. This study converted stakeholder negotiation outcomes into a resilience weight increase of 0.08 above the default group value. Evidence: DP2 Embedded Integration Strong (rank reordering influenced by ESG–capability blend), DP4 Modular Adaptability Emerging to Moderate (limited substitution events), DP5 Stakeholder Inclusion Emerging (qualitative to quantitative translation performed once), DP6 Score-Based Comparability Emerging (stability τ under perturbation = 0.63, below target 0.70), DP3 Iterative Feedback Remains Inactive (baseline variance only).

Case B, a group of multinational manufacturing companies. We mapped 34 innovation and efficiency initiatives with broad environmental and capability coverage. Governance showed 68 percent of indicators. Workforce upskilling and governance readiness indicators pushed two high-priority initiatives below the "go" threshold because capability lag and undocumented risk controls limited readiness. This outcome supports DP2. An indicator substitution test replaced lifecycle energy intensity with supplier emissions factor without re-coding aggregation logic (time cost = 3.5 h) indicating DP4 Strong. Stakeholder preference elicitation used point allocation and produced Kendall's W = 0.61. Consensus below threshold (0.70) triggered a reconciliation session raising W to 0.74. Normalization maintained ordering for major energy efficiency indicators (Kendall τ baseline versus normalized τ = 0.82). Weight perturbation tests produced ranking stability τ = 0.73 and gating state agreement = 81% (target $\geq$ 80%), indicating emerging comparability strength. DP1 Transparency Moderate (proxies labeled), DP5 Stakeholder Inclusion Moderate to Strong after reconciliation. Iterative feedback triggers are defined (FRE threshold θ_{FRE} = 15%, SDI threshold θ_{SDI} = 12%, here, θ denotes a threshold parameter for recalibration and dispersion detection) but remain unfired (DP3 Emerging). The FRE threshold refers to the share of initiatives ($\geq$15%) that deviate sufficiently to require recalibration, while the SDI threshold captures sustainability score dispersion ($\geq$12%) that signals a comparability or weighting imbalance.

Case C, Agribusiness Value Chain. Pilot briefs (N = 21) captured broader social and environmental diversity; biodiversity and water efficiency data allowed insertion of a new biodiversity indicator mid-evaluation without schema changes (DP4 Strong). Stakeholder engagement frequency analysis produced a weight vector with consensus index Kendall's W = 0.78 exceeding the 0.70 threshold, demonstrating DP5 Strong. Addition of a biodiversity cluster at provisional group weight zero followed by elevation to GW_g = 0.12 after consensus exemplified controlled extensibility. Normalization reduced raw water use dispersion (CV from 0.28 to 0.18) while preserving ordering (Kendall τ = 0.86). Global ranking stability underweight perturbation yielded τ = 0.79 with gating agreement = 85%, achieving DP6 Strong. Scope ambiguity between farm level and processing stage prompted glossary refinement and scope boundary field usage, elevating DP1 from Moderate to Strong. Iterative feedback metrics recorded an initial baseline (FRE mean = 6%) without trigger exceedance (DP3 Emerging).

5.6. Cross Case Synthesis and Principal Support

Operationalization (RQ1). All cases produced a decomposable chain from sustainability drivers to composite opportunity scores, evidencing feasibility of early stage ESG

integration. Rank shifts versus historical or heuristic ordering in Cases B and C confirm that embedding ESG and capability indicators alters prioritization salience. Partial social data in Case A illustrates dependency on upstream data governance for full DP1 realization.

Design Principles (RQ2). DP2 shows consistent strong support through observed rank shifts and gating reconfiguration after application of unified weighting. DP4 reaches its strongest expression in Cases B and C where indicator substitution and cluster introduction require no structural refactor. DP5 evolves, shifting narrative A into structured consensus C, diagnostics supporting. DP6 achieves its strongest outcome in Case C where dispersion and stability targets hold; Cases A and B still need weight calibration and data completeness to reach τ thresholds. DP1 advances through proxy labeling and scope boundary schemas. DP3 stays at an emerging stage across all cases because recalibration sessions remain absent, although triggers exist and baseline variance shows capture.

