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Hybrid Business Model Transformation and Financial Sustainability: Evidence from Ukraine's Structural Transition

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Abstract:
This study develops and empirically validates a hybrid transformational business model for service enterprises operating under structural transition conditions. Focusing on Ukraine's digitally evolving service sector, the research integrates SWOT benchmarking, qualitative adaptability assessment, and indicator-based computational modelling to compare eight archetypal business model configurations. An original multidimensional indicator system, capturing adaptability, strategic agility,

resilience, digital integration, customer elasticity, and circular alignment, was constructed using normalized financial and operational metrics. Comparative testing demonstrates that ecosystem-coordinated and digitally servitized configurations significantly outperform traditional transactional and on-demand models in terms of structural resilience and financial sustainability.

Building on these findings, the study synthesizes a hybrid architecture that integrates platform coordination, predictive digital infrastructure, subscription-based monetization, and circular value-retention mechanisms. Indicator-based verification confirms the superior adaptive capacity of the hybrid model across all integral metrics. Theoretically, the research advances business model scholarship by operationalizing adaptability as a quantifiable, multidimensional construct and moving beyond descriptive typologies toward measurable structural competitiveness. Practically, the results provide strategic guidance for managers and policymakers seeking to enhance financial sustainability, institutional resilience, and digital interoperability in transitional economic environments.

Keywords: business model transformation; hybrid architecture; digital servitization; financial resilience; circular value retention; transitional economies.

JEL Classification: L21; L86; O31; G32; Q56.

Introduction

Service enterprises operate in an environment characterized by accelerating digitalization, intensified competition, regulatory fragmentation, and growing sustainability pressures. Traditional service-oriented configurations, historically structured around transactional logic and reactive delivery, increasingly demonstrate limited adaptability to circular economy requirements, digital interoperability standards, and data-driven customer interaction architectures (Atstaja et al., 2022). As service ecosystems become platform-mediated and algorithmically coordinated, firms must transition from static operational models toward dynamically integrated business architectures.

Simultaneously, governance transformations toward value-oriented and human-centered public administration impose higher expectations regarding customer-centricity, transparency, and institutional accountability (Semenets-Orlova et al., 2022). Increased regulatory density, coupled with cybersecurity threats and financial instability risks, further necessitates the development of business models that are digitally resilient, compliance-traceable, and analytically verifiable (Kussainov et al., 2023).

Financial sustainability has become a critical dimension of this transformation. Heightened requirements for financial transparency, exposure to liquidity volatility, and sensitivity to macroeconomic shocks intensify the vulnerability of traditional service configurations (Lipczyńska, 2024). Empirical evidence indicates that digitalized market infrastructures may amplify systemic risk transmission during financial stress episodes, reinforcing the need for structurally resilient and data-integrated business architectures (Engler & Jeleskovic, 2024). Persistent liquidity constraints in the SME sector further underline the necessity of adaptive models capable of stabilizing cash flows and reducing margin volatility under turbulent conditions (Słowik, 2022).

Despite extensive research on digital servitization, circular business models, and platform ecosystems, the literature remains fragmented. Existing studies often examine these dimensions in isolation, without offering an integrated, indicator-based framework capable of comparatively measuring structural adaptability and financial resilience across business model configurations. Consequently, there is a need to move beyond descriptive typologies toward quantifiable evaluation of adaptive competitiveness.

In response to this gap, the present study aims to develop and empirically validate a hybrid transformational business model for service enterprises operating under transitional economic conditions. The proposed model integrates digital servitization, ecosystem coordination, and circular alignment within a unified architectural framework supported by a multidimensional indicator system.

To achieve this aim, the study addresses the following research questions:

RQ1: How do different service enterprise business model configurations differ in their transformational potential when assessed through SWOT-based structural benchmarking?

RQ2: What qualitative hierarchy of adaptability emerges across business models when evaluated against technological, market, institutional, financial, organizational, and circular challenges?

RQ3**:** How do business model configurations comparatively perform under an integral indicator-based testing framework measuring adaptability, resilience, digital integration, customer elasticity, and circular value retention?

RQ4**:** How can the most resilient structural components be synthesized into a hybrid business model architecture characterized by institutional-adaptive modularity?

RQ5: Does the synthesized hybrid configuration demonstrate superior operational efficiency, financial sustainability, and interoperability when subjected to the same indicator-based verification procedure?

This study develops an integral indicator-based framework for measuring business model adaptability and synthesizes a hybrid architecture that integrates digital servitization, ecosystem coordination, and circular alignment, empirically validating its structural superiority under transitional economic conditions.

1. Literature Review

A review of current academic research is necessary to identify conceptual approaches, typologies and tools for business model transformation in the service sector. Systematization of academic achievements provides a theoretical basis for further verification of adaptive strategies in a turbulent competitive environment.

Initially, Ventura & Silva e Meirelles (2025) identified four stages of structuring service provider business models, from individual to ecosystem, which reflected the escalation of digitalization and network integration. The authors proved the adaptability of value creation, configuration and appropriation strategies in the context of Industry 4.0.

Elaborating this approach, Kim et al. (2025) developed a two-dimensional framework of product-service systems (PSS) business models, combining the axes of servitization/ productization and internalization/externalization, which provided a typology of strategies in a matrix format. The authors proved the bidirectional convergence of production and service and the strategic importance of resource integration.

From the perspective of technological integration, Werner et al. (2025) developed the concept of a modular Digital Twin as a tool for system integration of sustainability data into service-oriented business models. The authors empirically confirmed its effectiveness for energy optimization modelling and simulation of production processes.

In the field of circularity, Alcayaga & Hansen (2025) developed a funnel framework of Smart Circular Systems, which identified 20 micro-activities and their interdependencies in servitization digital business models. The authors proved that the integration of these activities ensured the development of smart circularity and the transformation of the system of activities.

In the context of policy instruments, Bergmann et al. (2025) identified nineteen practices for restructuring business models under the influence of a mandatory maintainability index. The authors proved its functioning as an informative and managerial tool that catalysed the transition to repair-oriented circular models.

Ipaki & Hosseini (2025) formulated five integrated repair-oriented design strategies based on mass customization and standardization, which ensured the convergence of manufacturers' business interests and circular sustainability goals. The authors identified 28 barriers and 56 drivers, institutionalizing a framework for optimizing repairability.

From the perspective of small- and medium-sized enterprises (SME)-oriented transformations, Yap (2025) developed a business model innovation framework for Information and Communication Technology (ICT) reseller SMEs that combined resource management, stakeholder orchestration, strategic innovation, and dynamic capabilities. The author proved that the integration of these elements ensured adaptability, resilience, and long-term business sustainability.

Furthermore, de la Calle et al. (2025) created a framework for integrating digital service innovation into the business model of SMEs, which increased value propositions and operational efficiency. The authors proved the existence of barriers to monetization, organizational alignment, and customer data management.

Nasirinejad et al. (2025) developed a RAMS²-oriented framework for implementing Industry 4.0 in SMEs, which ensured the optimization of reliability, availability, maintainability, security, and sustainability. The authors proved its effectiveness in increasing operational efficiency, product quality, as well as financial and competitive resilience.

Finally, Yadav et al. (2025) conceptualized circular business models such as Resource Sharing and Product-as-a-Service as tools for the transition from a linear to a resource-efficient economy. The authors proved their potential in increasing sustainability, innovation, and competitive adaptability in circular ecosystems.

The reviewed publications demonstrate the multi-level evolution of service enterprise business models in the areas of digitalization, servitization, modularity, and circularity. The mentioned frameworks reflect the strategic convergence of resource integration, institutional orchestration, and innovative adaptability, which emphasizes the academic need to study the transformation of service enterprise business models as determinants of their competitive stability and resilience in a turbulent environment.

