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Original Article

Role of Enterprise Resource Planning Software (ERP) In Driving Circular Economy Practices in the United States

Dharani K[1], Gopika P[2]
[1,2] Holy Cross College, Trichy, Tamil Nadu, India

Abstract: *This study delved into the role of Enterprise Resource Planning Software (ERP) in facilitating circular economy within the United States. It identifies key stakeholders and driving forces necessary to extend producer responsibility, aligning with national circular economy strategies. An evaluation system is established to correlate producers' eco-design strategies with downstream recycling performance, drawing data from sustainable development reports and recycling platforms. The aim is to foster an open forum for competition and collaboration among stakeholders to enhance circularity and lifecycle environmental performance. The findings encourage producers to fully explore opportunities in the circular economy rather than solely focusing on waste disposal. The study advocates for ERP software policies that incentivize eco-design and innovation, aligning with global climate change mitigation efforts.*

Keywords: *Enterprise Resource Planning, United States, Economy Practices.*

I. INTRODUCTION

The global push for sustainable development has underscored the urgency of transitioning towards a circular economy, particularly in light of dwindling resources and escalating environmental degradation. As highlighted by Circle Economy (2022), the global circularity rate has declined from 9.1% in 2018 to 8.6% in 2020, while the extraction of virgin materials continues to rise steadily to meet escalating consumption demands, reaching 100 billion tons. This unsustainable trajectory necessitates a fundamental shift towards a circular economy, which aims to maintain the value of products, materials, and resources within the economy for as long as possible, thereby minimizing waste generation and environmental impacts (Tong et al., 2024).

Integral to the transition towards a circular economy is the concept of Enterprise Resource Planning (ERP). ERP software, as defined by Lindqvist (2000) and OECD (2001), extends the environmental responsibility of producers throughout the entire lifecycle of their products, encompassing stages from production to disposal. Initially emerging as a local environmental governance practice in Europe in the 1980s, ERP software has evolved into a globally recognized policy tool for promoting sustainable waste management and resource conservation (OECD, 2016).

Furthermore, the Circular Economy Memorandum of Understanding between the EU and China underscores the significance of ERP software in advancing circular economy goals (EC and NDRC, 2018). In China, the implementation of ERP software, particularly in the electronics industry, has demonstrated promising results through the establishment of government-funded recycling systems for electronic waste (e-waste) (Lindhqvist, 2000). The adoption of the Circular Economy Promotion Law in China further solidifies the integration of ERP software principles into waste management practices, emphasizing the role of producers in managing the entire lifecycle of products (Gu et al., 2019).

A. Background of the Role of Enterprise Resource Planning Software (ERP)

The concept of Enterprise Resource Planning Software(ERP).originated in the 1990s as a policy approach to address the environmental impacts of products throughout their lifecycle, obligating manufacturers to take responsibility for their products beyond the point of sale, including collection, recycling, and final disposal (Lindhqvist, 2000; OECD, 2001). While initially introduced as a local environmental governance practice in Europe, ERP software, gradually evolved into a widely adopted principle of waste management responsibility at the national and EU levels (OECD, 2016). Its adoption in various jurisdictions has been driven by the recognition of the need to shift towards a circular economy, where resources are conserved, and waste is minimized through closed-loop systems (EU Commission, 2015).

Despite its widespread adoption globally, challenges persist in fully realizing the potential of ERP software to promote circularity and sustainability, including issues related to the scope and coverage of ERP software schemes, as well as enforcement and compliance mechanisms (Campbell-Johnston et al., 2021; Pouikli, 2020). Moreover, there is a pressing need for greater harmonization and alignment of ERP software policies across jurisdictions to ensure consistency and effectiveness in addressing

global environmental challenges (Lifset et al., 2023). As the world continues to grapple with resource scarcity and environmental degradation, ERP software remains a crucial tool for advancing the transition towards a more sustainable and circular economy.

B. Importance of Circular Economy in the United States

In the United States, the transition to a circular economy is imperative for achieving sustainable development and mitigating environmental degradation. As one of the world's largest consumers and producers, the U.S. has a significant environmental footprint, contributing to global resource depletion and waste generation (Steffen et al., 2015). Embracing circular economy principles can help alleviate these pressures by minimizing waste generation, conserving resources, and promoting sustainable consumption and production patterns (EU Commission, 2015).

