World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Review Article)

Check for updates

Leadership-driven circular economy framework for advanced plastic recycling: Integrating advanced technologies, system dynamics and digital leadership

Md Shakil Molla [1, *] and Md Ferdus Al Hossain [2]

[1] *Department of Electrical and Electronic Engineering, Bangladesh Army University of Engineering and Technology, Qadirabad, Dayarampur, Natore-6431, Bangladesh.*

[2] *Department of Leather Engineering, Matrighor Limited, Hemayetpur, Tetuljhora Road, Savar, Dhaka-1340, Bangladesh.*

World Journal of Advanced Engineering Technology and Sciences, 2026, 18(01), 016-020

Publication history: Received on 30 November 2025; revised on 04 January 2026; accepted on 09 January 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.18.1.0013

Abstract

The escalating global plastic waste crisis demands not only technological innovation but also strong leadership and systemic governance to enable a truly circular economy. While advanced plastic recycling technologies such as chemical depolymerization, catalytic pyrolysis, and enzymatic recycling offer promising pathways beyond conventional mechanical recycling, their large-scale adoption remains limited due to organizational, economic, and policy barriers. This paper proposes an integrated, leadership-driven framework that connects advanced plastic recycling technologies with system dynamics thinking and digital leadership for sustainable circular transformation. By synthesizing insights from recent studies on advanced plastic recycling, leadership influence in sustainable supply chains, and digital leadership for circular economy (CE) performance, this research conceptualizes how leadership acts as a central leverage point enabling technological integration, cross-stakeholder collaboration, and long-term sustainability outcomes. The paper contributes a holistic perspective that bridges engineering innovation with leadership and governance, offering guidance for policymakers, industry leaders, and researchers seeking scalable and resilient plastic circularity solutions.

Keywords: Advanced Plastic Recycling; Circular Economy; Digital Leadership; System Dynamics; Sustainable Supply Chains; Industry 4.0

1. Introduction

Plastic materials have become essential in modern industrial and consumer applications due to their versatility, durability, and low production cost. However, the exponential growth in plastic production has not been matched by adequate recycling capacity, resulting in widespread environmental pollution and resource inefficiency [1]. A large share of plastic waste is still disposed of in landfills or leaks into natural ecosystems.

Conventional mechanical recycling techniques face several limitations, including contamination, polymer degradation, and low economic viability, often leading to downcycling rather than true circularity [1-2]. To overcome these challenges, advanced recycling technologies such as chemical depolymerization, AI-driven sorting, and digitally optimized recycling processes have gained increasing attention [3]. Although these technologies offer significant technical potential, their adoption remains fragmented and slow. Existing studies indicate that technological innovation alone cannot ensure circular economy (CE) transitions without strong leadership, governance, and coordination among stakeholders [3-4]. Leadership plays a crucial role in setting strategic direction, allocating resources, and aligning technology adoption with sustainability goals [5]. However, the role of leadership in plastic recycling systems has not been sufficiently explored from a systems perspective. This paper addresses this gap by proposing a Leadership-Driven

* Corresponding author: Md Shakil Molla.

Circular Economy framework that integrates digital leadership, advanced recycling technologies, and system dynamics thinking to explain the complex interactions driving circular plastic recycling [8-9].

2. Literature Review

2.1. Circular Economy and Plastic Recycling

The circular economy aims to replace linear "take–make–dispose" models with closed-loop systems that retain material value and minimize waste [6]. In plastic recycling, CE strategies focus on improving material recovery rates, reducing virgin plastic use, and lowering environmental impacts. However, many recycling systems remain linear due to institutional fragmentation and weak coordination [4].

2.2. Advanced Recycling Technologies

Advanced plastic recycling includes chemical recycling, solvent-based purification, AI-enabled sorting, and digital traceability systems. These technologies improve sorting accuracy and material quality, enabling higher-value recycling outcomes [3]. Nevertheless, high investment costs and organizational resistance often limit widespread adoption [2].

2.3. Digital Leadership and Sustainability

Digital leadership refers to the ability of leaders to leverage digital technologies to drive organizational transformation and sustainable value creation [5]. In sustainable supply chains, digital leadership improves transparency, collaboration, and data-driven decision-making [7]. Its application in circular plastic recycling systems, however, remains underexplored.

2.4. System Dynamics Approach

System dynamics (SD) is a modeling methodology used to analyze complex systems characterized by feedback loops, time delays, and non-linear relationships [8]. SD has been applied in sustainability and supply chain research but is rarely used to explicitly model leadership as an endogenous system variable.

3. Methodology

This research adopts a conceptual system dynamics methodology. The methodology consists of:

- Synthesizing prior research on circular economy, advanced recycling technologies, and digital leadership
- Identifying causal relationships among leadership decisions, technology adoption, and recycling performance [10], [11]
- Constructing reinforcing and balancing feedback loops to explain system behavior
- Following established SD principles, the study focuses on qualitative causal structures rather than numerical simulation [8].

