INTERNATIONAL JOURNAL OF COMPUTER SCIENCE & INFORMATION SYSTEM

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

Integrating Big Data and Circular Economy for Business Model Innovation: Theoretical Frameworks, Drivers, and Challenges

Johnathan R. Caldwell

Department of Management, University of Melbourne, Australia

Abstract: The convergence of big data analytics and circular economy principles presents transformative opportunities for business model innovation and sustainability. This study develops a comprehensive theoretical framework to explore how organizations can integrate big data into circular business models, examining both enablers and barriers to effective implementation. Drawing on a synthesis of prior empirical and conceptual research, the paper delineates the mechanisms through which data-driven insights support product lifecycle management, resource efficiency, and the creation of closed-loop systems (Zhang et al., 2017; Tseng et al., 2018). The study identifies strategic, organizational, and technological factors that influence the adoption of circular business models and highlights the potential for systemic innovation to drive competitive advantage and environmental value creation (Teece, 2010; Urbinati et al., 2017). Key findings suggest that while big data enables predictive capabilities and enhanced decision-making, organizational inertia, path dependency, and resource constraints pose significant barriers (Lehtimäki et al., 2020; Vermunt et al., 2019). The research also emphasizes the critical role of business model experimentation and stakeholder engagement in facilitating the transition toward sustainable, circular operations (Bocken et al., 2016b; Hofmann & Jaeger-Erben, 2020). This study contributes to both academic discourse and managerial practice by offering a structured framework for integrating digital and circular strategies, proposing pathways for future research, and outlining practical implications for policymakers and business leaders.

Keywords: Big Data, Circular Economy, Business Model Innovation, Sustainability, Product Lifecycle, Resource Efficiency, Organizational Transition.

INTRODUCTION

In an era marked by rapid technological advancement and mounting environmental pressures, organizations are compelled to rethink traditional linear business models. The linear paradigm,

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

characterized by a "take-make-dispose" approach, is increasingly recognized as unsustainable due to resource scarcity, regulatory pressures, and heightened stakeholder expectations (Tukker, 2015; Roos, 2014). Concurrently, digital technologies, particularly big data analytics, offer unprecedented capabilities for collecting, processing, and interpreting vast datasets to inform strategic decision-making (Surbakti et al., 2019; Thomas & Leiponen, 2016). Integrating these technological capabilities with circular economy principles—defined by the maximization of resource efficiency, material reuse, and closed-loop systems—has become a central objective for organizations seeking both environmental and economic resilience (Urbinati et al., 2017; World Economic Forum, 2016).

The intersection of big data and circular economy presents complex opportunities and challenges. On one hand, data-driven insights can enable predictive maintenance, optimize product design, and facilitate new service-oriented models that enhance sustainability (Zhang et al., 2017; Zheng et al., 2018). On the other hand, organizations face barriers such as technological complexity, insufficient data governance frameworks, and resistance to organizational change, which can inhibit the effective adoption of circular strategies (Vermunt et al., 2019; Tura et al., 2019). Despite increasing interest in both domains, existing research remains fragmented, often addressing either digital transformation or circular business models in isolation. There is a notable gap in literature regarding integrative frameworks that account for the synergistic potential of big data in driving circular business model innovation (Bocken et al., 2016a; Reim et al., 2019).

This paper aims to address this gap by developing a comprehensive theoretical framework that synthesizes the literature on big data and circular economy-driven business model innovation. The objectives of this study are threefold: first, to identify the drivers and barriers for integrating big data into circular business models; second, to examine how data-driven insights inform product lifecycle management, resource efficiency, and closed-loop system design; and third, to propose strategies for organizational transition toward sustainable, circular operations. By articulating the mechanisms through which big data can support circularity, this research contributes both to academic understanding and managerial praxis, providing actionable insights for practitioners, policymakers, and scholars in the field of sustainable innovation.

METHODOLOGY

This research adopts a conceptual, theory-building approach grounded in an extensive synthesis of peer-reviewed literature. Rather than relying on primary empirical data, the study employs a systematic review and integrative analysis methodology, aggregating insights from prior studies on big data applications, circular economy frameworks, and business model innovation. The selected references span multiple disciplines, including information systems, industrial engineering, sustainability studies, and management science, thereby ensuring a holistic examination of the research problem.