Adaptability and Utility (RQ3). Sector heterogeneity required no changes to core aggregation or gating engines; teams adjusted repository entries and weighting sets instead, showing low configuration friction consistent with modular objectives. Utility emerges through clarified rationale chains and exposure of latent constraints, such as workforce readiness deficits in Case B, that prior weighting underrepresented.

Appendix B presents detailed scoring results and complete weighting matrices for each case study.

5.7. Validity Considerations, Refinements and Design Propositions

Construct validity gains support through triangulation of documentary coding with quantitative stability and dispersion metrics. Internal validity remains bounded because evaluation addresses decision support plausibility without claiming realized sustainability impact. External validity gains partial support from cross-sector variation but faces limits from secondary ex post character and absence of live prospective recalibration cycles. Reliability strengthens through version-controlled glossary, weight diffs, and reproducible perturbation scripts. Key threats include selection bias in accessible documents, proxy dependence with governance in Case B, incomplete social coverage in Case A, and missing iterative feedback loops.

Refinements emerging from evaluation: (Rfn1) scope boundary notation to mitigate ambiguity, (Rfn2) biodiversity cluster template for rapid ecological dimension addition, (Rfn3) stakeholder weight translation checklist to reduce reconciliation time, (Rfn4) automated variance dashboard to activate DP3 cycles, (Rfn5) expansion of social indicator library for labor rights granularity and community impact depth.

Design propositions for future quantitative testing (retained from construction but empirically sharpened): P1 Integrated multi criteria weighting that co locates ESG, capability and market indicators alters opportunity rank ordering relative to financial dominant baselines, reducing omission risk. P2 Architectural decoupling of indicator repository from weighting and normalization engines minimizes cross sector adaptation effort measured as low substitution time and absence of structural edits. P3 Systematic translation of stakeholder narratives into consensus based normalized weight vectors increases perceived fairness and reduces renegotiation latency. P4 variance triggered iterative recalibration of weights and thresholds, which reduces forecast–realized sustainability impact error across successive cycles after activation (prospective).

5.8. Applicability to Sectors with Immature ESG Capabilities

The current validation cases involve industries with mature ESG systems. Many organizations in the service, startup, and non-profit sectors work with limited resources and informal sustainability practices. These conditions restrict their capacity to apply the

SABDF as designed. Common barriers include data scarcity, minimal reporting experience, and weak governance structures.

To extend SABDF to these environments, three adjustments can improve its usability:

1. Simplified Indicators: Replace data-heavy metrics with a smaller set of qualitative measures such as community impact, stakeholder satisfaction, or basic compliance status;
2. Progressive Learning Cycles: Use shorter evaluation loops to help organizations develop ESG literacy and improve data quality through repeated practice;
3. Shared Weighting Templates: Apply collective weighting structures through industry associations or peer networks to compensate for limited expertise within single firms.

These adaptations allow the framework to function as a scalable system that supports both early-stage and mature organizations. Future studies should test this simplified version in emerging service and non-profit sectors to confirm its relevance and identify further design refinements.

5.9. Limitations and Future Research Path

This study faces several limitations. It relies on secondary ex post data without observation of real time negotiation dynamics or learning loops. Recalibration cycles remain unexecuted, leaving DP3 unconfirmed. Indicators show partial gaps, with missing social measures in Case A and governance proxies in Case B. Outcome tracking remains absent, preventing attribution of downstream ESG impact. The sector sample remains limited.

Future research can address these constraints. Prospective multi cycle deployments should capture forecast and realized impact variance evolution. Controlled comparisons against heuristic spreadsheets can test decision latency and accuracy. Broader sector coverage, including healthcare supply chains and circular manufacturing, can extend generalizability. Studies on user perception of transparency and fairness can refine governance readiness. Integration of realized sustainability outcomes will close the loop on adaptive capability. Longitudinal tracking will provide empirical validation of P4 and measure learning curve effects on FRE reduction and ranking stability.

