Circular Economy Adoption in the Electrical and Electronic Equipment Sector: A Framework for Firm-level Enablers and Levers

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Introduction

The progression in technology, revolution in designing new products, and convincing market strategies attracts customers to purchase electronic items frequently. This has led to an exponential rise of EEE waste (Prakash & Barua, 2016). India ranks third in electronic-waste production in the world after China & USA. In the year 2022, India generated approximately 1.6 million tons of e-waste and is projected to reach 29 million tons by 2030 (Markets & Data, 2023). This surge in growth is primarily due to increase in mobile phone manufacturing and assembly operations (Chowdhary V., 2025). Hence, this raises critical sustainability and supply chain concerns, indicates a pressing need to implement circular economy (CE) strategies and involve all stakeholders in the electronic value chain (Bhattacharjee et al., 2023).

In India, the large proportion of e-waste, is handled by unorganized and unregulated sector. They are not fully capable of effective extraction methods, hence lowering the recovery rates of high value parts. Secondly, the inadequate access to proper infrastructure for proper processing and recovery of e-waste, is hindering the development of large-scale e-waste sustainable CE value chain. Third, the country is grappling with a technology boom and a rise in electronic product consumption, generating significantly large volumes of e-waste (Chowdhary V., 2025).

To address the above challenges, the country's regulations and policy frameworks are evolving to encourage recycling enterprises. The key founding policy includes e-waste management rules, that introduced a mechanism such as extended producer responsibility (EPR) and requires an online registration and reporting for Electrical and Electronic Equipment (EEE) manufacturing companies (Bhadra & Mishra, 2021). Despite being the progressive framework in place, there still remain barriers in implementation and enforcement. The government continuous interventions are

underway to provide financial incentives, and regulatory frameworks to businesses to encourage resource efficiency, eco-design and compliance with environmental and health standards (Bhattacharjee et al., 2023; Buttke et al., 2024).

The electronic industries' shift towards CE adoption is nascent in developing economies (Bhattacharjee et al., 2023). However, this shift will contribute towards alignment with '*United Nations Sustainable Development Goals'*(SDGs). CE adoption will accelerate progress across several SDGs, for example, SDG 7 ('affordable and clean energy'); SDG 9 ('industry innovation and infrastructure'); SDG 12 ('responsible consumption and production'); and SDG 13 ('climate action'). The alignment with these goals ensures operationalization through enforceable mechanism through supplier engagement, innovative business model, product design and innovation (Bhattacharjee et al., 2023).

CE implementation in EEE industry brings environmental, social and economic prosperity (MacArthur, 2023). From environmental viewpoint, CE implementation supports compliance with current regulations, improve resource efficiency and promote sustainability throughout the business value chain. Socially, CE adoption promotes workers health & safety, develop their innovation skills through reskilling and upskilling programs. Social impact of CE adoption also brings strong brand reputation for a firm. Finally, economic benefits of CE adoption results in reduction of operational cost, improving product and process efficiency (Zoka & Korez Vide, 2025). Despite, such huge benefits, the adoption of such paradigm in developing countries is still limited to a few pioneering firms, and the majority of value chain actors face implementation challenges with respect to ecosystem, design strategies and the business models. This gap underlines the need for systematic research and decision-making frameworks that can guide firms, suppliers and policymakers in translating CE principles into measurable actions.

Literature Review

The EEE sector is recognized as one of the high-priority sectors for CE adoption as this multi-billion-dollar industry is a primary contributor to global e-waste problem (Rittershaus et al.,

2025). The sector is frequently criticised for quick product launches, disregard for resource scarcity and continuation of unsustainable production and consumption patterns. This has led to limited integration of CE principles into operational practices which continue to restrict its sustainability potential. Suppliers, as key value chain actors in the ecosystem, often lack competence, technological readiness, and collaborative orientation essential for circular transition (Rizos & Bryhn, 2022). Given the critical need for sustainable practices and the potential benefits of CE, there is a growing body of research calling for a deeper understanding of firm level CE transition with the lens of enablers and levers. Although, many studies have identified enablers and barriers of CE adoption, but the levers of CE transition have received limited scholarly attention (Bressanelli et al., 2021). Levers refer to as important building blocks of CE transition as they are the tools and practices which firms implement to encourage CE practices, whereas enablers are the contextual force that makes it easier to implement levers into the processes.

