DETERMINANTS OF CIRCULAR ECONOMY DEVELOPMENT IN THE DIGITAL TRANSFORMATION ERA

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Abstract: ***The circular economy (CE) has become a strategic priority in Vietnam, yet its implementation remains limited by institutional, technological, behavioral, and financial challenges. As digital transformation (DX) accelerates, understanding which factors most strongly influence CE development is essential for guiding policy and practice. This study employs the Analytic Hierarchy Process (AHP) to assess the relative importance of six determinant groups: Institutions, Policies, and Governance; Digital Infrastructure and Foundational Technologies; Firms' Innovation and Technological Capabilities; Circular Awareness, Attitudes, and Consumer Behaviors; Green Financial Resources and Market Mechanisms; and Multi-Stakeholder Collaboration and Innovation Ecosystems. Expert evaluations from government, academia, industry, and international organizations indicate that CE development in Vietnam follows a policy-led, technology-enabled, and enterprise-driven pattern. Institutions and governance are the most influential determinants, followed by digital infrastructure and enterprise innovation, while consumer behavior, green finance, and collaboration exhibit lower influence. The findings provide evidence-based priorities for strengthening Vietnam's transition toward a digitally enabled circular economy.***

• Keywords: *circular economy development, digital transformation era, determinants, AHP.*

JEL codes: Q01, Q50, O33, Q56, L52

Date of receipt: 08th Oct., 2025
Date of receipt revision: 06th Dec., 2025
Date of delivery revision: 22th Nov., 2025
Date of approval: 20th Jan., 2026

DOI: https://doi.org/10.71374/jfar.v26.i1.06

1. Introduction

Vietnam presents a particularly relevant context where CE and DX intersect. While CE has been institutionalized through major legislative and strategic instruments - most notably the Law on Environmental Protection (2020) and the National CE Development Scheme (Decision 687/QĐ-TTg, 2022) - digital transformation is simultaneously being accelerated under the National Digital Transformation Program to 2030. Despite this strong policy momentum, Vietnam's CE transition continues to face significant barriers. These include fragmented regulatory implementation, underdeveloped digital infrastructure, limited technological capability among firms, low enterprise readiness for CE practices, insufficient sustainable consumption behaviors, weak cross-stakeholder collaboration, and constrained financial resources.

These challenges point to a critical research gap. Although the literature has examined CE and digital transformation extensively, studies that integrate the two domains into a unified analytical framework - particularly those providing structured, quantitative assessments of determinant importance in developing economy contexts - remain limited. Addressing this gap is essential for informing evidence-based policy design and prioritizing strategic interventions.

This study responds to this gap by identifying key determinant groups shaping CE development under digital transformation, constructing a hierarchical framework comprising six factor categories, and applying AHP to derive their relative importance. Through this multi-criteria evaluation, the study offers a rigorous, evidence-based prioritization of CE determinants and provides actionable insights to guide policymakers, enterprises, and stakeholders in advancing a digitally enabled circular economy in Vietnam.

2. Literature review

2.1. Theoretical and empirical foundations

The CE is a development model focused on optimizing resource use, extending product life cycles, and minimizing environmental impacts through reuse, recycling, and material regeneration. Digital transformation, by contrast, involves the adoption of technologies such as IoT, Big Data, AI, blockchain, and digital platforms to enhance operational and governance efficiency.

The convergence of CE and DX has led to the

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emergence of "Circular Economy 4.0" where digital technologies facilitate life-cycle tracking, traceability, reverse logistics, and innovative circular business models, while also strengthening data-driven governance and extended producer responsibility. In this context, CE and DX are mutually reinforcing and jointly supporting sustainable development goals.

Recent scholarship emphasizes that CE development under digital transformation is influenced by multiple determinants, including institutional conditions, technological infrastructure, firm capabilities, financial mechanisms, consumer behavior, and multi-stakeholder collaboration. The subsequent section reviews and analyzes these key determinant groups.

(1) Institutions, policies, and governance

Institutions and policies constitute the foundational mechanisms guiding and coordinating the transition toward a circular economy. A coherent legal framework - encompassing technical standards, environmental regulations, extended producer responsibility, and national CE strategies - is essential for enabling circular models. Within the digital transformation context, governments can leverage digital data, traceability platforms, and online monitoring systems to enhance transparency, implementation efficiency, and regulatory compliance (OECD, 2023). Numerous studies emphasize the catalytic role of institutional quality in initiating and accelerating CE development, particularly in developing economies (Kirchherr et al., 2017; Geissdoerfer et al., 2018).