2. Research Methodology

Research Design

This study adopts a cross-iterative analytical design integrating qualitative benchmarking, indicator-based modelling, and architectural synthesis. The research logic follows five sequential stages:

- Conceptual benchmarking of representative service enterprise business models;
- Stratification of competitive-environment challenges affecting structural adaptability;
- Development of an integral indicator system measuring adaptability, resilience, servitization intensity, and circular alignment;

- Computational modelling and comparative testing of business models;
- UML-based synthesis and verification of a hybrid transformational business model.

The cross-iterative design enables progressive refinement, where each analytical stage informs the subsequent modelling and verification phase.

2.2. Methods

Sample and Business Model Typology

The empirical benchmark of this study comprises eight representative business model configurations operating within the computer and telecommunications equipment repair and maintenance sector. This segment was deliberately selected due to its high exposure to technological turbulence, regulatory tightening, accelerated digitalization, and increasing circular economy pressures, factors that collectively intensify the need for structural adaptability and financial resilience.

The analysed business model typologies include: transactional model, subscription model, outsourcing model, on-demand model, product-service system (PSS) model, circular model, digital servitization model, ecosystem model. The structural characteristics, operational mechanisms, and academic anchoring of each model archetype are presented in Appendix A (Table A1).

These configurations reflect varying degrees of servitization, digital integration, institutional embedding, and strategic transformation maturity. Together, they provide a structured continuum ranging from traditional product-centric configurations to highly integrated, digitally orchestrated, and ecosystem-based architectures.

The selection of models was guided by four primary analytical criteria:

1. Structural organization of value creation;
2. Degree of digital integration;
3. Strategic orientation along the product–service continuum;
4. Level of circular and ecosystem embedding.

The selected typology does not represent individual firms, but rather archetypal structural configurations synthesized from contemporary academic literature and sectoral practices. This abstraction enables systematic cross-model comparison while avoiding firm-specific distortions. To systematically assess adaptive capacity, the study develops a structured stratification of the contemporary competitive environment. Rather than treating environmental turbulence as an undifferentiated exogenous force, the research decomposes it into analytically distinct yet interrelated challenge categories.

Seven categories of environmental pressure were identified:

- Technological challenges

Technological turbulence reflects accelerated innovation cycles, the integration of Industry 4.0 infrastructures, IoT-based diagnostics, predictive analytics, and cybersecurity demands. In the repair and maintenance segment, shortened technology life cycles and interoperability complexity intensify the need for continuous digital upgrading and algorithmic integration.

- Market challenges

Market pressures arise from increasing competition between local and global providers, platform-based disintermediation, price dumping, and the commoditization of standardized services. These dynamics compress margins and reduce the sustainability of purely transactional revenue architectures.

- Customer challenges

Customer expectations have shifted toward SLA-based guarantees, transparency, mobility, and personalization. The transition from reactive to predictive service provision requires deeper data integration and cognitive customer analytics.

- Institutional and regulatory challenges

Service enterprises increasingly operate within dense regulatory environments characterized by cybersecurity standards, environmental directives, data protection requirements, and compliance auditing. In transitional economies, regulatory unpredictability may further amplify institutional risk exposure.

- Financial and economic challenges

Capital intensity associated with digital infrastructure, currency volatility, liquidity constraints, and investment fragility create structural vulnerability, particularly among SMEs. High CAPEX requirements for digital transformation must be balanced against uncertain demand conditions.

- Organizational and human resource challenges

The shortage of STEM competencies, need for reskilling, cross-functional integration, and cyber-resilience culture formation represent critical internal constraints on transformation capacity.

- Circular and environmental challenges

The transition toward circular economy principles introduces requirements for eco-design, life-cycle management (LCM), reverse logistics, and value retention. Enterprises must integrate sustainability metrics without undermining profitability.

The seven-category framework fulfils three methodological functions: Benchmarking Function – It provides a structured lens for qualitative adaptability assessment across business model archetypes; Indicator Construction Function – It informs the weighting logic of the integral adaptability and sustainability metrics; Synthesis Function – It guides the architectural composition of the hybrid transformational model.

Decomposing environmental turbulence into measurable structural vectors, the study moves beyond descriptive environmental scanning and operationalizes adaptability as a multidimensional construct.

The detailed taxonomy and operational characteristics of each challenge category are presented in Appendix A (Table A2).

Instrumentation and Indicator System

The indicator system operationalizes adaptability as a composite construct integrating financial, operational, customer-oriented, digital, and circular performance dimensions. Rather than relying on isolated performance metrics, the study formalizes adaptive capacity through weighted aggregation of normalized core business indicators, thereby enabling cross-model comparability and integral evaluation. The instrument comprises nine principal indices structured across five analytical domains:

The Adaptability Index (AI) measures the structural responsiveness of a business model to technological, market, and regulatory turbulence. It aggregates normalized performance metrics reflecting revenue dynamics, profitability, customer stability, acquisition efficiency, and break-even resilience. Positive contributors (RGR, GM, ROI, NPS) are balanced against structural cost and instability factors (CAC, BEP, churn rate), ensuring symmetrical evaluation of growth and vulnerability components.

The Strategic Agility Index (SAI) captures the speed and elasticity of strategic response by emphasizing revenue responsiveness, customer retention stability, loyalty dynamics, and cost adaptation efficiency.

The Resilience Coefficient (RC) evaluates shock absorption capacity by comparing pre- and post-disturbance performance levels across margin, retention, and revenue indicators. The geometric aggregation structure ensures proportional balancing of stability and recovery dynamics. The RAMS² Composite Index (Reliability, Availability, Maintainability, Security, Sustainability) provides an integrated operational resilience measure derived from weighted normalized performance parameters. This composite reflects structural continuity under turbulence.

The Innovation Flexibility Ratio (IFR) measures the intensity of adaptive transformation by capturing incremental changes in loyalty, revenue growth, and margin dynamics.

The Digital Integration Degree (DID) reflects the embeddedness of digital infrastructure within the business model by combining acquisition efficiency, retention stability, margin optimization, and growth performance.

The Customer Retention Elasticity (CRE) assesses the sensitivity of customer stability to environmental pressures, balancing retention rates, loyalty scores, and acquisition costs.

The Sustainability Alignment Metric (SAM) evaluates integration of sustainable development principles through profitability-return balance and capital-efficiency stabilization.

The Circular Value Retention Index (CVRI) measures value preservation capacity within circular configurations by assessing profitability and reinvestment effectiveness while accounting for margin leakage.

All indicators were constructed using normalized values of classical business metrics: Revenue Growth Rate (RGR), Gross Margin (GM), Return on Investment (ROI), Customer Retention / Churn Rate (CR), Net Promoter Score (NPS), Customer Acquisition Cost (CAC). Break-Even Point (BEP). Normalization was performed using min-max scaling to ensure dimensional homogeneity and cross-model comparability. Weighting coefficients (ω, β, ψ, λ, φ, θ, γ, κ) were calibrated iteratively to maintain structural proportionality and to avoid dominance of any single performance dimension. The full mathematical specification of all indices is presented in Table 1.

Table 1. Integral Indicators of Business Model Adaptability

Analytical Domain	Indicator	Compact Mathematical Specification
Adaptability and Strategic Flexibility	Adaptability Index (AI)	$AI = \Sigma(\omega_i X_i)$, i=1..7
	Strategic Agility Index (SAI)	$SAI = \Sigma(\beta_i X_i)$, i=1..4
Resilience and Sustainability	Resilience Coefficient (RC)	$RC = [(GM\_post/GM\_pre) \times ((1-CR\_post)/(1-CR\_pre)) \times ((1+RGR\_post)/(1+RGR\_pre))]^{(1/3)}$
	RAMS² Composite Index	$RAMS^2 = \Sigma(\psi_i X_i)$, i=1..5
Innovation and Digital Integration	Innovation Flexibility Ratio (IFR)	$IFR = \Sigma(\lambda_i \Delta X_i)$, i=1..3
	Digital Integration Degree (DID)	$DID = \Sigma(\varphi_i X_i)$, i=1..4
Customer-Centric Elasticity	Customer Retention Elasticity (CRE)	$CRE = \Sigma(\theta_i X_i)$, i=1..3
Sustainability and Circularity	Sustainability Alignment Metric (SAM)	$SAM = \Sigma(\gamma_i X_i)$, i=1..3
	Circular Value Retention Index (CVRI)	$CVRI = \Sigma(\kappa_i X_i)$, i=1..3

Note: XiX_iXi represents normalized business performance variables derived from RGR, GM, ROI, CR, NPS, CAC, and BEP. Min–max normalization and directional adjustment were applied so that higher values indicate stronger adaptability. Weighting coefficients ensure proportional balance across indicators.
Source: Authors' conceptual framework and calculations.