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

The methodology unfolds in three stages. First, a comprehensive literature search was conducted to identify studies examining big data, circular economy, and business model innovation. Databases searched included Scopus, Web of Science, and Google Scholar, with keywords such as “big data analytics,” “circular business models,” “sustainability-driven innovation,” and “product lifecycle management.” Inclusion criteria focused on studies offering theoretical frameworks, empirical analyses, or applied case studies that explicitly link data analytics with circular economic practices. This stage ensured a robust foundation for theoretical integration.

Second, the extracted literature was systematically analyzed to identify recurring themes, conceptual linkages, and research gaps. This thematic synthesis involved coding articles for key dimensions such as technological enablers, organizational barriers, strategic drivers, and innovation outcomes. For instance, studies on business model transformation patterns (Zolnowski et al., 2016) were juxtaposed with analyses of circular business model adoption barriers (Vermunt et al., 2019; Tura et al., 2019), revealing nuanced intersections between data utilization and circularity.

Third, the study employs theoretical integration to construct a conceptual framework. Drawing on established business model literature (Teece, 2010; Zott et al., 2011), the framework situates big data as an enabling resource within the broader circular economy ecosystem. It delineates the processes through which data-driven insights can inform product design, operational efficiency, and closed-loop resource management while accounting for organizational, technological, and market-level constraints. This methodology emphasizes descriptive rigor, enabling a detailed exploration of both enabling conditions and barriers while ensuring that the framework remains grounded in prior research and practical relevance.

RESULTS

The integrative analysis yields a multi-dimensional understanding of how big data can support circular business model innovation. First, big data is identified as a critical enabler for resource optimization and lifecycle management. By collecting and analyzing operational, environmental, and consumer data, firms can identify inefficiencies, predict maintenance needs, and anticipate demand patterns (Zhang et al., 2017; Tseng et al., 2018). This predictive capability allows organizations to extend product lifecycles, reduce material wastage, and design modular, repairable products that align with circular principles (Bakker et al., 2014; Copani & Behnam, 2020).

Second, big data facilitates the commercialization of circular innovations through enhanced market understanding and service differentiation. Data-driven insights enable firms to develop new service-oriented business models, such as product-service systems (PSS) and subscription-based offerings, which prioritize resource efficiency while capturing ongoing customer value (Zheng et al., 2018; Bocken et al., 2016a). These models leverage predictive analytics to align production with demand, optimize inventory,

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

and reduce environmental impact, demonstrating the intersection of technological capability and strategic business model innovation (Thomas & Leiponen, 2016; Roos, 2014).

Third, organizational and strategic drivers are critical to successful integration. Studies indicate that leadership commitment, cross-functional collaboration, and the cultivation of data literacy are foundational for translating analytical insights into actionable business strategies (Surbakti et al., 2019; Hofmann & Jaeger-Erben, 2020). Moreover, aligning circular initiatives with corporate values and sustainability goals enhances stakeholder engagement and fosters legitimacy, which is particularly salient in industries subject to regulatory scrutiny and public attention (Henry et al., 2023; Breuer & Lüdeke-Freund, 2017).

Conversely, significant barriers inhibit the widespread adoption of data-driven circular business models. Path dependency, organizational inertia, and resource constraints limit the flexibility required for business model experimentation (Lehtimäki et al., 2020; Vermunt et al., 2019). Technological barriers, including insufficient interoperability between data systems, poor data quality, and limited analytical capabilities, further constrain the potential for innovation (Surbakti et al., 2019; Thomas & Leiponen, 2016). These challenges highlight the need for integrated strategies that simultaneously address technological, organizational, and market-level constraints.

DISCUSSION

The findings elucidate the intricate dynamics at the intersection of big data, circular economy, and business model innovation. From a theoretical standpoint, the research extends the literature by framing big data not merely as a technological tool but as a strategic enabler of circularity. By situating analytics within the broader ecosystem of resource efficiency and closed-loop management, the study highlights the potential for systemic transformation that transcends incremental operational improvements (Urbinati et al., 2017; Tura et al., 2019).