(2) Digital infrastructure and foundational technologies

Digital infrastructure serves as a critical enabler of CE, especially as the "Circular Economy 4.0" paradigm becomes increasingly prominent. Technologies such as IoT, Big Data analytics, artificial intelligence, blockchain, and cloud computing support product life-cycle tracking, material flow management, reverse logistics optimization, and automation of sorting and recycling operations (Rosa et al., 2020). These technologies not only improve transparency but also empower firms and regulators to make data-driven decisions, thereby enhancing operational efficiency and precision within CE systems (Bressanelli et al., 2018; ITU, 2024).

(3) Firms' innovation and technological capabilities

Enterprises are central actors in CE implementation. Innovation capability encompasses the adoption of eco-design principles, circular business models, remanufacturing and recycling technologies, and smart supply-chain management enabled by digital tools. Research demonstrates that firms with higher levels of digitalization are better positioned to implement CE practices due to improved data analytics, resource optimization, and flexible production processes (Ranta et al., 2021; Ghosh, 2023). Moreover, innovation capability facilitates the creation of new business models - such as Product-as-a-Service and the sharing economy - thereby enhancing both economic and environmental value.

(4) Green finance and market mechanisms

Green finance is a decisive factor in scaling CE initiatives at both the enterprise and national levels. Financial resources - ranging from green credit and sustainable investment funds to tax incentives, secondary material markets, and environmental pricing instruments such as carbon taxes - play a pivotal role. Under the influence of DX, fintech and blockchain technologies enhance transaction transparency, verify green activities, and support the development of carbon and recycled-material markets (UNDP, 2023; Wang et al., 2021). Green finance thus acts as a key driver of technological innovation while reducing risks for firms transitioning to circular models.

(5) Consumer awareness, attitudes, and circular behaviors

Consumer behavior represents a critical "market pull" mechanism in CE. Positive awareness and attitudes toward recycled, reused, shared, and sustainable products enable firms to scale circular activities (Camacho-Otero et al., 2018). Digital transformation promotes circular behaviors through waste-sorting applications, reuse platforms, digital communication campaigns, and online education systems (OECD, 2023). Such behavioral shifts help create markets for circular products and strengthen the implementation of environmental policies.

(6) Multi-stakeholder collaboration and innovation ecosystems

CE requires the participation of diverse stakeholders, including government agencies, firms, academic institutions, civil society organizations, local communities, and international partners. DX facilitates the formation of innovative ecosystems where shared data, transparent information flows, and digital platforms strengthen interactions among actors

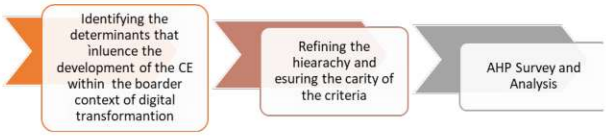
(UNIDO, 2022). Multi-stakeholder collaboration is crucial for technological diffusion, the development of eco-industrial parks, and the implementation of large-scale circular business models (Ellen MacArthur Foundation, 2023; Bocken et al., 2017).

Although interest in the circular economy and digital transformation (DX) is growing, significant research gaps remain. Current studies tend to examine CE and DX separately, offering limited insight into their interactions. Empirical evidence from developing countries is sparse, despite their unique institutional, technological, and behavioral conditions. Moreover, few studies systematically evaluate the relative importance or causal relationships among CE determinants in digital contexts, and the roles of multi-stakeholder collaboration and circular consumption behavior are insufficiently addressed. These gaps underscore the need for comprehensive empirical research that identifies and quantifies the key determinants of CE development under digital transformation, thereby strengthening theoretical understanding and informing more effective sustainability policies.

2.2. Methodology

This study employs a quantitative research design based on the AHP to determine the relative importance of stakeholder-related determinants influencing the development of the circular economy in Vietnam. The research follows a three-stage sequential process designed to ensure that the analytical framework is both theoretically robust and practically relevant. An overview of the entire research design is presented in Figure 1.