Despite these potential benefits, the United States lags behind the European Union in terms of comprehensive waste and circular economy policies (EU Commission, 2014). The absence of a cohesive regulatory framework focused on waste prevention and circularity has resulted in significant environmental and economic losses. Limited emphasis on waste prevention within the current Enterprise Resource Planning Software (ERP), framework further exacerbates these challenges (Dalhammar, 2018). As a result, the U.S. faces mounting pressures to address its unsustainable consumption and production practices, necessitating a shift towards circular economy principles.

The disconnect between waste and circular economy policies in the United States underscores the urgent need for policy interventions aimed at promoting sustainable resource management practices. While waste management efforts have improved over the years, there remains a considerable amount of waste that is not reused or recycled, leading to inefficient resource utilization and environmental degradation (EU Commission, 2014). Moreover, the linear "take-make-dispose" model predominates in many sectors of the U.S. economy, perpetuating a cycle of resource depletion and environmental pollution (Steffen et al., 2015). Transitioning to a circular economy requires a paradigm shift towards closed-loop systems that prioritize resource efficiency, product durability, and end-of-life management (EU Commission, 2015). By incentivizing producers to design products with circularity in mind and promoting sustainable consumption behaviors among consumers, the United States can move towards a more sustainable and resilient economic model.

Addressing the challenges associated with transitioning to a circular economy in the United States requires a multifaceted approach that engages stakeholders across various sectors. Collaboration between government, industry, academia, and civil society is essential for developing and implementing effective policy measures that promote circularity and resource efficiency (Steffen et al., 2015). Furthermore, raising awareness and fostering a culture of sustainability among consumers is critical for driving demand for circular products and services (EU Commission, 2015). Building on successful initiatives and best practices from other regions, such as the European Union, can provide valuable insights and guidance for developing tailored solutions that meet the unique needs and challenges of the U.S. context (Dalhammar, 2018).

By embracing the principles of circular economy and implementing proactive policy measures, the United States can position itself as a global leader in sustainable development and environmental stewardship, while simultaneously fostering economic growth and resilience.

C. Purpose of the Paper

This paper aims to explore the role of Enterprise Resource Planning Software (ERP) in advancing circular economy goals, particularly within the context of the United States. By examining international experiences, policy frameworks, and implementation strategies, the paper seeks to provide insights into how ERP software can be leveraged to promote sustainable waste management practices and foster a transition towards a circular economy.

D. Structure of the Paper

The remainder of the paper is organized as follows. Section 2 presents a comprehensive literature review to elucidate the evolution of ERP software governance structures globally, with a focus on challenges and opportunities in implementation. Section 3 outlines the methodology employed in this study, including research design, data collection methods, and analysis techniques. Section 4 presents the findings and discussions, exploring the current state of ERP software implementation and its implications for circular economy initiatives. Finally, Section 5 offers concluding remarks and recommendations for policymakers and stakeholders to enhance the effectiveness of ERP software in advancing circular economy objectives.

II. LITERATURE REVIEW

A. Concept of Enterprise Resource Planning Software (ERP)

The concept of Enterprise Resource Planning Software(ERP) emerged in the 1990s as a policy approach aimed at addressing the environmental impacts of products throughout their lifecycle (Lindhqvist, 2000; OECD, 2001). ERP software mandates manufacturers to extend their responsibility beyond the point of sale, encompassing collection, recycling, and final disposal of their products (Lindhqvist, 2000). Initially introduced as a local practice in Europe, ERP software gained momentum and was adopted nationally and at the EU level, driven by the imperative to transition towards a circular economy (The State Council, 2016; OECD, 2016). This transition emphasizes resource conservation and waste minimization through closed-loop systems.

In the development of ERP software systems, various organizational structures are tailored to different product types, aligning with local policy priorities (OECD, 2016). In China, for instance, key elements such as involving stakeholders in setting recycling targets, stimulating eco-design and new business models, and enhancing transparency in waste flows have been emphasized (The State Council, 2016). However, in the United States, ERP software systems are largely fragmented and confined to the state level, lacking comprehensive federal legislation (Tong & Yan, 2013). This decentralized approach poses challenges in ensuring consistency and effectiveness across jurisdictions, limiting the full potential of ERP software to promote circularity and sustainable resource management (Campbell-Johnston et al., 2021; Pouikli, 2020).

The evaluation framework for ERP software performance encompasses both individual and collective responsibilities of enterprises. Individual responsibility focuses on product lifecycle management and incentivizes ecological design through independent information disclosure by production enterprises. Collective responsibility aims at leveraging social resources and environmental benefits by integrating collection and recycling sectors into producers' supply chains, fostering a closed-loop system (Pouikli, 2020).