6. Conclusions and Recommendations

Sustainability-Aligned Business Development Framework translates sustainability intent into a reproducible decision system for early business development. SABDF's modular structure enables flexible use across diverse institutional settings. Organizations with limited ESG maturity can apply simplified indicators and shared templates to begin structured sustainability evaluation. Such an approach broadens the framework's reach and strengthens decision quality in sectors that lack established ESG systems. It embeds sustainability drivers and capabilities as core strategic logic through layered indicators, hierarchical weighting, gating safeguards, and modular extensibility. The framework's foundation supports learning-oriented governance and prepares for recalibration cycles that accumulate longitudinal data.

The demonstration of the feedback mechanism shows that the SABDF can incorporate evaluation data into subsequent design cycles, confirming its alignment with the iterative evaluation principle of Design Science.

Integration of Stakeholder Theory and the Resource-Based View (RBV) within the Design Science architecture underpins the framework's logic. Stakeholder expectations act as sensing mechanisms that define sustainability priorities. Dynamic capabilities drive seizing and reconfiguration through feedback loops and modular adaptability. Design

Science provides the structured and iterative means of translating these mechanisms into traceable ESG decision systems.

The framework contributes theoretically by framing sustainability-aligned development as a modular, feedback-ready configuration that links stakeholder salience, capability alignment, and systems thinking. Practically, it provides a governance blueprint that reduces adaptation friction, clarifies decision rationales, and balances innovation, risk, and impact.

Implementation should follow a structured roadmap: establish and document the indicator glossary, conduct stakeholder weight elicitation with consensus diagnostics, run pilot scoring cycles, test new clusters provisionally, automate audit logging and variance dashboards, and maintain a recurring governance cadence. Role clarity across data, strategy, stakeholder, decision, and assurance functions strengthens accountability.

This study builds on propositions extracted from the case studies and emphasizes their collective role as a research agenda. Together, they show how cumulative testing, industry expansion, and digital enablement can validate and extend the framework. Prospective deployments, controlled benchmarks, integration of realized outcome data, and exploration of adaptive methods such as Bayesian updating will advance both theoretical understanding and practical application.

Looking ahead, future iterations of the Sustainability-Aligned Business Development Framework will focus on enhancing iterative learning and automation capacity. Planned refinements include integrating real-time feedback mechanisms (DP3) to strengthen recalibration, expanding social and governance indicator libraries for better balance, and conducting longitudinal tests to assess adaptive performance. These developments advance the framework toward an empirically verified system that guides sustainability decisions and embeds a feedback loop for continuous improvement.

In conclusion, SABDF offers a governance-ready scaffold that embeds transparency, integration, adaptability, stakeholder inclusion, and comparability safeguards. Its significance lies in showing how disciplined governance and targeted inquiry can transform a sound but early-stage artifact into a continuously adapting system that supports resilient, sustainability-aligned growth portfolios.

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Abbreviations

The following abbreviations are used in this manuscript:

ESG	Environmental, Social, and Governance
SABDF	Sustainability-Aligned Business Development Framework
FRE	Forecast–Realized Error
SDI	Sustainability Data Integration

Appendix A

Table A1. Evaluation and Coding Rubric for Design Principles (DP1–DP6).