Figure 1. Research process



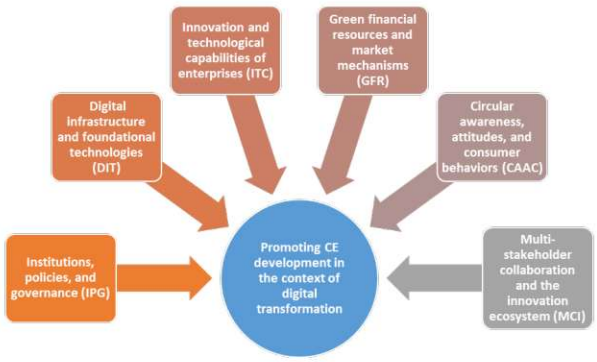
Based on the literature review and expert consultation, the study develops a two-level hierarchical structure for the AHP model as follows:

Level 1: Overall Goal - Promoting circular economy development in the context of digital transformation in Vietnam.

Level 2: Determinants affecting circular economy development under digital transformation.

Drawing on previous studies and expert consultations, the research identifies six determinants, as presented in Figure 2.

Figure 2. The AHP hierarchical model of circular economy development in the digital transformation era



The AHP, developed by Saaty (1980), was applied to quantify the relative importance of determinants. The method involves pairwise comparisons among criteria to derive ratio-scale priorities through matrix eigenvalue computation.

First, experts were asked to compare each pair of elements at the same hierarchical level using the nine-point Saaty scale, where 1 indicates equal importance and 9 denotes extreme importance of one element over another. Individual comparison matrices were then aggregated using the geometric mean to form a group judgment matrix, ensuring that collective opinions represent the consensus view of all experts.

Next, the priority vector (weights) was obtained by normalizing the principal eigenvector of each comparison matrix. The Consistency Index (CI) and Consistency Ratio (CR) were computed to verify the logical coherence of judgments using the following formulas:

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI}$$

where λ_{max} is the maximum eigenvalue of the matrix, n is the number of criteria, and RI denotes the Random Index based on matrix size (Saaty & Vargas, 2001). A matrix is considered consistent when CR $\leq$ 0.10.

After confirming consistency, the global weights of each sub-determinant were calculated by multiplying its local weight by the corresponding weight of the parent determinant. These global weights were subsequently used to rank the relative importance of the determinants shaping circular economy development.

3. Research findings and discussion

Pilot interviews were first conducted to refine the hierarchical structure, clarify the wording of criteria

and sub-criteria, and ensure the coherence of the pairwise comparison questionnaire. Expert feedback helped sharpen conceptual definitions, remove overlapping elements, and improve consistency across hierarchical levels, thereby enhancing the clarity and methodological rigor of the final AHP instrument.

The formal AHP survey involved fourteen purposively selected experts with substantial experience in circular economy, digital transformation, environmental policy, and sustainability governance. Their diverse institutional affiliations, professional backgrounds, and years of experience strengthened both the representativeness and analytical robustness of the study. Most experts had more than five years of professional experience, including senior government officials, academic researchers, consultants, and industry practitioners. While experts from government and academia formed the majority - reflecting their central role in CE policy and planning - participants from enterprises and civil society organizations contributed valuable practical insights into implementation-related challenges.

Table 1. Demographic characteristics of the 14 experts

Variable	Category	Frequency (n = 14)	Percentage (%)
Gender	Male	9	64.3
	Female	5	35.7
Age Group	30-39 years	3	21.4
	40-49 years	6	42.9
	≥ 50 years	5	35.7
Highest Academic Qualification	Master's Degree	4	28.6
	PhD / Doctorate	10	71.4
Field of Expertise	Environment & Circular Economy	4	28.6
	Digital Transformation / ICT	3	21.4
	Sustainable Development	3	21.4
	Policy & Public Administration	2	14.3
	Business & Innovation Management	2	14.3
Professional Experience	5-10 years	3	21.4
	11-15 years	5	35.7
	>15 years	6	42.9
Work Sector	Academia / Research Institutes	7	50.0
	Government Agencies	3	21.4
	Business / Industry	2	14.3
	NGOs / International Organizations	2	14.3

Note: This table provides a summary of the demographic characteristics of the 14 experts participating in the AHP evaluation.

