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ADDRESSING THE MORAL CONUNDRUM: INTEGRATING INFORMAL E-WASTE WORKERS INTO SUSTAINABLE MANAGEMENT SYSTEMS

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The rapid surge in electronic devices has led to an exponential rise in electronic waste (e-waste), necessitating a robust strategy for its management. The Green Deal, within its overarching vision for sustainability, champions a circular economy and advocates for eco-friendly practices, encompassing e-waste management. In India, where the informal sector dominates e-waste handling, outdated methods and lack of regulation pose environmental and health hazards. This article examines the dichotomy between informal and formal e-waste management, exploring challenges faced by both sectors and proposing a cradle-to-cradle (C2C) model for sustainable collaboration. The aim of the research is to transform e-waste from a problem into an opportunity, envisioning a sustainable future in e-waste management. The research method involves the use of a rigorous approach using critical analysis and a comprehensive literature review to clarify the complexities in the field of electronic waste (e-waste) management. The synthesis of studies, from assessing enablers of e-waste management to evaluating circular economy models, provides valuable insights for stakeholders and policymakers. The study scrutinizes the existing infrastructure, discusses challenges, and proposes a strategic model bridging formal-informal e-waste management.

Keywords: *Cradle -to-Cradle; eco-friendly; e-waste, sustainable.*

INTRODUCTION

In the digital era, the proliferation of electronic devices has brought about unparalleled convenience and connectivity. Yet, the rapid evolution of technology has also birthed a parallel challenge: the management of electronic waste, or e-waste. Electronic waste poses an indirect yet profound threat, inflicting adverse effects on humans, animals, and the environment by polluting natural resources such as air, soil, and water. The prolonged accumulation and contamination of e-waste have the potential to severely impact environmental resources (Rajesh et al., 2022). The Green Deal initiative aims to spearhead a sustainable, environmentally friendly approach across various sectors, including waste management. When it comes to electronic waste (e-waste), the Green Deal addresses this critical issue through a comprehensive framework that emphasizes circular economy principles, resource efficiency, and eco-friendly practices. In countries like India, where the e-waste sector is predominantly handled by the informal segment, the methods employed often lead to environmental degradation and pose significant health risks to workers.

This article delves into the dichotomy between the informal and formal sectors of e-waste management in India. It highlights the crucial role of local scrap vendors in handling electronic waste, while also shedding light on the drawbacks of their outdated and hazardous recycling methods. Moreover, it addresses the challenges faced by formal recyclers in implementing environmentally friendly practices amid stiff competition from the informal sector.

The absence of robust regulations governing e-waste disposal exacerbates the situation, leading to improper handling, environmental pollution, and health hazards. However, within this complex landscape, there exists a potential solution rooted in the cradle-to-cradle (C2C) approach. This article explores a proposed model that seeks to transform the negative environmental impact of the informal sector into a positive force, fostering a sustainable collaboration between formal and informal recycling practices.

By examining the existing infrastructure, discussing the challenges, and proposing a C2C-based model, this article aims to advocate for a strategic roadmap that bridges the gap between formal and informal e-waste management. Through collaboration and innovative strategies, it envisions a future where e-waste becomes an opportunity for positive economic, environmental, and social transformation.

RESEARCH METHODS

This study's approach involves gathering data from primary and secondary sources. Secondary data was collected from credible publications like Environmental Science and Pollution Research, Science of the Total Environment, ScienceDirect, Recovery of Materials and Energy for Resource Efficiency, and The Journal for Decision Makers by IIM-A.

This study employs a critical analysis approach to examine and evaluate existing literature, empirical studies, and conceptual frameworks related to e-waste management, circular economy practices, and sustainable strategies. The critical analysis method allows for a comprehensive review and synthesis of diverse perspectives, enabling a deeper understanding of the complexities and challenges within the field. In addition to the secondary data, primary information was obtained through semi-structured interviews. The participants for these interviews were selected from experts and professionals specializing in environmental engineering. Additionally, representatives from prominent organizations including NASSCOM, Central Pollution Control Board, and the Public Works Department in the Indian state of Kerala were included in the interview process. These interviews offered invaluable perspectives and insights from crucial stakeholders within the region's e-waste management domain. By combining both primary and secondary data sources, this study ensures a comprehensive and well-rounded analysis of the enablers of e-waste management in the circular economy, with a specific focus on the Indian perspective. The inclusion of expert opinions and existing literature enhances the credibility and depth of the research findings, providing valuable information for stakeholders and policymakers in the field of e-waste management.