Indicator modelling and cross-model benchmarking were implemented in Python using the NumPy, pandas, and scikit-learn libraries. The computational procedure consisted of the following sequential stages:

- Normalization of raw performance metrics using min–max scaling to ensure dimensional homogeneity and cross-model comparability;
- Weighted aggregation of normalized indicators into composite indices according to the specified coefficient structure;
- Construction of integral adaptability and resilience measures;
- Comparative benchmarking across business model archetypes;
- Iterative sensitivity recalibration of weighting coefficients to test structural stability of ranking outcomes.

Robustness was assessed through controlled variation of weighting parameters within predefined proportional ranges. The stability of relative model positioning across recalibration scenarios indicated structural consistency of the indicator system and reduced sensitivity to marginal coefficient adjustments. No significant rank reversals were observed under moderate coefficient perturbations, supporting internal methodological coherence.

The algorithmic implementation ensures full analytical traceability and reproducibility of results. All transformation steps, from normalization to index construction, are formally specified in Table 1 and can be replicated under identical parameter conditions. In parallel, UML modelling tools were employed to synthesize and visualize the structural architecture of the hybrid transformational business model. Class, component, activity, and sequence diagrams formalized system interoperability, stakeholder coordination, and modular adaptability.

However, several methodological limitations should be acknowledged. First, the weighting structure, although iteratively calibrated, retains a degree of normative design and may reflect analytical prioritization choices. Second, the use of normalized aggregated indicators abstracts from firm-specific heterogeneity and sectoral micro-variations. Third, the modelling framework assumes linear weighted relationships among performance components, which may not fully capture nonlinear adaptive dynamics.

Despite these constraints, the indicator system provides a structured and transparent comparative framework for evaluating business model adaptability under conditions of technological turbulence and institutional transition.

3. Results

The initial stage of the empirical analysis involved SWOT-based benchmarking of the eight business model archetypes (Table 2). The objective was to identify structural asymmetries in adaptability, revenue stability, technological integration, and institutional resilience under contemporary competitive turbulence.

Table 2. SWOT Analysis of Business Models of Service Enterprises

Business model	Strengths	Weaknesses	Opportunities	Threats
Transactional Model	Standardized tariffs; low barriers to entry; ease of operational implementation.	Lack of long-term contracts; low margins; limited customer loyalty.	Transaction automation; scaling in local markets.	Price dumping; displacement by more adaptive models.
Subscription Model	Regularized cash flows; SLA guarantees; increased customer retention.	High infrastructure support costs; dependence on SLA performance.	Expansion of service packages; preventive and predictive maintenance.	Customer churn because of SLA violations; market dumping.
Outsourcing Model	Economies of scale; integration into the customer's business processes; strategic resilience.	Contract dependency; complexity of process coordination.	Long-term partnerships; diversification of services.	Contract termination; regulatory restrictions.
On-Demand Model	Flexibility; rapid response; minimal SLA obligations.	Income instability; low level of service personalization.	Use of mobile platforms; dynamic pricing.	Competition with digital market places; demand volatility.
Product-Service System (PSS) Model	Product + service integration; lifecycle management; service upgrade capability.	High CAPEX; complexity of management coordination.	Cross-subsidization; formation of long-term relationships.	Techno-algorithmic risks; dependence on manufacturers.
Circular Model	E-waste minimization; closed supply chains; compliance with eco-standards.	High reverse logistics costs; limited resale profitability.	Eco-certifications; growing demand for green solutions.	Competition with low-cost providers; environmental regulatory pressure.
Digital Servitization Model	Predictive maintenance; big data analytics; IoT integration.	High CAPEX for digitalization; cyber threats.	Expansion of digital services; process optimization.	Cyberattacks; rapid technology obsolescence.
Ecosystem Model	Platform orchestration; multi-stakeholder cooperation; value chain expansion.	Management complexity; dependence on partners.	Co-innovation; development of service platforms.	Conflicts of interest; regulatory barriers.

Source: Authors' conceptual framework.

The SWOT stratification reveals a differentiated hierarchy of structural robustness. The Digital Servitization and Ecosystem models demonstrate superior adaptive potential due to platform-based coordination, predictive maintenance capabilities, data-driven orchestration, and multi-stakeholder interoperability. Their strengths lie in scalability, algorithmic integration, and enhanced customer retention mechanisms.

In contrast, the Transactional model exhibits structural fragility characterized by margin compression, absence of recurring revenue mechanisms, and limited customer lock-in. The On-Demand model, although flexible, remains vulnerable to demand volatility and price competition.

The Subscription and Product-Service System (PSS) models occupy an intermediate adaptive position, combining recurring revenue stabilization with increased operational and capital complexity. The Circular configuration demonstrates environmental compliance advantages and value-retention potential but faces scaling constraints and higher reverse logistics costs.

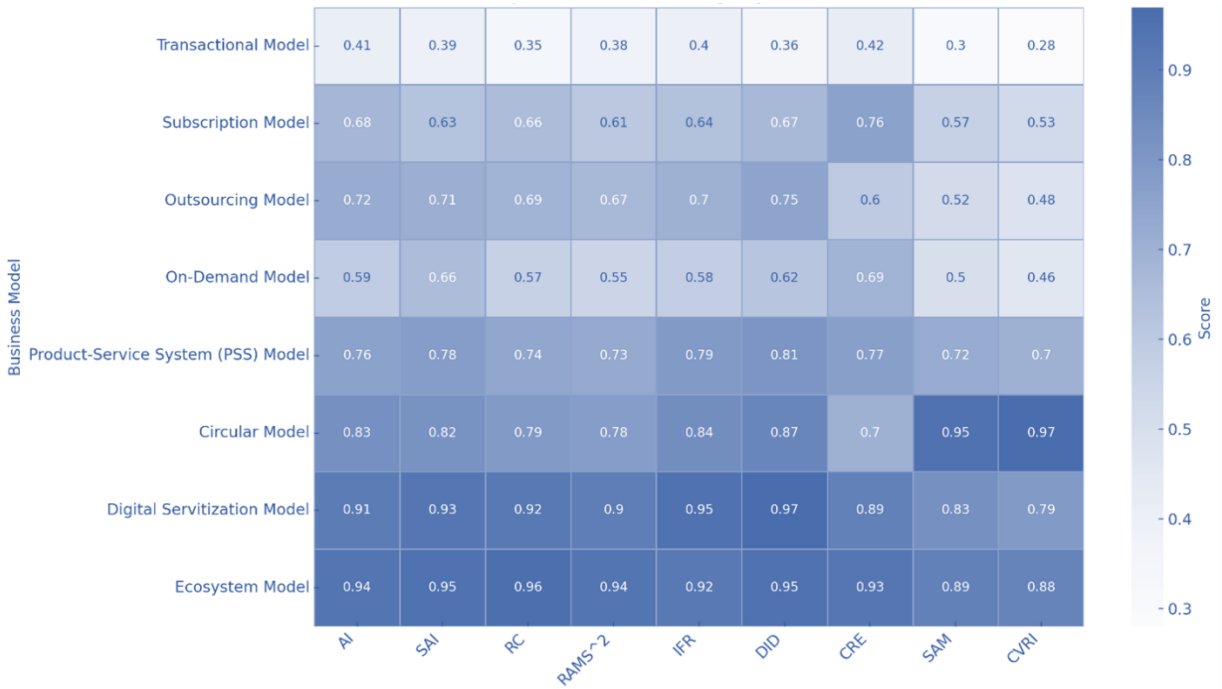
Overall, the SWOT benchmarking establishes a structural differentiation that anticipates quantitative disparities in adaptability and resilience metrics.