4. Leadership-Driven Circular Economy Framework

4.1. Framework Overview

The proposed LD-CE framework positions digital leadership as the core driver of circular plastic recycling systems. Leadership decisions influence investment in advanced technologies, workforce skill development, digital infrastructure, and cross-stakeholder collaboration [15-16].

4.2. Reinforcing Feedback Loops

R1: Leadership–Technology–Performance Loop

Strong digital leadership promotes investment in advanced recycling technologies, leading to improved recycling efficiency and material quality. Enhanced performance reinforces leadership credibility, encouraging further investment.

R2: Data-Driven Decision Loop

Digital monitoring and analytics improve decision quality, resulting in optimized recycling operations and increased system transparency, which further supports digital transformation.

4.3. Balancing Feedback Loops

B1: Cost Constraint Loop

High initial investment costs may slow technology adoption, requiring leadership interventions such as incentives and policy support.

B2: Organizational Resistance Loop

Resistance to change can counteract innovation efforts, highlighting the importance of leadership in change management and skill development.

5. Results

This section presents the results derived from the conceptual system dynamics analysis of the proposed Leadership-Driven Circular Economy (LD-CE) framework for advanced plastic recycling. The results focus on identifying dominant feedback structures, leadership-driven leverage points, and system-level performance outcomes rather than numerical simulation outputs.

5.1. Identification of Dominant Feedback Loops

The system dynamics analysis reveals that plastic recycling performance is primarily governed by two reinforcing loops and two balancing loops, with digital leadership acting as a central control variable.

The Leadership–Technology–Performance reinforcing loop (R1) demonstrates that strong digital leadership increases investment in advanced recycling technologies, such as AI-based sorting and chemical recycling. This investment improves recycling efficiency and output quality, which in turn strengthens organizational confidence in leadership decisions and encourages further technological investment. This reinforcing behavior explains how leadership commitment can accelerate circularity over time [3], [5].

The Data-Driven Decision reinforcing loop (R2) shows that leadership-enabled digital infrastructure improves data availability and transparency across recycling operations. Enhanced data quality leads to better operational decisions, reduced process inefficiencies, and higher material recovery rates. Improved system performance further justifies the expansion of digital tools, reinforcing the loop [7], [8].

5.2. Impact of Digital Leadership on Technology Adoption

The results indicate that digital leadership significantly moderates the adoption rate of advanced recycling technologies. In systems characterized by weak leadership, high capital costs and organizational resistance dominate decision-making, resulting in delayed or partial technology adoption [15], [16]. In contrast, strong digital leadership reduces perceived investment risk by enabling long-term strategic planning, cross-functional coordination, and stakeholder alignment [12], [14].

The analysis shows that leadership-driven vision and communication reduce organizational resistance by promoting digital skills development and change readiness. As a result, technology adoption shifts from incremental implementation to system-wide integration, leading to measurable improvements in recycling efficiency and circular value creation [2], [3].

5.3. System-Level Recycling Performance Outcomes

At the system level, the LD-CE framework produces three key performance outcomes:

- Improved Recycling Efficiency
  Leadership-enabled investments in advanced technologies increase sorting accuracy, reduce contamination, and enhance material recovery rates, directly improving recycling efficiency [2], [3].
- Enhanced Circular Value Retention
  The integration of digital monitoring and advanced processing allows higher-quality recycled plastics to re-enter production cycles, reducing reliance on virgin materials and supporting circular economy objectives [4], [6].
- Greater System Resilience
  Digital leadership improves adaptive capacity by enabling rapid response to market fluctuations, policy changes, and supply disruptions. This resilience emerges from improved feedback visibility and coordinated decision-making across the recycling value chain [7], [13].

5.4. Influence of Balancing Constraints

Despite the dominance of reinforcing loops, the results highlight two critical balancing mechanisms that constrain system growth.

The Cost Constraint balancing loop (B1) indicates that high upfront investment requirements can slow technology adoption, particularly in organizations with limited financial capacity. Leadership interventions such as phased investment strategies and policy-driven incentives are necessary to weaken this constraint [1], [6].

The Organizational Resistance balancing loop (B2) shows that cultural inertia and skill gaps can counteract digital transformation efforts. The analysis demonstrates that leadership-driven training programs and participatory change management strategies are effective in reducing resistance and restoring reinforcing growth dynamics [5].

---

6. Conclusions and Recommendations

This study proposed a Leadership-Driven Circular Economy (LD-CE) framework for advanced plastic recycling by integrating advanced recycling technologies, system dynamics thinking, and digital leadership. Addressing the persistent gap between technological potential and practical implementation, the framework demonstrates that leadership is a central system driver rather than an external influencing factor. The results highlight that without leadership-enabled coordination, governance, and strategic vision, even the most advanced recycling technologies fail to deliver sustained circular outcomes.