To ensure the reliability and validity of the AHP assessment, the study engaged a panel of fourteen experts with extensive backgrounds in circular economy, environmental management, digital transformation, sustainability, and public policy. As summarized in Table 1, many experts held doctoral degrees and had over ten years of professional experience, ensuring strong subject-matter expertise. The panel's composition - spanning academia, government, industry, and international organizations - provided a balanced and multidimensional foundation for evaluating the determinants of circular economic development in the context of digital transformation.

Table 2. Aggregated pairwise comparison matrix for the six determinants

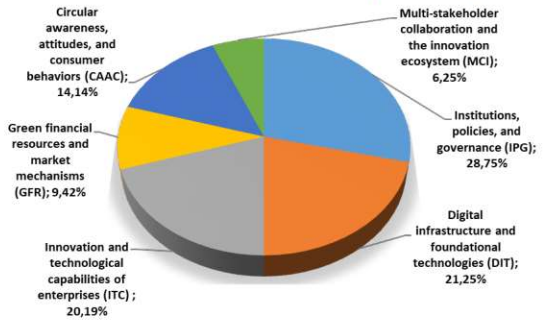
	IPG	DIT	ITC	GFR	CAAC	MCI
IPG	1.000	1.929	1.929	2.000	2.929	3.643
DIT	0.500	1.000	2.000	2.000	2.071	2.857
ITC	0.500	2.000	1.000	2.000	2.000	2.000
GFR	0.333	0.500	0.500	1.000	0.500	2.000
CAAC	0.500	0.488	0.500	2.000	1.000	3.000
MCI	0.250	0.357	0.500	0.500	0.333	1.000

Note: Values represent the geometric means of all expert judgments.

Abbreviations: IPG - Institutions, policies, and governance; IT - Digital infrastructure and foundational technologies; ITC - Innovation and technological capabilities of enterprises; GFR - Green financial resources and market mechanisms; CAAC - Circular awareness, attitudes, and consumer behaviors; MCI - Multi-stakeholder collaboration and the innovation ecosystem.

In Table 2, each entry indicates the relative importance of the determinant in the corresponding row compared with the determinant in the corresponding column. A value greater than 1 signifies that the row determinant is judged to be more influential than the column determinant, whereas a value less than 1 indicates the opposite. Diagonal values are equal to 1, reflecting the equal importance of each determinant when compared with itself.

Figure 03. AHP-derived weights of the six determinants of circular economy development



Note: Weights are derived from the principal eigenvector of the aggregated pairwise comparison matrix. The CR for the aggregated judgment was < 0.1, indicating acceptable consistency.

The figure presents the normalized weights of the six determinant groups in the AHP model, offering a visual complement to Table 2 by illustrating the proportional distribution of expert judgments within the CE-DX framework. The AHP results indicate a differentiated hierarchy of influences across the determinants shaping circular economy development in the digital transformation era. The weight distribution reflects Vietnam's early-stage CE transition and aligns with broader patterns in emerging economies, highlighting a trajectory that is policy-led, technology-enabled, and enterprise-driven

Institutions, Policies, and Governance (IPG): The Primary Driver of CE Development

With the highest weight (0.2875), IPG stands as the most influential determinant of CE development. This highlights the pivotal role of the State in providing regulatory clarity, steering CE transition pathways, and establishing governance mechanisms that enable implementation. Key policy instruments - such as the Law on Environmental Protection (2020), Decree No. 08/2022/NĐ-CP, and the National CE Development Scheme (2022) - serve as foundational institutional anchors. This finding aligns with OECD (2023), UNIDO (2022), and Ellen MacArthur Foundation (2023), which emphasize that CE transitions in developing economies are fundamentally shaped by coherent policy frameworks that condition behavioral, technological, and market responses.

Digital Infrastructure and Foundational Technologies (DIT): A Critical Enabling Pillar

DIT ranks second (0.2125), underscoring its role as a critical technological enabler of CE 4.0. Core digital technologies - including IoT, AI, big data analytics, cloud computing, and blockchain - enable real-time material flow monitoring, life-cycle data management, and transparency in EPR systems. Consistent with Rosa et al. (2020) and ITU (2024), the results confirm that digital technologies are essential for scaling circular practices by reducing information asymmetrical and improving reverse logistics efficiency. Vietnam's rapid digital transformation further reinforces DIT as a prerequisite for integrating CE principles into industrial processes and public-sector operations.