A structured qualitative adaptability assessment was conducted across seven environmental challenge categories (technological, market, customer, institutional, financial, organizational, and circular). The detailed matrices for each configuration are presented in Appendix B (Tables B1–B8).

The qualitative benchmarking confirms a clear hierarchy of adaptive capacity. The Ecosystem and Digital Servitization models exhibit high techno-algorithmic embeddedness, regulatory compatibility, and customer-centric elasticity. These models demonstrate multidimensional resilience across digital, financial, and institutional domains.

Conversely, traditional transactional configurations display limited digital integration and reduced institutional buffering capacity. Intermediate models exhibit selective strengths but lack cross-modular interoperability. These findings provide conceptual justification for the subsequent indicator-based modelling and comparative validation. The quantitative benchmarking results derived from the integral indicator system are presented in Figure 2.

Figure 2. Matrix of Indicator-Based and Model-Based Testing of Business Models of Service Enterprises



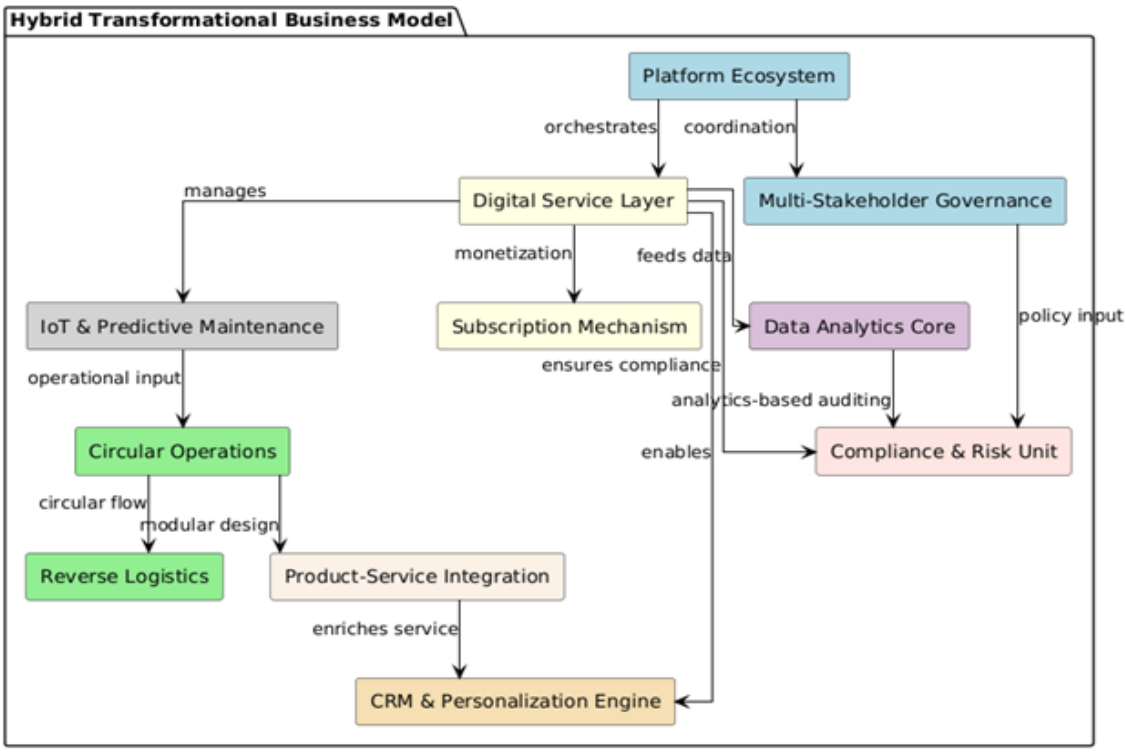
Source: created by the authors in Python.

The computational analysis confirms the qualitative hierarchy. The Ecosystem Model achieves the highest composite adaptability and digital integration scores, followed closely by the Digital Servitization Model. Both configurations demonstrate elevated performance across Adaptability Index (AI), Resilience Coefficient (RC), Digital Integration Degree (DID), and Circular Value Retention Index (CVRI).

In contrast, the Transactional model consistently ranks lowest across adaptability, agility, and resilience metrics. Subscription and PSS models demonstrate moderate stabilization effects through recurring revenue mechanisms but remain structurally less interoperable than ecosystem-based architectures. The stability of ranking outcomes under iterative weight recalibration supports the internal robustness of the indicator system.

Building upon benchmarking and computational testing, a hybrid transformational architecture was synthesized through UML-based structural integration of the most resilient model components.

Figure 3. UML Architecture of A Hybrid Transformational Business Model



Source: created by the authors in UML-based environment

The hybrid model integrates:

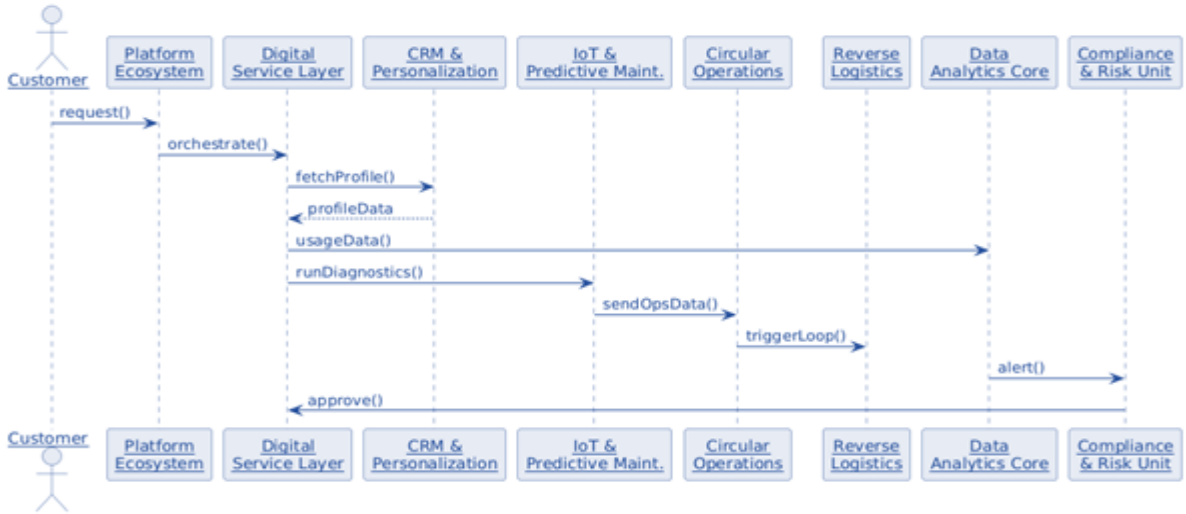
- Ecosystem-based platform coordination,
- Digital servitization infrastructure (IoT, predictive maintenance, CRM),
- Subscription-based monetization logic,
- Circular value-retention mechanisms (LCM, reverse logistics),
- ESG-aligned compliance and cybersecurity modules.

This configuration establishes cross-modular adaptability by combining technological interoperability, recurring revenue stabilization, and institutional traceability within a unified architectural framework.

Figure 4 shows the sequence architecture of user interaction with a hybrid transformational business model of service enterprises, which structurally integrates digital service orchestration

(DSL), customer personalization (CRM), infrastructure diagnostics (IoT), circular operations (CO–RL), analytical monitoring (DAC), and compliance control (CRU). The request trace from initiation to reverse audit is visualized, ensuring cognitive adaptability, functional interoperability, and regulatory traceability. The scheme forms the architectural prerequisite for the final iteration, indicator-based and model-based verification of the hybrid model using a set of adaptive metrics (Figure 5).