The research underscores the importance of business model experimentation as a mechanism for navigating uncertainty. Iterative approaches, including prototyping, pilot testing, and stakeholder co-creation, enable firms to refine circular strategies while mitigating risks associated with technological adoption and market acceptance (Bocken et al., 2016b; Pieroni et al., 2021). Furthermore, the analysis reveals that circular business models are context-dependent, requiring adaptation to industry characteristics, regulatory environments, and organizational capabilities (Pollard et al., 2021; Kanther, 2025).

Limitations of this study include its reliance on secondary data and conceptual synthesis, which, while providing theoretical depth, may not fully capture sector-specific dynamics or operational nuances. Empirical validation through longitudinal case studies and multi-industry comparisons would enhance the robustness of the proposed framework. Additionally, the rapid evolution of both big data technologies

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

and circular economy regulations necessitates continuous updating of theoretical models to remain relevant and actionable (Zolnowski et al., 2016; Hofmann & Jaeger-Erben, 2020).

Future research directions include exploring the integration of artificial intelligence and machine learning in circular business model innovation, assessing the socio-economic impacts of circular strategies, and investigating cross-industry collaborations that leverage data-driven ecosystems for shared value creation. Further studies could also examine the role of organizational culture and leadership in facilitating the transition toward data-enabled circularity, providing insights into change management and strategic alignment in complex organizational settings (Pedersen et al., 2019; Lehtimäki et al., 2020).

CONCLUSION

This study demonstrates that the convergence of big data analytics and circular economy principles offers profound opportunities for business model innovation. By providing predictive insights, enabling lifecycle optimization, and supporting service-oriented strategies, big data functions as a catalyst for sustainable, resource-efficient operations. However, successful integration requires overcoming technological, organizational, and strategic barriers, emphasizing the importance of experimentation, stakeholder engagement, and leadership commitment. The proposed theoretical framework offers a structured approach for understanding and operationalizing these dynamics, providing guidance for both scholars and practitioners. By bridging digital transformation with circular economy principles, organizations can achieve competitive advantage while contributing to environmental sustainability, thereby reconciling economic and ecological imperatives in the twenty-first century.

REFERENCES

1. Bakker, C., M. d. Hollander, E. van Hinte, and Y. Zijlstra. 2014. Products that last: Product design for circular business models. Delft: TU Delft Library.
2. Bocken, N., Short, S., Rana, P., Evans, S. 2013. A value mapping tool for sustainable business modelling. Corporate Governance, 13(5), 482–497.
3. Bocken, N.M.P. 2015. Conceptual framework for shared value creation based on value mapping. Global Cleaner Production Conference, Sitges, Barcelona, 1-4 November 2015.
4. Bocken, N.M.P., de Pauw, I., van der Grinten, B., Bakker, C. 2016a. Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 32(1), 67-81.
5. Bocken, N., Short, S. 2016. Towards a sufficiency-driven business model: Experiences and opportunities. Environmental Innovation and Societal Transitions, 18, 41-61.
6. Bocken, N.M.P., Weissbrod, I., Tennant, M., 2016b. Business model experimentation for sustainability. Sustainable Design & Manufacturing Conference, Crete, Greece, 4-6 April 2016.
7. Boons, F. 2016. Sustainable business models as social process. Symposium on “Sustainable Business Models: towards Meaningful Organizations and Organizing”, Academy of Management Annual Conference, Anaheim (CA), 4–9 August 2016.

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

8. Boons, F. and Lüdeke-Freund, F. 2013. Business models for sustainable innovation. State-of-the-art and steps towards a research agenda. Journal of Cleaner Production, 45, 9–19.

9. Breuer, H. & Lüdeke-Freund, F. 2017. Values-Based Network and Business Model Innovation. International Journal of Innovation Management, 21(3).

10. Copani, G., & Behnam, S. 2020. Remanufacturing with upgrade PSS for new sustainable business models. CIRP Journal of Manufacturing Science and Technology, 29, 245–256.

11. Henry, M., Hoogenstrijd, T., & Kirchherr, J. 2023. Motivations and identities of "grassroots" circular entrepreneurs: An initial exploration. Business Strategy and the Environment, 32(3), 1122–1141.