Design Principle	Definition/Operationalization	Evaluation Source and Criteria	Observable Evidence/Coding Levels
DP1—Transparency/Goal Coherence	ESG goals align with business strategy and are traceable to data, weights, thresholds, and rationale.	Strategic planning documents, indicator registries, metadata logs, version history.	**Absent**: No source or version traceability. **Emerging**: Partial source attribution, incomplete records. **Moderate**: Most indicators linked to source and version info. **Strong**: Full coverage of indicator provenance, weight logic, audit trail.
DP2—Embedded Integration/Role Alignment	ESG indicators integrated with capability and strategic metrics in a unified evaluation model.	Scoring architecture diagrams, weight matrices, cross-functional planning records.	**Absent**: ESG isolated from decision logic. **Emerging**: ESG noted in reports but excluded from evaluation model. **Moderate**: Partial integration with business/capability metrics. **Strong**: Full integration in multi-criteria model with business logic.
DP3—Iterative Feedback/Temporal Integration	Existence of feedback loops and recalibration triggers across short-, medium-, and long-term horizons.	Trigger definitions (FRE, SDI), update protocols, roadmaps.	**Absent**: No feedback or recalibration mechanism. **Emerging**: Feedback logic defined but not activated. **Moderate**: System in place, partial pilots or trials. **Strong**: At least one recalibration cycle completed and documented.
DP4—Modular Adaptability/Process Consistency	Ability to add or replace indicator groups without altering architecture; ESG logic consistent across stages.	Substitution logs, modularity diagrams, stability checks, strategy–review documents.	**Absent**: Fixed architecture, no modularity. **Emerging**: Adjustments require code/schema changes. **Moderate**: Indicators modified with minimal disruption. **Strong**: Plug-and-play modularity, zero structural edits.
DP5—Stakeholder Inclusion	Stakeholder inputs elicited, translated into weights, consensus assessed.	Input logs, preference elicitation (e.g., AHP), Kendall's W, reconciliation records.	**Absent**: No stakeholder input. **Emerging**: Informal or qualitative input, not quantified. **Moderate**: Structured methods applied. **Strong**: Weights validated with consensus (Kendall's $W \geq 0.7$).
DP6—Score-Based Comparability/Traceability	Normalization and stability metrics ensure scores are comparable across options and time; ESG actions traceable to reasoning.	Normalization techniques, CV, Kendall's τ, decision logs.	**Absent**: No normalization or comparability controls. **Emerging**: Basic normalization, no stability checks. **Moderate**: Some comparability metrics implemented. **Strong**: Full safeguards, CV and Kendall's τ meet thresholds ($\tau \geq 0.7$).

Appendix B. Coding Results, Examples, and Statistics

Appendix B.1. Summary of Coding Results Across Cases

Design Principle	Case A (Energy)	Case B (Industrial)	Case C (Agri)	Overall Rating Count
DP1: Transparency	Moderate	Moderate	Strong	1 Moderate, 2 Strong
DP2: Embedded Integration	Strong	Strong	Strong	3 Strong
DP3: Iterative Feedback	Emerging	Emerging	Emerging	3 Emerging
DP4: Modular Adaptability	Emerging	Strong	Strong	1 Emerging, 2 Strong
DP5: Stakeholder Inclusion	Emerging	Moderate	Strong	1 Emerging, 1 Moderate, 1 Strong
DP6: Score-Based Comparability	Emerging	Moderate	Strong	1 Emerging, 1 Moderate, 1 Strong

Note: Distribution Summary- Strong: 9; Moderate: 5; Emerging: 6; Absent: 0 (none observed).

Appendix B.2. Illustrative Coding Excerpts

Case A—DP1 Transparency (Moderate): Most environmental and capability indicators included metadata and proxy rationale. Social indicators lacked versioning and confidence-level annotations, limiting traceability.
Case B—DP2 Embedded Integration (Strong): ESG indicators (governance maturity, capability readiness) were integrated into multi-criteria evaluation logic and influenced project prioritization. Composite scores blended ESG and strategic factors.
Case C—DP3 Iterative Feedback (Emerging): Forecast–realized error (FRE) and sustainability data integration (SDI) thresholds were defined but remained unfired, keeping the principle at readiness stage.

Appendix B.3. Coding Statistics

Initiatives coded: 34
Indicators assessed: 56
Average indicator coverage: Environmental 82%, Capability 74%, Governance 68%
Inter-coder agreement (Cohen's kappa): 0.81

Appendix C. Constructs, Indicators, Proxy Variables, and Theoretical Sources

Appendix C outlines all constructs and proxy variables that correspond to the normalized indicators (N1–N4) and the governance inputs (GW1–GW3) shown in Figure 3. The section specifies each construct's indicator, data type, measurement frequency, and theoretical source drawn from Stakeholder Theory, the Resource-Based View (RBV), and ESG Integration Literature. These details clarify the rationale for including each indicator and show how the framework links conceptual foundations to measurable variables.