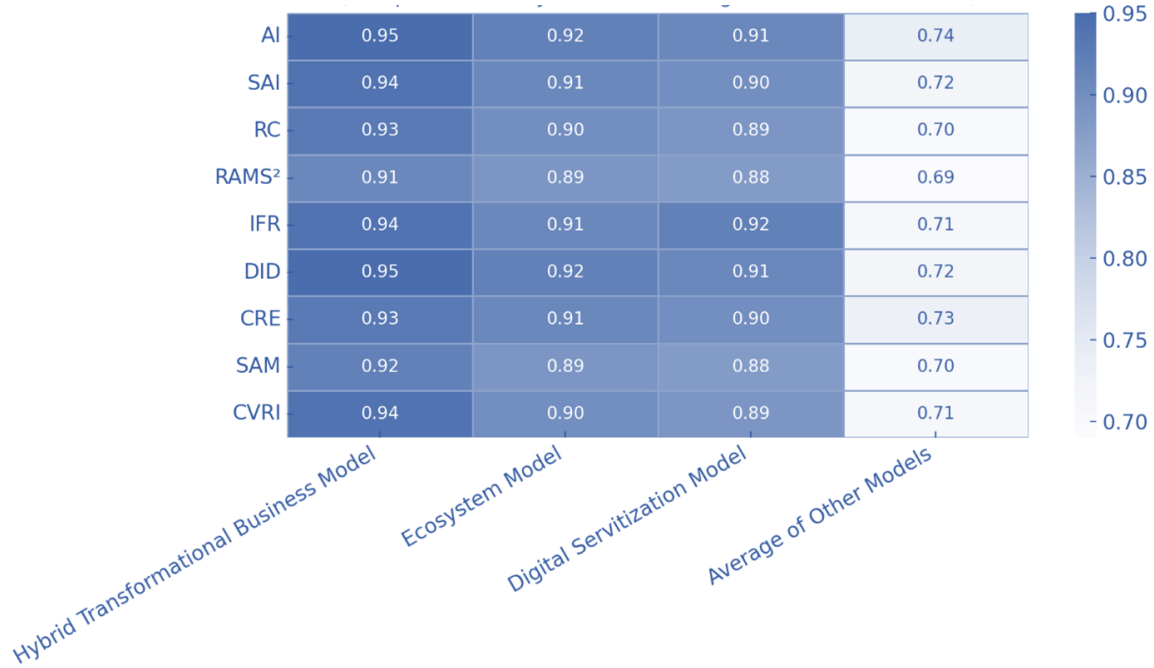
Figure 4. Sequence Architecture of User Interaction



Source: created by the authors in UML-based environment

The sequence diagram operationalizes this structure by illustrating stakeholder interaction flows, from service initiation to predictive diagnostics, circular reintegration, and compliance monitoring. The architecture ensures cognitive personalization, operational traceability, and regulatory resilience. The synthesized hybrid model was subjected to the same integral indicator testing framework. The verification matrix is presented in Figure 5.

Figure 5. Indicator-Based and Model-Based Verification Matrix of the Hybrid Business Model



Source: created by the authors in Python.

The results demonstrate that the hybrid configuration outperforms all benchmark archetypes across integral metrics, including AI, SAI, RC, RAMS², IFR, DID, CRE, SAM, and CVRI. Compared to the leading standalone configurations (Ecosystem and Digital Servitization), the hybrid model exhibits:

- Greater revenue predictability,
- Enhanced shock absorption capacity,
- Improved customer retention elasticity,
- Higher digital integration coherence,
- Stronger circular alignment.

These findings confirm that adaptive transformation is maximized not through isolated model optimization but through cross-modular synthesis of digital, ecosystem, and circular capabilities.

3.7. Financial Sustainability Implications

From a financial sustainability perspective, the hybrid model strengthens cash flow stability and reduces revenue volatility through servitization-driven recurring income structures. Digital integration lowers operational friction and improves working capital turnover, while circular value retention mitigates capital intensity pressures.

In transitional economic environments characterized by institutional instability and capital constraints, such structural adaptability enhances long-term solvency and reduces dependency on external financing.

From the perspective of financial sustainability, the verified hybrid transformational business model strengthened revenue predictability and risk absorption through servitization-driven recurring cash flows, subscription-based monetization, and portfolio diversification of service streams. Digitalization and data-driven orchestration reduced operating leverage and transaction costs, improved working-capital turnover, and mitigated liquidity volatility, which is particularly critical in the Ukrainian transition economy characterized by demand shocks and capital constraints. The integration of predictive maintenance, circular value retention, and ecosystem partnerships additionally lowered CAPEX pressure, reduced debt dependency, and enhanced long-term solvency by stabilizing margins under conditions of institutional and market turbulence.

In transitional economic environments characterized by institutional instability and capital constraints, such structural adaptability enhances long-term solvency and reduces dependency on external financing.

4. Discussion

The findings position the hybrid transformational architecture as a structurally superior configuration relative to contemporary digital servitization and circular business model frameworks. Unlike partial or domain-specific approaches identified in prior research, the proposed model integrates digital, ecosystem, and circular capabilities within a single indicator-verified architecture.

Karatzas et al. (2025) classify digital servitization trajectories in manufacturing SMEs through logistic regression analysis, emphasizing organizational and contextual determinants of business model selection. While their framework identifies adoption patterns, it does not operationalize comparative adaptability across structural configurations. In contrast, the present study introduces an integral indicator system that quantitatively differentiates adaptive capacity and demonstrates the structural dominance of ecosystem-integrated models.

Similarly, Xu et al. (2025) conceptualize business model innovation through migration and expansion mechanisms in the Industrial Internet context. Their contribution focuses on value reconfiguration processes but lacks formalized resilience metrics. The hybrid model developed in this study advances the literature by embedding innovation within a measurable adaptability and resilience structure, linking transformation not only to value creation but also to financial sustainability.

Purwaningwulan & Christina (2025) demonstrate that AI-enabled service tools improve communication efficiency but do not fully substitute traditional interaction modes. The present findings extend this insight by showing that digital augmentation alone is insufficient unless integrated within platform coordination and recurring revenue mechanisms. The empirical results confirm that isolated digitalization does not yield maximal adaptability without ecosystem orchestration.

Krishnan et al. (2025) identify Industry 4.0 integration as a driver of supply chain sustainability. However, their analysis remains centered on operational efficiency. The hybrid model proposed here incorporates Industry 4.0 capabilities while simultaneously integrating customer elasticity, regulatory traceability, and circular value retention into a unified resilience framework.

Circular-oriented contributions (Sharma, 2025; Rizzitello et al., 2025; Kant et al., 2025) emphasize environmental transformation but frequently treat sustainability as an isolated strategic layer. The indicator-based validation in this study demonstrates that circular alignment (SAM and CVRI) achieves highest effectiveness when embedded within digitally integrated and ecosystem-coordinated architectures. Circularity, therefore, functions as a reinforcing rather than autonomous transformation vector.

Ozturkoglu et al. (2025) highlight barriers to sustainable servitization, including financial constraints and regulatory fragmentation. The hybrid architecture addresses these constraints structurally through subscription-based monetization, digital cost optimization, and platform-based risk sharing. The high CRE, SAM, and RC scores indicate that financial stabilization and regulatory compatibility are endogenous outcomes of cross-modular integration.

Collectively, the results suggest that business model transformation should not be conceptualized as linear servitization or incremental digitalization. Instead, adaptive superiority emerges from cross-domain modular synthesis, where ecosystem coordination, predictive digital infrastructure, recurring revenue logic, and circular retention mechanisms reinforce one another.

The study thus advances the literature by shifting from descriptive typologies toward measurable structural competitiveness grounded in integral adaptability metrics.

Conclusion

This study developed and empirically validated a hybrid transformational business model for service enterprises operating under structural transition conditions. Through SWOT benchmarking, qualitative adaptability assessment, and indicator-based computational modelling, the research demonstrated that adaptive superiority arises from cross-modular integration rather than isolated model optimization.