Institutions, Policies, and Governance (IPG): The Dominant Driver

With the highest weight (0.2875), IPG emerges as the most influential determinant, reaffirming the centrality of the State in orchestrating CE transitions. Vietnam's recent regulatory milestones - including the Law on Environmental Protection (2020), Decree No. 08/2022/NĐ-CP, and the National Scheme for CE Development (2022) - serve as institutional cornerstones that define CE goals, establish technical standards, and operationalize extended producer responsibility (EPR). This finding is consistent with OECD (2023), UNIDO (2022), and the Ellen MacArthur Foundation (2023), all of which emphasize that CE transitions in developing economies are critically dependent on regulatory coherence. In such contexts, policy direction precedes technological adoption, market responses, and behavioral shifts, thereby placing IPG at the forefront of CE system formation.

Digital Infrastructure and Foundational Technologies (DIT): A Key Enabler of CE 4.0

Ranked second (0.2125), DIT highlights the enabling function of digital technologies in supporting CE 4.0. Advanced technologies - IoT, AI, big data, blockchain, and cloud computing - facilitate real-time tracking of material flows, automated sorting processes, supply-chain visibility, and the digital verification of EPR compliance. This result aligns with Rosa et al. (2020) and ITU (2024), who identify digital infrastructure as a precondition for scaling CE strategies. In Vietnam's context, the rapid expansion of digital platforms under the National Digital Transformation Program has laid the technological groundwork for integrating CE principles into industrial operations and environmental governance. The relatively high weight of DIT confirms that CE deployment increasingly depends on digital readiness.

Innovation and Technological Capabilities of Enterprises (ITC): Operationalizing CE in Practice

With a weight of 0.2019, ITC ranks closely behind DIT, demonstrating the critical role of enterprises in translating CE policy frameworks into operational practices. Firms drive CE implementation through eco-design, remanufacturing technologies, advanced recycling systems, circular supply chains, and data-driven business models such as Product-as-a-Service. This result corroborates Ranta et al. (2021) and Ghosh (2023), who argue that enterprise-level innovation capacity is a determining factor in CE operationalization. The near equivalence of ITC and DIT suggests that even strong digital infrastructure requires corresponding firm-level competencies to generate transformative effects. Thus, enterprises constitute the "execution layer" of CE transitions.

Circular Awareness, Attitudes and Consumer Behaviors (CAAC): An Emerging but Constrained Driver

CAAC holds a moderate weight (0.1414), reflecting its emerging role in enabling "market pull" for circular products. However, its influence remains limited by structural constraints such as insufficient CE awareness, weak waste-sorting practices, and skepticism toward recycled materials. As highlighted by OECD (2023) and Camacho-Otero et al. (2018), consumer behavior in developing economies tends to evolve after enabling institutional and technological conditions are established. Vietnam's CE context follows this pattern: behavioral change is important but secondary, depending on stronger regulatory enforcement, accessible CE products, and reliable information systems.

Green Financial Resources and Market Mechanisms (GFR): A Developing but Underutilized Component

The low weight of GFR (0.0942) indicates that while green finance is theoretically essential for scaling CE initiatives, it remains nascent in practice. Vietnam's green credit systems are limited, carbon markets are still in early development, and secondary raw material markets lack liquidity. Consistent with OECD (2024) and UNDP (2023), financial institutions face data gaps, unclear taxonomies, and verification challenges, which constrain investment flows into CE sectors. As CE and DX ecosystems mature, however, the role of green finance is expected to increase.

Multi-Stakeholder Collaboration and Innovation Ecosystems (MCI): Currently Weak but Strategically Vital

MCI carries the lowest weight (0.0625), revealing fragmentation in collaborative networks across government, industry, academia, and local communities. The lack of data-sharing platforms, limited industrial symbiosis initiatives, and weak inter-agency coordination hinder ecosystem formation. This aligns with UNIDO (2022), which notes that collaboration deficits are typical in early-stage CE systems. Despite its current weakness, MCI is strategically crucial for long-term CE resilience, particularly as Vietnam advances toward industrial ecosystems and circular clusters.

4. Implications

The findings of this study generate several important theoretical, managerial, and policy implications that advance both scholarly understanding and practical implementation of the circular economy within the digital transformation context.