Since leading global firms are experimenting with industry 5.0 technologies (Santiago et al., 2025), circular product design (Svensson-Hoglund et al., 2021) and servitized business models (Bressanelli et al., 2021) to enhance sustainability, such practices are largely underexplored in the Indian EEE sector. Consequently, electronic companies face increasing pressure to strategically prepare for the recovery and disposal of End-of-Life (EOL) products, they lack structured methodology and decision-support framework to implement CE strategies effectively. Therefore, the key problems this thesis addresses are as follows:

1. To understand CE transition at a firm-level in Indian EEE sector.
2. To determine the vital enablers & levers of CE transition in Indian EEE sector.

The research aims at addressing many critical gaps. First, it has been observed that the existing research in the area of CE adoption is fragmented. Most of the studies focused on generalized insights into the manufacturing industry (Coluccia et al., 2024; Masi et al., 2024; Vidal et al., 2024). Considering the potential of CE transition in the EEE sector, this is a notable gap to fill. Also, the amount of e-waste generation, regulatory intensity and proper disposal of EOL products, a sector specific investigation of CE adoption at a firm-level is essential.

Second, several studies in the existing literature have examined factors, enablers and barriers of CE transition (Khan et al., 2022; Lu et al., 2024), however, the literature has not consistently distinguished between the enablers and levers. The contextual factors, that is, enablers facilitate CE adoption, while the levers represent the actionable practices firms can deploy. While past studies have analysed multiple enablers, the role of levers has been comparatively neglected, and the interdependence amongst them, have received very less scholarly attention. This lack of conceptual clarity regarding importance and interdependence among enablers and levers, restricts the ability of the firms to effectively plan CE strategies.

Evolving paradigms such as Industry 5.0, innovation in product design, servitized business models, and sustainability integration have received little academic attention in the context of Indian EEE sector (Bressanelli et al., 2021; Santiago et al., 2025; Svensson-Hoglund et al., 2021). Since, these paradigms plays an important role to sector's transition towards circularity, their incorporation into the existing framework remains underexplored, which is a notable research gap which this study will consider.

Lastly, the frameworks in existing literature are often limited to single decision-making techniques, sometimes fail to capture the complexity of CE adoption. while the traditional approaches are useful in providing insights, but they are inadequate for addressing multidimensional relationships amongst enablers and levers of CE adoption. A hybrid multi-criteria decision making (MCDM) framework involving 'Delphi method' and 'Grey DEMATEL' is proposed in this study. The proposed framework, remain underutilized, despite their potential to capture interdependencies and systematically rank the alternatives.

To conclude, the literature revels that while CE transition has gained momentum in the research community, there still remains critical gaps in sector-specific analysis, clarity between enablers and levers, and methodological rigor. Hence, the thesis seeks to bridge these gaps by developing a comprehensive framework for accessing the enablers and levers of CE transition in the EEE sector.

Research Methodology

The research focuses on the adoption of circular economy (CE) practices within the EEE sector in India. Given the sector's critical role in the face of environmental and regulatory pressures, as well as concerns about resource efficiency, a systematic literature review (SLR) was meticulously undertaken in Chapter two of the thesis. The review involves gaining an in-depth understanding of firm-level CE adoption, which enables the identification of prevailing themes, gaps, and proposed research questions The SLR has led to the identification of the methodology of the proposed research objective, which is, identification and analysis of critical enablers and levers of CE transition in the EEE sector. To address this a hybrid multi-criteria decision-making framework based on Delphi method and Grey DEMATEL technique is proposed.

The research was carried out in three phases to systematically identify, validate, and analyze the enablers and levers of CE adoption. Phase one involves identification of potential enablers and levers for the adoption of CE practices. Then, in phase two, a Delphi-method was adopted where the industry experts were engaged to validate and finalize the critical enablers and levers. This step ensured that the criteria considered in the study were based on academic research while also reflecting the realities of the Indian EEE industry. Finally, in the last phase, Grey DEMATEL method was applied to examine the priority and the cause-and-effect relationships among the identified enablers and levers. This multi-phase approach ensured both theoretical rigor and practical relevance in facilitating a strategic and actionable transition toward achieving resilient and sustainable supply chains for the future through the adoption of circular practices.