The theoretical contribution lies in the formalization of adaptability as a multidimensional, quantifiable construct integrating digital integration, financial resilience, customer elasticity, and circular alignment. By introducing a structured indicator system and applying it consistently

across archetypal configurations, the study advances business model research from conceptual classification toward measurable structural competitiveness.

The findings indicate that ecosystem-coordinated and digitally servitized configurations exhibit higher resilience to technological turbulence, regulatory density, and financial volatility. The hybrid synthesis further enhances these capabilities by stabilizing revenue flows, reducing operational friction, and strengthening circular value retention.

From a policy perspective, the results underscore the importance of institutional frameworks that facilitate digital interoperability, platform governance, and circular compliance infrastructures. In transitional economies, regulatory digitalization, transparent procurement systems, and cybersecurity standardization function as catalysts for enterprise-level adaptive transformation. Policymakers should therefore prioritize ecosystem-enabling regulation rather than sector-fragmented interventions.

For managers, the evidence suggests that sustainable competitiveness cannot be achieved through incremental digital upgrades alone. Strategic emphasis should be placed on subscription-based monetization, predictive maintenance integration, cross-organizational collaboration, and life-cycle value retention mechanisms. Adaptive resilience emerges from architectural coherence rather than technological accumulation. Although the modelling framework relies on weighted aggregation and normalized indicators, the robustness analysis confirms structural stability of comparative outcomes. Future research may extend this approach through longitudinal field validation and nonlinear modelling of adaptive dynamics across sectors.

In conclusion, the study demonstrates that financial sustainability and strategic resilience in service enterprises are structurally conditioned by integrated digital-ecosystem architectures. The hybrid transformational model offers a scalable reference framework for enterprises navigating institutional turbulence and competitive volatility in transitional economic environments.

Credit Authorship Contribution Statement

Sapin, V: Conceptualization; Methodology; Formal analysis; Indicator system development; Writing – original draft; Visualization; Supervision; Prokopenko, S.: Methodology; Software; Data curation; Computational modelling; Validation; Writing – review & editing; Havadzyn, N.: Literature review; Theoretical framework development; Investigation; Writing – review & editing; Postova,V.: Qualitative benchmarking; SWOT analysis; Data interpretation; Writing – review & editing; Halan, K.: UML-based architectural modelling; Visualization; Validation; Writing – review & editing.
All authors contributed to the discussion of results and approved the final version of the manuscript.

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The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval Statement

Ethical approval was waived due to the use of secondary data sources and the retrospective nature of the study. All data used were either publicly available or derived using custom text-mining scripts, and no human participants were involved.

References

Adsiz, T., & Ozturkoglu, Y. (2025). A conceptual framework for a new service model: Digital servitization with an Industrial 4.0 perspective. *Journal of Global Operations and Strategic Sourcing, 18*(2), 267–284. https://doi.org/10.1108/jgoss-08-2022-0091

Alcayaga, A., & Hansen, E. G. (2025). Smart circular economy as a service business model: An activity system framework and research agenda. *R&D Management, 55*(2), 508-530. https://doi.org/10.1111/radm.12707

Almunawar, M. N., Anshari, M., & Fauzi, A. M. (2025). Modeling circular economic activities: A business ecosystem perspective through the value exchange network framework. *International Journal of Sustainable Development & World Ecology*, *32*(4), 415–427. https://doi.org/10.1080/13504509.2025.2474937

Anning-Dorson, T. (2025). The evolution and impact of business models in africa's emerging digital economy. In *Digital business transformation in Africa, volume I* (pp. 35–74). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-91756-1_3

Arnezti, N., Ikhsanti, P. M., Alika, D. Z., Ummah, F., Syaukani, R. C. A. S., Saputra, M. A., ... Ramadhan, Z. D. H. (2025). A review on literature: How information and communication technology (ICT) supports circular economy for sustainable development. *Social, Ecology, Economy for Sustainable Development Goals Journal*, *2*(2). https://doi.org/10.61511/seesdgj.v2i2.2025.1419

Atstaja, D., Koval, V., Grasis, J., Kalina, I., Kryshtal, H., & Mikhno, I. (2022). Sharing model in circular economy towards rational use in sustainable production. *Energies*, *15*(3), 939. https://doi.org/10.3390/en15030939

Bakiji, M., & Shehu, V. (2025). Economic and business viability of it outsourcing in North Macedonia. *SEEU Review*, *20*(1), 92–109. https://doi.org/10.2478/seeur-2025-0046

Bergmann, M., Ntsondé, J., Beulque, R., & Micheaux, H. (2025). Business models for strong circularity—the role of informative policy instruments promoting repair. *Business Strategy and the Environment, 34*(2). https://doi.org/10.1002/bse.4096

Campos, J. N. (2025). Institutional influences over reuse and redistribution circular business models: Implications for public policy. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5127078

Chaudhuri, R., Chatterjee, S., Ghosh, A., Vrontis, D., & Thrassou, A. (2025). Sustainable innovation for shared mobility: Contextual and consumer factors of an Indian car subscription business model. *International Journal of Entrepreneurial Behavior & Research, 31*(2-3), 344–368. https://doi.org/10.1108/ijebr-01-2022-0090

Darwish, R., Magnusson, M., Sandström, G. Ö., & Pernestål, A. (2025). Contested spaces: Business model tensions and control challenges in industry-converging ecosystems. *International Journal of Innovation Management, 29*(2), 1–24. https://doi.org/10.1142/s1363919625500227

de la Calle, A., Freije, I., & Larrinaga, M. A. (2025). Digital service innovation in SMEs: Identifying the barriers for business model evolution. *Journal of Enterprise Information Management*. https://doi.org/10.1108/jeim-03-2024-0115

Słowik, D. S. (2022). Changes in the financial liquidity of business entities of the small and medium-sized enterprises sector in Poland. *Journal of Applied Economic Sciences)*, *4*(78), 315–320. https://doi.org/10.57017/jaes.v17.4(78).03

Engler, M., & Jeleskovic, V. (2024). Electronic trading and financial crisis effects in the e-mid interbank market: A multivariate multiplicative error model analysis. *Journal of Applied Economic Sciences*, *1*(83), 63–76. https://doi.org/10.57017/jaes.v19.1(83).04

Ipaki, B., & Hosseini, Z. (2025). Repair-Oriented design and manufacturing strategies for circular electronic products, from mass customization/standardization to scalable repair economy. *Results in Engineering*, *25*, 104169. https://doi.org/10.1016/j.rineng.2025.104169

Kant, S., Adula, M., & Duloma, H. (2025). The rise of product-as-a-service models in the digital era redesigning business models for circular innovation in the horn of africa. In *Advances in Finance, Accounting, and Economics* (pp. 133–160). IGI Global. https://doi.org/10.4018/979-8-3373-0578-3.ch007

Karatzas, A., Dousios, D., Raja, J. Z., & Papadopoulos, G. (2025). An exploration of digital servitization business models in manufacturing SMEs. *Journal of Small Business Management*, 1–44. https://doi.org/10.1080/00472778.2024.2448966

Kim, H., Seo, B. G., & Kim, J. (2025). Development of a two-way framework for the product-service system business model: Focusing on convergence perspective. *Research Square*. https://doi.org/10.21203/rs.3.rs-6242333/v1

Krasuski, A. (2025). Conceptualising the transition from a product-centric business model to a service-centric model. In *Studies in systems, decision and control* (pp. 1–19). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-98901-8_1

Krishnan, R., Phan, P. Y., Krishnan, S. N., Agarwal, R., & Sohal, A. (2025). Industry 4.0-driven business model innovation for supply chain sustainability: An exploratory case study. *Business Strategy and the Environment*, *34*(1). https://doi.org/10.1002/bse.3970

Krüger, K., Böttcher, T., Jonas, M. E., & Krcmar, H. (2025). Leveraging digital product passports to overcome circular economy challenges: Comparative insights from the textile and semiconductor industries. In *2025 IEEE Conference On Technologies For Sustainability (SusTech)* (pp. 1–8). IEEE. https://doi.org/10.1109/sustech63138.2025.11025717