The findings yield three central theoretical insights: early-stage CE transitions in emerging economies are predominantly policy-led and institution-driven; digitalization enhances CE outcomes only when supported by adequate enterprise innovation capacity; and behavioral, financial, and collaborative mechanisms tend to mature later, following institutional and technological consolidation. Managerially, the results highlight the need to strengthen regulatory coherence, develop CE standards, expand digital monitoring systems, and support enterprise innovation through incentives and SME-focused programs. Policy implications reinforce these priorities, emphasizing digital infrastructure investment, EPR traceability, consumer awareness initiatives, and the formation of multi-stakeholder and industrial symbiosis networks. Collectively, these implications position Vietnam to advance toward a digitally enabled circular economy through a transition pathway that is institutionally guided, technologically empowered, and enterprise-centered, while progressively fostering behavioral, financial, and collaborative foundations.

5. Conclusion: This study identifies and prioritizes the key determinants shaping circular economy development in Vietnam's digital transformation era. The AHP results reveal a policy-led, technology-enabled, and enterprise-driven transition pathway, with institutional quality, digital readiness, and firm-level innovation emerging as dominant drivers, while behavioral, financial, and collaborative mechanisms play secondary but evolving roles. These findings offer a structured foundation for strengthening CE implementation through coordinated institutional reforms, technological advancement, and enterprise capability development. Overall, the study provides actionable guidance for policymakers and industry leaders seeking to advance Vietnam toward a digitally enabled circular economy.

Refereces:

Bocken, N. M. P., Olivetti, E. A., Cullen, J. M., Potting, J., & Lifset, R. (2017). aking the Circularity to the Next Level: A Special Issue on the Circular Economy: Taking Circularity to the Next Level. Journal of Industrial Ecology, 24(4), 709-725.

Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). Exploring how usage-focused business models enable circular economy through digital technologies. Sustainability, 10(3), 639.

Camacho-Otero, J., Boks, C., & Pettersen, I. N. (2018). Consumption in the circular economy: A literature review. Sustainability, 10(8), 2758.

Decision No. 687/QĐ-TTg. (2022). Approval of the National Scheme for Circular Economy Development. Government of Vietnam. https://vanban.chinhphu.vn/

Ellen MacArthur Foundation. (2023). Circular economy in a digital age. https://www.ellenmacarthurfoundation.org/

Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. Journal of Cleaner Production, 277, 123-142.

Ghosh, S., Raut, R. D., Mandal, M. C., & Ray, A. (2023). Are the small-and medium-sized enterprises in developing countries ready to implement circular economy practices? An empirical quest for key readiness factors. IEEE Transactions on Engineering Management, 71, 7467-7478.

ITU (2024). ICT Development Index. https://www.itu.int/itu-d/reports/statistics/idi2024/

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation & Recycling, 127, 221-232.

Law on Environmental Protection. (2020). National Assembly of Vietnam. https://vbpl.vn/

OECD. (2023). Digitalisation and the circular economy: Opportunities for developing countries. OECD Publishing.

OECD. (2024). Circular economy indicators and country outlooks. OECD Publishing. https://www.oecd.org/

Pagoropoulos, A., Pigosso, D. C. A., & McAloone, T. C. (2017). The emergent role of digital technologies in the circular economy: A review. Procedia CIRP, 64, 19-24.

Ranta, V., Aarikka-Stenroos, L., & Väisänen, J.-M. (2021). Digital technologies catalyzing business model innovation for the circular economy: A systematic review. Technological Forecasting and Social Change, 169, 120-125.

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D., & Terzi, S. (2020). Assessing relations between Circular Economy and Industry 4.0: a systematic literature review. International Journal of Production Research, 58(6), 1662-1687.

Saaty, T. L. (1980). The analytic hierarchy process. McGraw-Hill.

Saaty, T. L., & Vargas, L. G. (2001). Models, methods, concepts & applications of the analytic hierarchy process. Springer.

UNDP. (2023). Green finance in emerging markets: Trends and digital innovations. United Nations Development Programmed. https://www.undp.org/

UNIDO. (2022). Circular Economy and Digitalization: Building Industrial Ecosystems. United Nations Industrial Development Organization. https://www.unido.org/

Wang, S., Wang, H., Zhang, Z., & Li, J. (2021). Fintech-driven innovations in green finance: Implications for circular economic transitions. Journal of Environmental Management, 295, 113-119.