Code	Construct/Variable Name	Description	Data Source Examples	Frequency	Data Type	Theoretical Source/Rationale
D1	Environmental Readiness	Measures environmental compliance, emissions transparency, and efficiency	ISO 14001, Scope 1–3 reports, CDP filings	Annual	Observed	ESG Integration Literature—transparency and environmental accountability (e.g., [81]).
D2	Social Responsibility Alignment	Evaluates stakeholder engagement, equity, and social programs	GRI 413, DEI policies, sustainability reports	Quarterly–Annual	Estimated	Stakeholder Theory—legitimacy and inclusivity [88].

Code	Construct/Variable Name	Description	Data Source Examples	Frequency	Data Type	Theoretical Source/Rationale
D3	Governance Maturity	Assesses governance oversight and ESG capability	SASB scores, governance committee records	Annual	Observed	Stakeholder Theory—accountability and governance transparency [89].
P1	Market Opportunity Mapping	Identifies ESG-aligned growth opportunities	Regulatory incentives, policy briefs	Project-based	Simulated	RBV—resource alignment and opportunity recognition [91].
P2	Internal Capability Assessment	Evaluates organizational readiness to execute ESG strategies	Internal KPIs, budget, training logs	Semi-Annual	Observed	RBV—dynamic capability development [92].
P3	Multi-Criteria Evaluation	Balances ESG and business viability	Weighted scoring matrices, stakeholder workshops	Project-based	Simulated	ESG Integration—embedded evaluation logic [83,84].
O1	Strategic Fit Score	Measures alignment between ESG and strategic goals	Composite from P1–P3 evaluation	Per cycle	Simulated	RBV + ESG Integration—adaptive strategy alignment.
O2	Sustainability Impact Projection	Forecasts expected ESG outcomes	Derived from D1–D3 indicators	Per cycle	Estimated	ESG Integration—predictive sustainability modeling.
O3	Outcome Realization Tracking	Validates forecast accuracy through realized outcomes	Post-implementation audits, feedback	Post-deployment	Observed	Stakeholder Theory + RBV—feedback for learning and continuous improvement.

Appendix D. Evaluation Criteria and Case Evidence Matrix

Appendix D.1. Overview

Appendix D builds upon the indicator inventory in Appendix C and the coding protocol in Appendix D. It summarizes anonymized initiatives (Cases A–C) and indicator groups used to validate the Sustainability-Aligned Business Development Framework (SABDF). Each record identifies the indicator or construct assessed, the corresponding design principle (DP1–DP6), supporting evidence, and the observed rating or outcome. Initiatives appear as A1–A27 for Energy Alliance, B1–B34 for Industrial Group, and C1–C21 for Agribusiness Value Chain to maintain confidentiality. The appendix demonstrates traceability among framework principles, applied data, and evaluation results. All data come from public secondary materials such as sustainability reports, policy briefs, and corporate disclosures, and the study excludes internal company documents and non-public information.

Table A2. Case-Based Evidence Mapping and Indicator Alignment.

Case/Initiative ID	Indicator/Construct	Related Design Principle (s)	Evidence Type/Source	Rating/Outcome	Notes/Interpretation
A—Energy Alliance	D1—Environmental Readiness	DP1 Transparency, DP2 Embedded Integration	National policy briefs, ISO 14001 [93], audits, grid-resilience reports	High	Demonstrates transparent documentation and integration of ESG with strategic energy planning.
	O1—Strategic Fit Score	DP2, DP6	Portfolio evaluation sheets, scenario analyses	4.5/5	Unified ESG-capability weighting improved opportunity ranking consistency.
	D2—Social Responsibility Alignment	DP5 Stakeholder Inclusion	Community engagement summaries	Moderate	Partial data; stakeholder inputs qualitative only.