Kussainov, K., Goncharuk, N., Prokopenko, L., Pershko, L., Vyshnivska, B., & Akimov, O. (2023). Anti-corruption management mechanisms and the construction of a security landscape in the financial sector of the EU economic system against the background of challenges to European integration: Implications for artificial intelligence technologies. *Economic Affairs (New Delhi), 68*(1), 509-521. https://doi.org/10.46852/0424-2513.1.2023.20

Lipczyńska, A. (2024). Financial reporting and analysis: Evaluating property, financial position, and results in business entities. *Journal of Applied Economic Sciences*, *4*(86), 539–550. https://doi.org/10.57017/jaes.v19.4(86).16

Nasirinejad, M., Afshari, H., & Sampalli, S. (2025). Empowering SMEs in the fourth industrial revolution: A framework for maintenance 4.0 adoption. *Procedia Computer Science*, *253*, 1382–1391. https://doi.org/10.1016/j.procs.2025.01.200

Ozturkoglu, Y., Ozturkoglu, O., & Danisman, E. (2025). New business model proposal in the digital age: Sustainability-focused servitization. *Journal of Enterprise Information Management*. https://doi.org/10.1108/jeim-02-2025-0124

Purwaningwulan, M. M., & Christina, C. H. (2025). Transformation of intelligent assistant services in public service companies in Indonesia. *AIP Conference Proceedings*, *3200*(1), 040021. https://doi.org/10.1063/5.0102466

Rizzitello, E., Busacca, A., Roma, P., & Perrone, G. (2025). Linking circular business models with value sources: A cluster-based literature review. *Business Strategy & Development*, *8*(2). https://doi.org/10.1002/bsd2.70111

Semenets-Orlova, I., Shevchuk, R., Plish, B., Moshnin, A., Chmyr, Y., & Poliuliakh, R. (2022). Human-Centered approach in new development tendencies of value-oriented public administration: Potential of education. *Economic Affairs (New Delhi), 67*(5), 899-906. https://doi.org/10.46852/0424-2513.5.2022.25

Sharma, D. (2025). Green sustainability initiatives in service sector. In *Advances in computational intelligence and robotics* (pp. 485–502). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-8034-5.ch024

Song, J., Liu, X., Cifuentes-Faura, J., & Duan, J. (2025). ICT, heterogeneous labour structure and productivity of producer service enterprises: Evidence from China. *International Journal of Manpower, 46*(2), 267–290. https://doi.org/10.1108/ijm-11-2023-0649

Tang, R. W., Mi, L., Chan, X. W. C., Yan, H., & Cavusgil, S. T. (2025). Corporate social responsibility and technological advancement of international service enterprises: Links and gaps in the literature. *Management International Review, 65,* 415–458. https://doi.org/10.1007/s11575-025-00578-4

Vargas, D., & Fontoura, L. (2024). Problems and solutions in adopting information and communication technology in micro and small enterprises. *International Journal of Information Systems and Project Management*, *12*(1), 43–73. https://doi.org/10.12821/ijispm120103

Ventura, M. A. d. A., & Silva e Meirelles, D. (2025). Business model structuration in Industry 4.0: An analysis of the value-based strategies of smart service providers in Brazil. *Journal of Manufacturing Technology Management, 36*(1), 134–158. https://doi.org/10.1108/jmtm-12-2023-0548

Werner, A., Schuseil, F., Hämmerle, M., Schaper, S., & Hölzle, K. (2025). Modular Digital Twin – an approach for generating and exploiting product sustainability information towards service-oriented business models. *International Journal of Production Research*, *63*(3), 1–19. https://doi.org/10.1080/00207543.2024.2366997

Xu, Y., Bai, Z., Wang, Z., Song, X., Zhang, Y., & Zhang, Q. (2025). Research on business model innovation of SMEs in the industrial internet era: Building theory from the case of PAYA. *Nankai Business Review International, 16*(1), 104–127. https://doi.org/10.1108/nbri-09-2023-0085

Yadav, A. K., Kanwal, P., & Dewasiri, N. J. (2025). Circular business models with resource sharing and product-as-a-service. In *Advances in business strategy and competitive advantage* (pp. 197–234). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-9241-6.ch008

Yap, C. Y. (2025). *Establishing business model innovation framework for business sustainability: A case study on ICT reseller SMEs in Malaysia* [Doctoral dissertation], University of Wales Trinity Saint David. https://repository.uwtsd.ac.uk/id/eprint/3766/

Appendix A:

Table A1: Sample of business models typology

Business Model	Short description	Main mechanisms	Academic studies
Transactional Model	One-time provision of repair and maintenance services without long-term commitments.	Direct payments; standardized price lists; fixed rates; low personalization; lack of long-term customer binding.	Song et al. (2025)
Subscription Model	Regular service maintenance for a subscription fee with a guaranteed SLA.	Recurrent payments; preventive and predictive maintenance; contractual obligations; SLA monitoring; formation of stable cash flows; increased customer loyalty.	Chaudhuri et al. (2025)
Outsourcing Model	Delegation of technical support functions to an external service provider.	Long-term contracts; integration into the customer's business processes; economies of scale; strategic relocation of resources; increased operational resilience.	Bakiji & Shehu (2025)
On-Demand Model	Flexible and prompt provision of services at the client's request.	Online booking; mobile service teams; dynamic pricing; minimum SLAs; rapid response to incidents; optimization of resource allocation.	Ugiwal & Jha (2025)
Product-Service System (PSS) Model	Integration of equipment sales and long-term service support.	Combination of "product + service"; extended warranties; life cycle management; service upgrades; retrofitting; cross-subsidization of income.	Wang & Zheng (2025)
Circular Model	Implementation of the principles of maintainability, reuse and resale.	Modular design; re-sale of refurbished equipment; closed supply chains; reverse logistics; minimization of e-waste; compliance with eco-standards.	Arnezti et al. (2025)
Digital Servitization Model	Use of digital platforms and IoT for forecasting and optimization of service processes.	Remote diagnostics; predictive maintenance; big data analytics; CRM integration; real-time monitoring; digital twin application for optimization.	Adsiz & Ozturkoglu (2025)
Ecosystem Model	Cooperation of service enterprises with manufacturers and distributors within a common platform.	Data exchange; multi-stakeholder orchestration; platform management; co-innovation; interoperability standards; value chain expansion.	Almunawar et al. (2025)

Source: created by the authors

Table A2. Competitive environment stratification

Challenge category	The essence of the challenge	Key characteristics	Academic studies
Technological challenges	Accelerated digitalization and innovation pressure from equipment manufacturers.	Fast technology life cycle; IoT integration; need for predictive maintenance; adaptation to Industry 4.0; high complexity of diagnostics.	Tang et al. (2025)
Market challenges	Intensifying competition between local and global providers.	Price dumping; emergence of new players; growing role of online platforms; service standardization; reduction of marginality.	Darwish et al. (2025)
Customer challenges	Transformation of consumer expectations and service requirements.	Increased demand for SLA guarantees; focus on speed and mobility of services; individualization of service; transparency and control of customer data.	Krasuski (2025)
Institutional and regulatory challenges	Complex regulatory framework and environmental standards.	Requirements for disposal and recycling; environmental sustainability directives; cybersecurity regulations; control of access to customer data; licensing.	Campos (2025)
Financial and economic challenges	Limited resources and increasing innovation costs.	High CAPEX for digital solutions; dependence on currency fluctuations; instability of demand; financial vulnerability of SMEs; low investment attractiveness.	Anning-Dorson (2025)
Organizational and human resource (HR) challenges	Shortage of qualified personnel and need for new competencies.	Insufficient STEM specialists; need for constant reskilling; dependence on narrow-profile specialists; staff rotation; high training costs.	Vargas & Fontoura (2024)
Circular and environmental challenges	Implementation of sustainable development and circular economy principles.	Increased demand for repair-oriented design; reduction of electronic waste; eco-design; reuse of components; integration of green practices.	Krüger et al. (2025)