12. Hofmann, F., & Jaeger-Erben, M. 2020. Organizational transition management of circular business model innovations. Business Strategy and the Environment, 29(6), 2770–2788.

13. Kanther, S. D. 2025. Integrating circular business models in construction: A framework for design and planning to enhance sustainability. International Journal of Sustainability and Innovation in Engineering, 3, 26–33. https://doi.org/10.56830/IJSIE202502

14. Lehtimäki, H., Piispanen, V. V., & Henttonen, K. 2020. Strategic Decisions Related to Circular Business Model in a Forerunner Company: Challenges Due to Path Dependency and Lock-In. South Asian Journal of Business and Management Cases, 9(3), 402–412. https://doi.org/10.1177/2277977920957957

15. Pedersen, E. R. G., Earley, R., & Andersen, K. R. 2019. From singular to plural: exploring organisational complexities and circular business model design. Journal of Fashion Marketing and Management, 23(3), 308–326. https://doi.org/10.1108/JFMM-04-2018-0062

16. Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. 2021. Developing a process model for circular economy business model innovation within manufacturing companies. Journal of Cleaner Production, 299, 126785. https://doi.org/10.1016/j.jclepro.2021.126785

17. Pollard, J., Osmani, M., Cole, C., Grubnic, S., & Colwill, J. 2021. A circular economy business model innovation process for the electrical and electronic equipment sector. Journal of Cleaner Production, 305, 127211. https://doi.org/10.1016/j.jclepro.2021.127211

18. Reim, W., Parida, V., & Sjödin, D. R. 2019. Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research. Sustainability, 11, 2558. https://doi.org/10.3390/su11092558

19. Roos, G. 2014. Business model innovation to create and capture resource value in future circular material chains. Resources, 3, 248–274. https://doi.org/10.3390/resources3010248

20. Surbakti, F., Wang, W., Indulska, M. and Sadiq, S. 2019. Factors influencing effective use of big data: A research framework. Information & Management, 57(1), 103146.

21. Thomas, L. and Leiponen, A. 2016. Big data commercialization. IEEE Engineering Management Review, 44(2), 74–90.

22. Teece, D. J. 2010. Business Models, Business Strategy and Innovation. Long Range Planning, 43(2–3), 172–194. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S002463010900051X

23. Tseng, M., Tan, R., Chiu, A., Chien, C. and Kuo, T. 2018. Circular economy meets industry 4.0: Can big data drive industrial symbiosis? Resources, Conservation and Recycling, 131, 146–147.

Volume10 Issue12, December-2025, pg. 01-07

Published Date: - 01-12-2025

E-ISSN: 2536-7919
P-ISSN: 2536-7900
SJIF 2019: 4.58 2020: 5.046 2021: 5.328

24. Tukker, A. 2015. Product services for a resource-efficient and circular economy - A review. Journal of Cleaner Production, 97, 76–91.

25. Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S. and Valkokari, P. 2019. Unlocking circular business: A framework of barriers and drivers. Journal of Cleaner Production, 212, 90–98.

26. Urbinati, A., Chiaroni, D. and Chiesa, V. 2017. Towards a new taxonomy of circular economy business models. Journal of Cleaner Production, 168, 487–498.

27. Vermunt, D., Negro, S., Verweij, P., Kuppens, D. and Hekkert, M. 2019. Exploring barriers to implementing different circular business models. Journal of Cleaner Production, 222, 891–902.

28. World Economic Forum. 2016. Intelligent Assets Unlocking the Circular Economy Potential. Retrieved from https://www.weforum.org/reports/intelligent-assets-unlocking-the-circular-economy-potential

29. Zhang, Y., Ren, S., Liu, Y., Sakao, T. and Huisingh, D. 2017. A framework for Big Data driven product lifecycle management. Journal of Cleaner Production.

30. Zheng, P., Lin, T., Chen, C. and Xu, X. 2018. A systematic design approach for service innovation of smart product-service systems. Journal of Cleaner Production.

31. Zolnowski, A., Christiansen, T. and Gudat, J. 2016. Business model transformation patterns of data-driven innovations.

32. Zott, C., Amit, R. and Massa, L. 2011. The business model: Recent developments and future research. Journal of Management, 37(4), 1019–1042.