Data Analysis & Discussions

The study aims at identifying the enablers and levers of CE adoption specific to EEE sector. The study’s data was collected from seventeen experts within the EEE industry. First the Delphi method was adopted to finalize the list of enablers and levers extracted from the extant literature. Further, the Grey-DEMATEL method was utilized to obtain the prominent enablers and levers and their associations. The DEMATEL method analyses factors and helps us understand the causal relationship among them (Bai & Sarkis, 2013; Werner-Lewandowska et al., 2025). The top three

critical factors of CE transition are Industry 5.0, circular product design, and consumer & society, followed by circular supply chain and government intervention. The findings also revealed that government intervention and Industry 5.0 are the two top cause group enablers of CE adoption, whereas the two prominent effect group levers are financial investment followed by competence & skill set building of the workforce. The findings bring important implications for practitioners and policymakers, offering them the roadmap to prioritize the enablers and levers based on their rank and association. Hence, the proposed framework guides them in creating a strategic plan for effective CE transition to achieve the resilient supply chains of the future.

The results obtained highlights the strategic importance of enablers and levers for supply chain and operations management practitioners in the electronic industry. These enablers and levers are crucial in achieving the strategic goal of achieving CE transition at a firm level. Therefore, managers must develop a comprehensive strategic plan prioritizing the four key factors necessary for transitioning from the traditional linear 'take-make-dispose' model to a more balanced and circular paradigm.

Conclusion, Limitations and Directions for Future Research

This thesis proposed a hybrid methodological decision-making framework for advancing towards CE adoption in the Indian EEE sector. The exponential rise in e-waste poses a significant challenge for its management. Hence, the EEE sector is recognized as a high-priority sector for CE transition. The key objective of CE transition is to deliver economic, environmental and social benefit through the circular flow of resources. Integrating CE practices into business has a substantial impact on the entire value chain by reducing waste production, enhancing resource efficiency, and promoting sustainability-focused collaboration among stakeholders.

The study draws its foundation from a Systematic Literature Review of 94 peer-reviewed papers, which identified three major themes of CE adoption – ecosystem, design strategies, and circular business models. The frameworks proposed in this thesis consider many realistic factors like, the enablers & levers of CE adoption, and uncertainty involved in decision-making.

All said and done, there is always a scope of enhancement and expansion. Circular Economy adoption is a smouldering challenge in all industries that make a committed involvement of technological, economic, environmental and social factors. This thesis has tried to make sincere efforts in applying multi-criteria decision-making techniques to the area of circular economy adoption through the lens of enablers and levers.

This research provides valuable information for academician, practitioners and policy makers. Nevertheless, like every research study has some limitations that must be recognized. These limitations are discussed in two folds – one for the systematic literature review and the other for the study of enablers and levers of CE adoption. In SLR initially, the author searched the specified keywords exclusively on the Scopus digital database. As a result, the author may have overlooked some similar research that is included in other databases.

Second, although the study successfully analysed significant enablers and levers of CE transition, several limitations remain, which open avenues for enhancement and future study. Based on the current state of sustainability and CE practices at the firm level, the author found six 'enablers', and seven 'levers' of CE adoption. These may not account for dynamic changes over time. Therefore, to capture these evolving enablers and levers and their interdependencies in future, longitudinal studies are necessary. Further study may emphasize on tracking phases of enablers and levers and how particular enablers and levers gain or lose importance.

Third, this study is sector specific, focused only on EEE sector. In the upcoming research, scholars can replicate the research for e-commerce, automotive, or healthcare. This would help to assess the generalizability of the findings. Since the said industries face diverse CE adoption challenges, testing the framework in this perspective would help assess whether the identified enablers and levers are sector-specific or universally applicable.

Finally, the thesis is based on the following research papers in the order of appearance in the thesis:

1. **Sehgal, S.**, Gugnani, R., & Bali, S. (*2025*). Navigating Circular Economy Transition at a Firm Level: A Systematic Literature Review of the Electronic Industry. *International Journal of System Assurance Engineering and Management*, *1-17*. https://doi.org/10.1007/s13198-025-02948-5

2. **Sehgal, S.**, Bali, S., Gunasekaran, A., Roy, M. H., & Gugnani, R. (2025). Leveraging Circular Economy Transition to Achieve Resilient and Sustainable Supply Chains of the Future: A

study of EEE Industry. *Sustainable Futures*, *10*, *101053*. https://doi.org/10.1016/j.sftr.2025.101053

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