Source: created by the authors

Appendix B

Table B1: Qualitative analysis of the adaptability of the Transactional Model

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	Low techno-integration; risk of displacement	Basic digitalization of operations; transaction automation
Market	Price dumping; weak value proposition	Pricing flexibility; increased channel availability
Customer	Limited loyalty; weak personalization	Implementation of loyalty programmes; basic CRM
Institutional and Regulatory	Minimal compliance	Implementation of basic compliance control
Financial and Economic	High volume dependence; instability	Diversification of services; flexible pricing
Organizational and HR	Minimal staffing requirements	Training in basic digital skills
Circular and Environmental	Lack of eco-integration	Focus on eco-certified supplies

Source: created by the authors

Table B2: Qualitative analysis of Subscription Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	High demands on SLA-compliant digital infrastructures	Predictive maintenance integration; CRM/ERP system modernization
Market	High competition; need for sustainable value positioning	Implementation of differentiated packages; subscription personalization
Customer	Rising expectations for service level, SLA and transparency	SLA control, omnichannel support, customer behaviour analytics
Institutional and Regulatory	Requirements for quality of service, data protection, SLA performance	Deployment of compliance monitoring, ISO certification, GDPR adaptation
Financial and Economic	High CAPEX; dependence on customer retention	Predictive cash flow planning; service cost optimization
Organizational and HR	Need for service-oriented personnel	HR profiling, SLA-oriented training, support automation
Circular and Environmental	Low direct circularity, however – impact through the service cycle	Inclusion of green options in subscription, Life Cycle Management (LCM) service extension

Source: created by the authors

Table B3: Qualitative analysis of the Outsourcing Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	Dependence on the compatibility of IT architectures with customer systems	API unification; middleware integration; cloud platform implementation
Market	Intense global competition; high level of B2B substitution	Development of unique service competencies; specialization in niche services
Customer	High expectations for SLA, transparency, availability	SLA audit; service customization; constant two-way communication with customers
Institutional and Regulatory	Requirements for contractual compliance, data protection, security standards	Outsourcing legal support; adaptation to regional regulatory regimes (GDPR, ISO)
Financial and Economic	Dependence on contract financing; risks of exchange rate fluctuations	Contract hedging; long-term SLA models with fixed rates
Organizational and HR	High level of competencies; shortage of qualified personnel	Creation of internal training centres; certification of specialists; personnel reserve
Circular and Environmental	Low level of integration of environmental practices into service processes	Incorporation of green SLA; environmental expertise at the contract design stage

Source: created by the authors

Table B4: Qualitative analysis of the On-Demand Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	Dependence on mobile platforms; risks of instability of IT infrastructure	Cloud scalability; SLAs with platform providers; multi-channel integration
Market	Volatile demand; consumer price sensitivity; competition with marketplaces	Dynamic pricing; partnership with aggregators; targeting local niches
Customer	Expectation of instant response, mobility, transparency of the service	Implementation of real-time monitoring; UI/UX optimization; automated feedback
Institutional and Regulatory	Low level of formalized compliance procedures	Establishment of basic privacy policies; legalization of content and transactions
Financial and Economic	Fragmented revenues; instability of cash flows	Integration of prepayment systems; balancing between freelancers and in-house services
Organizational and HR	High personnel mobility level; difficulty of quality standardization	Implementation of gamified quality assessment systems; automated training of operators
Circular and Environmental	Lack of eco-standards in most services	Development of eco-friendly options for consumers; inclusion of eco-indicators in service marketing

Source: created by the authors

Table B5: Qualitative analysis of the Product-Service System (PSS) Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	High algorithmic complexity; dependence on IoT and LCM integration	Implementation of modular architecture; use of interoperable APIs; automated LCM
Market	Demand shift towards service-oriented models; need for service upgrade	Development of adaptive service packages; product customization; service differentiation
Customer	Expectation of comprehensive, personalized solutions with high SLA levels	Development of CRM; implementation of SLA-oriented tools; use of predictive maintenance
Institutional and Regulatory	Need to meet both technical and service standards	Certification of products and services; multi-level quality audit system; compliance with technical and legal norms
Financial and Economic	High CAPEX; complexity in financial life cycle planning	Use of LCM financial modelling; phased implementation; cross-subsidization of service modules
Organizational and HR	High requirements for multidisciplinary staff qualifications	Formation of cross-functional teams; hybrid personnel profiles; continuous upskilling programmes
Circular and Environmental	Need for eco-design and recycling management	Implementation of LCA (Life Cycle Assessment); modular eco-design; eco-compliance certification

Source: created by the authors

Table B6: Qualitative analysis of the Circular Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	High complexity of reverse logistics; need for traceability and eco-tech	IoT integration for cycle monitoring; automation of logistics processes; digital LCM platforms
Market	High competition with low-cost providers; difficulty of scaling	Development of segmented value propositions; positioning through eco-branding
Customer	Narrow target audience formation; insufficient maturity of customer eco-preferences	Educational campaigns; implementation of eco-loyalty programs; transparency in CO_2 fingerprint
Institutional and Regulatory	High requirements for recycling, licensing, and circular protocols	Full compliance with ESG and EU Green Deal; participation in voluntary certification
Financial and Economic	High costs of eco-integration; limited short-term profitability	CAPEX optimization through ecosystem partnership; green stock leasing
Organizational and HR	Need for specialists in eco-design, certification, LCA	Upskilling of personnel in the field of circular economy; creation of LCM competence centres
Circular and Environmental	Need to ensure full life cycle with minimization of e-waste	Full integration of LCM; eco-design; regeneration; recycling; compliance with ISO 14040

Source: created by the authors

Table B7: Qualitative analysis of the Digital Servitization Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	High level of techno-algorithmic complexity; need for continuous modernization	Implementation of scalable architectures; use of modular AI components; edge computing
Market	Constantly updating value proposition; technological differentiation against competitors	Adaptive pricing; digital twins for service validation; flexible API interfaces
Customer	Increased expectations for personalization, data availability, speed of response	Integration of CRM/PRM systems; cognitive UX modules; SLA optimization based on ML analytics
Institutional and Regulatory	Strict requirements for cybersecurity, data protection, interoperability	Implementation of ISO/IEC 27001, NIS2, GDPR standards; audit of logs and digital compliance
Financial and Economic	High CAPEX for digitalization; need for ROI from smart services	Gradual capitalization of digital assets; use of XaaS models; optimization of OPEX through AI
Organizational and HR	Deficit of digital competencies; need for STEM talents and cyber resilience	Formation of digital centres of competence; strategic reskilling; DevSecOps culture
Circular and Environmental	Need to consider LCM and energy efficiency of digital services	Integration of ESG metrics; optimization of data centres; application of Green IT solutions

Source: created by the authors

Table B8: Qualitative analysis of the Ecosystem Model adaptability

Challenge Category	Impact of the challenge on the model	Typical actions for impact reduction
Technological	High complexity of integrating disparate digital platforms; need for interoperability	Use of open standards (e.g., REST, GraphQL); API orchestration; platform modularity
Market	Risk of loss of control over the value chain due to multi-actor approach	Joint monetization mechanisms; coordination of value streams; formation of joint development strategies
Customer	Relative expectations for individualized, comprehensive solutions	Integration of omnichannel services; formation of segmented value-offers; flexible UX customization
Institutional and Regulatory	Existence of conflicts of jurisdictions; regulation of partnerships and data	Creation of legal frameworks for inter-party interaction; alignment with international standards (e.g., ISO)
Financial and Economic	Uneven capitalization between ecosystem participants; risk of resource asymmetry	Risk-sharing mechanisms; joint investment in R&D; cost optimization through network synergies
Organizational and HR	High requirements for multi-disciplinarity and inter-organizational coordination	Building partner competence hubs; implementation of common standards for personnel certification
Circular and Environmental	Difficult coordination of eco-strategy at the level of all participants	Shaping a common environmental policy; ecological traceability systems in the ecosystem