This framework facilitates a comprehensive assessment of producers' performance in ERP software, crucial for advancing circular economy objectives. Fig shows the proposed performance evaluation framework for a comprehensive assessment on the producer's performance in ERP software.

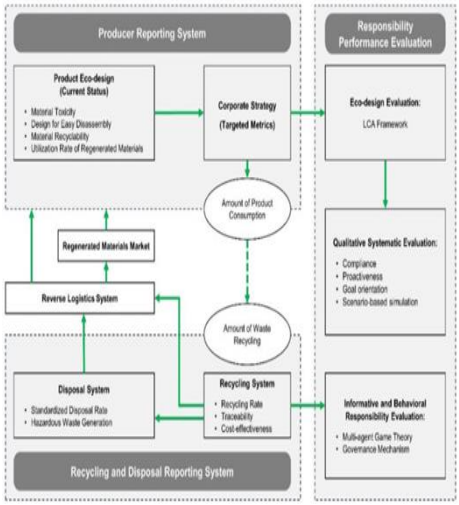

Figure 1: Performance Evaluation Framework for Comprehensive Assessment on the Producer's Performance in ERP Software

Source (https://www.sciencedirect.com/science/article/pii/S2773167724000049)

B. Circular Economy Principles

Central to the concept of ERP software is the transition towards a circular economy, where resources are conserved, and waste is minimized through closed-loop systems. The circular economy emphasizes the importance of maintaining the value of products, materials, and resources for as long as possible (Tuong et al.,2024). In the United States, embracing circular economy principles can help alleviate environmental pressures and promote sustainable consumption and production patterns. Stimulating eco-design and new business models is crucial in this transition, as it incentivizes manufacturers to improve product design and reduce environmental impacts throughout the product lifecycle (Eisenreich et al., 2022).

Moreover, increasing transparency in waste flows enables stakeholders to make informed decisions and track progress towards circularity goals. By aligning ERP software with circular economy principles, the United States can foster innovation, create new economic opportunities, and mitigate environmental degradation.

C. ERP SOFTWARE Implementation in Other Countries

The implementation of ERP software in other countries provides valuable insights into best practices, success stories, and lessons learned. Case studies from countries like China demonstrate the importance of involving key stakeholders in setting recycling targets and stimulating eco-design and new business models (Pouikli, 2020). Success stories in the e-waste recycling sector highlight the potential for ERP software to improve environmental standards and material recovery efficiency (Yu et al., 2014; Zeng & Li, 2019). However, challenges remain, particularly in achieving transparency in waste flows and involving informal recycling sectors in decision-making processes (Huang et al., 2020; Tong et al., 2018b). Lessons learned from these experiences emphasize the need for collaboration among industry, government, and academia to develop effective ERP software policies and ensure their successful implementation. By leveraging international experiences, the United States can tailor its approach to ERP software implementation and address specific challenges within its own context.

D. Current State of Circular Economy Initiatives in the United States

The legislative landscape and policy framework for circular economy initiatives in the United States are still evolving, with limited federal-level initiatives compared to other countries (Tong & Yan, 2013). While some states have implemented ERP software programs for specific products, such as electronics and batteries, the lack of federal coordination presents challenges in achieving nationwide consistency and effectiveness (Campbell-Johnston et al., 2021). Nonetheless, increasing awareness of environmental issues and the potential economic benefits of circular economy practices offer opportunities for further development and collaboration among stakeholders at both the state and federal levels.

III. METHODOLOGY

To comprehensively explore Enterprise Resource Planning Software (ERP) practices in the United States, a mixed-methods research design was employed. This included qualitative analysis of existing literature and a case study approach. The qualitative analysis allowed for a deep understanding of theoretical perspectives, while case studies provided insights into real-world applications (Tong & Luo, 2024; Tong et al., 2018a).

Data collection involved a thorough review of academic papers, reports, and policy documents related to ERP software in the United States. Additionally, interviews were conducted with industry experts and stakeholders to gather diverse perspectives and insights (Ministry of Environmental Protection, 2015; Wu, 2014).

Thematic analysis was employed to identify key themes and patterns within the collected data. Comparative analysis allowed for the comparison of ERP software strategies and outcomes across different sectors and regions. Furthermore, a cross-sectoral examination was conducted to understand the interconnectedness of various industries and stakeholders within the ERP software framework.