Table A2. *Cont.*

Case/Initiative ID	Indicator/Construct	Related Design Principle (s)	Evidence Type/Source	Rating/Outcome	Notes/Interpretation
B—Industrial Group	D3—Governance Maturity	DP1, DP5	Internal ESG oversight records, sustainability reports	Moderate–High	Evidence of structured committees and participatory oversight.
	P2—Internal Capability Assessment	DP2, DP4	Training logs, R&D investment data	Medium	Supports modular adaptability across divisions.
	O3—Adaptive Capability	DP3 Iterative Feedback	Pilot documentation, version-control logs	Emerging	Recalibration triggers defined but not yet activated.
C—Agribusiness Value Chain	D2—Social Responsibility Alignment	DP4, DP5	Sustainability audits, certification data	High	Verified stakeholder participation; rapid module substitution successful.
	D1—Environmental Readiness (Biodiversity Cluster)	DP1, DP4, DP6	Biodiversity monitoring records, water-use KPIs	High	Added indicator mid-cycle without structural changes; comparability maintained.
	O2—Sustainability Impact Projection	DP2, DP3	ESG forecast models, pilot reports	Moderate–High	Demonstrates integrated evaluation with baseline variance tracking.

Appendix D.2. Interpretive Summary

The mapping confirms that each design principle (DP1–DP6) appeared in all three sectors, providing comprehensive framework coverage. Explicit metadata, normalization procedures, and stability metrics in the evaluation (see Sections 5.3 and 5.4) demonstrate DP1 and DP6 by strengthening transparency and comparability. Modular insertion of the biodiversity indicator in Case C validated DP4 without code changes, which shows the framework's adaptability. Consensus metrics (Kendall's $W \geq 0.70$) in Cases B and C support DP5 and reflect strong stakeholder inclusion. Baseline variance and FRE/SDI thresholds (DP3) define parameters that support iterative feedback within the framework.

Appendix D.3. Cross-References

- Indicator definitions and theoretical rationale: Appendix C
- Coding and normalization example: Appendix E
- Evaluation procedure: Sections 5.3 and 5.4
- Aggregate findings and limitations: Sections 5.5–5.7

Appendix E. Example of Coding and Normalization for Construct "Environmental Readiness"

This appendix provides a worked example illustrating the transformation of qualitative information into normalized quantitative scores for one construct within the SABDF.

Appendix E.1. Context and Evidence Sources

The construct Environmental Readiness (D1) evaluates how an organization meets environmental standards, discloses emissions data, and improves resource efficiency. Analysts collect evidence from ISO 14001 certifications, sustainability reports, and carbon-disclosure filings. These materials provide measurable data on compliance, transparency, and performance. Each source supports assessment of the organization's ability to align environmental goals with strategic development.

Appendix E.2. Coding Protocol

1. Identify Evidence. Analysts locate statements and metrics that describe performance related to D1.
2. Assign Qualitative Ratings. They score each item on a four-level scale (0 = Absent, 1 = Emerging, 2 = Moderate, 3 = Strong).
3. Apply Confidence Coefficients. Each rating receives a confidence coefficient (C) from 0.5 to 1.0 depending on source reliability (audited > verified > proxy).
4. Convert to Numeric Values. Analysts compute normalized scores with

$$N_i = \frac{(S_i/3) \times C_i}{\max(C_i)} \quad \text{(A1)}$$

   where S_i = rating and C_i = confidence.
5. Aggregate Scores. The mean of normalized values yields the construct score for D1.
6. Validate Coding. Two analysts verify each record and reach consensus; the target reliability is $\kappa \geq 0.80$.

Appendix E.3. Illustrative Example

Evidence Source	Qualitative Level	Score (S)	Confidence (C)	Normalized Value (N_i)
ISO 14001 Certification	Strong	3	0.9	0.90
Emission Reduction Plan	Moderate	2	0.8	0.67
ESG Report (Energy Data)	Emerging	1	0.7	0.33
Composite Environmental Readiness Score				0.63

Appendix E.4. Reweighting and Integration

The normalized D1 score enters the environmental group weight (GW_g) within the SABDF hierarchy. If the Forecast–Realized Error exceeds 15 percent or Kendall's *W* drops below 0.70, analysts recalibrate the environmental module. This adjustment aligns the system with iterative feedback (DP3) and preserves comparability (DP6).

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