By applying a system dynamics perspective, the study revealed how digital leadership shapes reinforcing and balancing feedback loops that govern recycling performance. Leadership-driven investments in advanced technologies, digital infrastructure, and workforce capabilities generate reinforcing effects that improve recycling efficiency, circular value retention, and system resilience. At the same time, balancing constraints such as high capital costs and organizational resistance can significantly slow progress if not actively managed through leadership interventions. From a theoretical standpoint, this research contributes to circular economy literature by explicitly embedding leadership as an endogenous component of circular systems. Unlike prior studies that treat leadership as a contextual or exogenous variable, the proposed framework demonstrates how leadership decisions dynamically interact with technology adoption and system performance over time. The integration of system dynamics further enhances understanding of non-linear behaviors, time delays, and leverage points within plastic recycling systems.

Practically, the findings offer actionable insights for industry leaders and policymakers. Strong digital leadership enables strategic alignment among stakeholders, reduces resistance to technological change, and supports data-driven governance structures essential for scaling advanced plastic recycling. Policymakers can leverage these insights to design leadership-oriented incentives, digital infrastructure investments, and regulatory frameworks that accelerate circular economy transitions. Despite its contributions, this study is conceptual in nature and does not include quantitative system dynamics simulation or empirical case validation. Future research should extend the proposed framework through numerical modeling, sensitivity analysis, and real-world case studies across different regional and industrial contexts. Such efforts would further validate the leadership-driven mechanisms identified in this study and support evidence-based policymaking for sustainable plastic recycling systems.

In conclusion, achieving circularity in plastic recycling requires more than technological innovation alone. It demands digitally empowered leadership, systemic thinking, and coordinated governance capable of transforming fragmented recycling activities into resilient, circular ecosystems.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," *Science Advances*, vol. 3, no. 7, e1700782, 2017.

[2] Y. A. Bipasha, "Predicting fraud in credit card transactions," *International Journal of Science and Research Archive*, vol. 15, no. 2, pp. 1167–1177, 2025.

[3] K. Ragaert, L. Delva, and K. Van Geem, "Mechanical and chemical recycling of solid plastic waste," *Waste Management*, vol. 69, pp. 24–58, 2017.

[4] M. B. Uddin, M. R. Islam, M. N. Uddin, and A. Halim, "Next-generation plastic recycling: Breakthrough developments and the path toward a circular economy," *World Journal of Advanced Engineering Technology and Sciences*, vol. 16, no. 1, pp. 513–527, 2025.

[5] Y. A. Bipasha, "Stock market prediction using LSTM," *International Journal of Science and Research Archive*, vol. 12, no. 2, pp. 3146–3153, 2024.

[6] M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, "The circular economy—A new sustainability paradigm?" *Journal of Cleaner Production*, vol. 143, pp. 757–768, 2017.

[7] Md Razibul Islam, "Digital leadership and circular economy performance in sustainable supply chains," *World Journal of Advanced Engineering Technology and Sciences*, vol. 17, no. 3, pp. 503–508, 2025, doi: 10.30574/wjaets.2025.17.3.1583.

[8] Y. A. Bipasha, "Market efficiency, anomalies and behavioral finance: A review of theories and empirical evidence," *World Journal of Advanced Research and Reviews*, vol. 15, no. 2, pp. 827–839, 2022.

[9] Ellen MacArthur Foundation, *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition*, Ellen MacArthur Foundation, Cowes, UK, 2015.

[10] Md Razibul Islam, "System dynamics of leadership influence in sustainable supply chains," *World Journal of Advanced Engineering Technology and Sciences*, vol. 17, no. 3, pp. 509–514, 2025, doi: 10.30574/wjaets.2025.17.3.1584.

[11] J. D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World*, New York, NY, USA: McGraw-Hill, 2000.

[12] Md Razibul Islam, "Circular economy leadership for sustainable industrial transformation: A holistic framework for resilient and resource-efficient growth," *World Journal of Advanced Engineering Technology and Sciences*, vol. 17, no. 3, pp. 253–262, 2025, doi: 10.30574/wjaets.2025.17.3.1540.

[13] Y. A. Bipasha, "Blockchain technology in supply chain management: Transparency, security, and efficiency challenges," *International Journal of Science and Research Archive*, vol. 10, no. 1, pp. 1186–1196, 2023.

[14] K. K. Mondal, Y. A. Bipasha, S. A. S. M. Naim, and P. Podder, "Hybrid sentiment analysis of drug reviews using ML and lexicon-based methods," in *Proc. 6th Int. Conf. on Inventive Research in Computing Applications (ICIRCA)*, Coimbatore, India, 2025, pp. 1090–1095.

[15] Khandoker Hoque, Md Boktiar Hossain, Denesh Das, Partha Protim Roy . Integration of IoT in Energy Sector. International Journal of Computer Applications. 186, 36 (Aug 2024), 32-40. DOI=10.5120/ijca2024923981 2.

[16] Rahman, F., Das, D., Sami, A., Podder, P., & Michael, D. L. (2024). Liver cirrhosis prediction using logistic regression, naïve bayes and KNN. International Journal of Science and Research Archive, 12(1), 2411-2420.