IV. IMPLEMENTATION RESULTS AND DISCUSSIONS

The implementation of a performance evaluation framework for major electronics producers in the United States was conducted based on systematic qualitative analysis of their public reports on sustainability and corporate social responsibility (Tong & Luo, 2024). This evaluation framework, similar to the one utilized in China, encompassed seven key aspects including eco-design, procurement, manufacturing, transportation and sales, use and maintenance, recycling, and other related information. The framework consisted of primary and secondary indicators, totaling 32 indicators in total as shown in table 1 (CHEARI, 2020).

Table 1: The Implemented Evaluation Framework for Electronics Producers in USA

Primary Indicators	Secondary Indicators	Aspect of Information
1. Ecological Design	1.1 Lightweight design	Physical
	1.2 Modular design	Physical
	1.3 Universal design	Physical
	1.4 Easy disassembly design	Physical
	1.5 Hazardous substance management	Physical
	1.6 Use of recycled materials	Physical
	1.7 Improve recyclable utilization rate of products	Physical
	1.8 Service life extension	Physical

	1.9 Labels for easy recycling	Physical
	1.10 Green packaging	Physical
	1.11 Product energy efficiency	Physical
2. Procurement	2.1 Supplier performance evaluation	Physical
	2.2 supplier classification management system	Physical
	2.3 Supplier Training	Physical
	2.4 Related environmental information about supplier	Informative
3. Manufacturing	3.1 Green process and equipment	Physical
	3.2 Hazardous waste management	Physical
	3.3 Use of clean energy consumption	Physical
	3.4 Production process energy consumption	Physical
4. Transportation and Sales	4.1 Green logistics	Physical
	4.2 Promotion of green products	Physical
	4.3 Green product identification	Informative
5. Use and Maintenance	5.1 Providing product upgrade service	Physical
6. Recycling	6.1 Providing waste product recycling services	Physical
	6.2 Recycled products get legal and standardized treatment	Physical
	6.3 Self-build or jointly establish disposal enterprises	Physical
	6.4 Closure of recycling information	Informative

A. Improving Information Disclosure for Enterprise Resource Planning

The results of the study were as shown in figure 2 below:

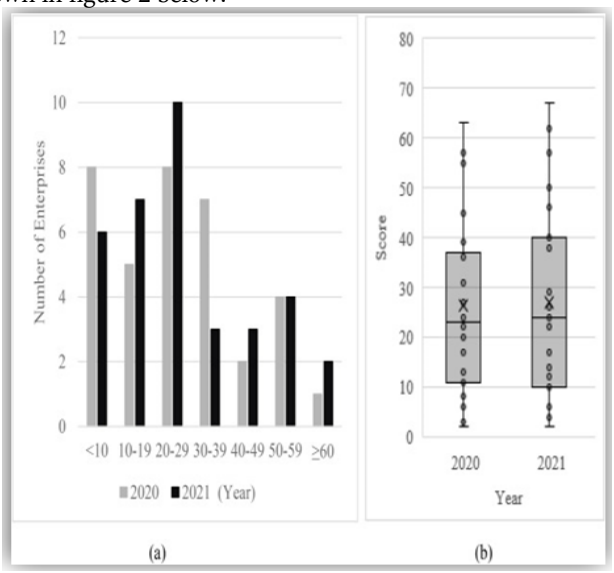

Figure 2: Distribution of Information Disclosure Scores of Electrical and Electronic Enterprises in 2020 and 2021

Source: (Annual Report on the implementation of extended Resource Planning for electrical and electronic products (CHEARI, 2020, 2021).

Based on the results depicted in Figure 2, it is evident that there has been an improvement in the proactivity and quality of environmental information disclosure among major electronics producers in the United States. The distribution of information disclosure scores for electrical and electronic enterprises in 2020 and 2021 shows a positive trend towards detailed information disclosure and clear commitments to achieve recycling targets (CHEARI, 2020, 2021).

The widening gap between well-performing and poor-performing enterprises underscores the need for positive incentives to encourage better performance. Factors such as government regulation requirements, market expectations, and economic benefits are driving producers to participate in voluntary information disclosure initiatives (Ministry of Environmental

Protection, 2015; Wu, 2014). For instance, the mandates set by environmental regulatory authorities and the guidelines issued by stock exchanges have played crucial roles in promoting environmental information disclosure.

B. Expanding the System to Cover the Entire Circular Value Chains

In the United States, the recycling systems for electronics and automobiles involve complex multilevel circulation and cascade utilization processes. However, challenges such as data dispersion and fragmentation hinder effective recycling and processing. Encouraging producers to participate in the construction of reverse logistics systems is crucial, necessitating the establishment of information traceability mechanisms (Sun et al., 2018).

New business models, such as Internet-based platforms for second-hand trading and bidding distribution, offer opportunities to reshape traditional recycling practices. These platforms facilitate product traceability management throughout the product lifecycle, enhancing the participation of companies along the circular value chain (Sun et al., 2018). Integration of ecological design with end recovery and treatment systems highlights the initiative of producer participation in improving the environmental performance of product lifecycles.

C. Integrating Circular Economy with Carbon Emission Reduction Initiative

Circular economy strategies hold significant potential for carbon emission reduction in the United States. Increasingly, producers of electronics and automobiles are setting carbon emission reduction targets and reporting their strategies systematically (Pauliuk et al., 2021). The integration of circular economy strategies with corporate climate actions aligns with the evolving governance structure for climate actions worldwide.

Producers are exploring new methods of information sharing along the supply chain to achieve carbon neutrality. The construction of a voluntary carbon market provides additional incentives for producers to establish their carbon assets through supply chain management (Pauliuk et al., 2021). The mainstream adoption of circular economy strategies in corporate Environmental, Social, and Governance (ESG) practices underscores the importance of integrating sustainability initiatives with climate action.

D. Creating Niches for New Technologies and New Business Models

Effective implementation of the ERP software system necessitates the consideration of both upstream ecological design and downstream waste product recycling and treatment. Information sharing mechanisms, such as the EU's digital-product passport proposal, facilitate transparency and traceability along the entire value chain (European Union, 2018). New technologies, such as smart grid and Internet of Things, empower producers to design product service systems that prioritize sustainability and stewardship throughout the product lifecycle.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The transition towards a circular economy is imperative for achieving sustainable development and mitigating environmental degradation in the United States. Enterprise Resource Planning Software (ERP) plays a crucial role in driving circular economy practices by extending the environmental responsibility of producers throughout the entire lifecycle of their products. Through the implementation of ERP software frameworks, producers are incentivized to adopt sustainable practices such as eco-design, resource-efficient procurement, and end-of-life management, thereby promoting waste minimization and resource conservation.

The findings from this study highlight the progress and challenges in ERP software implementation in the United States. Improved information disclosure among major electronics producers demonstrates a positive trend towards environmental transparency and accountability. However, challenges such as data dispersion and fragmentation in recycling systems underscore the need for enhanced collaboration and coordination across the circular value chain. Integrating circular economy principles with carbon emission reduction initiatives presents opportunities for further environmental gains and climate action.

B. Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance the effectiveness of ERP software in driving circular economy practices in the United States:

1. Develop a comprehensive federal-level ERP software framework: Establishing a cohesive regulatory framework for ERP software at the federal level will provide consistency and clarity for producers operating across different states. This

framework should encompass clear guidelines, targets, and incentives to promote sustainable product design, recycling, and resource recovery.

2. Strengthen collaboration and coordination: Foster collaboration among stakeholders, including government agencies, industry associations, academic institutions, and civil society organizations, to develop and implement ERP software policies and initiatives. Promote knowledge sharing, capacity building, and best practice exchange to enhance the effectiveness of ERP software implementation.
3. Encourage innovation and investment in circular solutions: Provide incentives and support for research and development of innovative technologies and business models that promote circularity and resource efficiency. Foster public-private partnerships to accelerate the adoption of circular solutions and facilitate the transition towards a circular economy.
4. Enhance consumer awareness and engagement: Raise awareness among consumers about the importance of sustainable consumption and the role of ERP software in promoting circular economy practices. Provide education and outreach programs to empower consumers to make informed choices and participate in recycling and waste reduction efforts.
5. Evaluate and monitor ERP software performance: Establish mechanisms for monitoring and evaluating the performance of ERP software programs, including transparency and accountability measures. Regularly assess the effectiveness of ERP software initiatives in achieving circular economy objectives and identify areas for improvement and optimization.

By implementing these recommendations, policymakers, industry stakeholders, and civil society can work together to accelerate the transition towards a circular economy in the United States, thereby promoting sustainable development and environmental stewardship for future generations.

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