Research Question: How can the informal sector be effectively integrated into e-waste management practices while ensuring minimal environmental impact?

LITERATURE REVIEW

This literature review constitutes a comprehensive exploration, delving into the multifaceted landscape of e-waste management, circular economy models, and sustainable practices. The amalgamation of studies ranging from assessing enablers impacting e-waste management to exploring the adverse effects of e-waste on health and the environment, alongside innovative concepts like the Green e-Waste Channel, signifies a collective effort to unravel the complexities surrounding this critical domain. This synthesis aims to illuminate crucial insights for stakeholders, policymakers, and environmental conservation endeavours, presenting a mosaic of perspectives crucial in navigating the intricate realm of e-waste management in the digital age. About 80% of e-waste from developed countries is illegally exported to developing countries especially China, India, Nigeria, Ghana and Pakistan, because of the lower labor costs and lack of governmental regulations (Kumar et al., 2016). Top of Form

In Sharma et al. (2020) article "Assessing enablers of e-waste management in the circular economy using the DEMATEL method: An Indian perspective," the study focuses on identifying factors negatively impacting the e-waste ecosystem by examining various enablers. These enablers include collaboration with environmental partners, subsidy benefits, precious material recovery, deposit refund scheme implementation, initiatives supporting employee health, environmental awareness programs, fostering a green image, reducing landfill practices, establishing environmental management systems, complying with environmental legislation, and minimizing hazardous substances. The study aims to offer insights for stakeholders and policymakers to enhance e-waste management practices, specifically within the Indian context. Rautela et al. (2021) in their work "E-waste management and its effects on the environment and human health," explore the toxic effects of e-waste on human health and the environment. Additionally, the study analyzes global e-waste distribution and proposes strategies for formalizing the informal sector to improve e-waste management, advocating for a cradle-to-cradle model for a more effective approach.

Bondolf et al. (2007) in "The Green e-Waste Channel as an environmentally friendly and socially responsible concept to manage e-waste in emerging economies," address current challenges in e-waste management by introducing the Green e-Waste Channel concept. This approach incorporates environmental friendliness, economic sustainability, and social responsibility for a long-term, sustainable solution. The study includes a SWOT analysis to further support this concept. Bhaskar et al. (2019), in "E-Waste Management in India: Issues and Strategies," assess the current state of e-waste management in India, identifying diverse sector challenges and exploring potential avenues for improvement. Emphasizing the significance of informal-formal partnerships, the study aims to develop a resilient e-waste management system that safeguards livelihoods and mitigates external costs.

Busu and Busu (2018), in "Modeling the Circular Economy Processes at the EU Level Using an Evaluation Algorithm Based on Shannon Entropy," present a dual perspective encompassing both linear and circular economic processes within the European Union context. The study provides insights into the evolution of economic models, their implications for resource utilization, sustainability, and overall economic well-being. Araujo Galvão et al. (2018), in "Circular Economy: Overview of Barriers," conduct a content analysis to classify barriers hindering the implementation of circular economy practices. The barriers are categorized into technological challenges, policy and regulatory constraints, financial and economic limitations, managerial hurdles, performance indicator issues, customer-related concerns, and social factors. McDonough and Braungart (2002), in "Cradle to Cradle: Remaking the Way We Make Things," introduce the cradle-to-cradle design concept, emphasizing sustainability and mimicking natural processes. Unlike the linear "cradle to grave" approach, this model envisions a continuous cycle of materials, promoting environmental friendliness and regeneration. Ministry of Environment, Forest and Climate Change (MoEFCC),

Government of India. (2016). E-waste (Management) Rules, 2016 defines Extended Producer Responsibility (EPR) and Producer Responsibility Organization (PRO), essential in managing e-waste sustainably.

These studies collectively contribute insights into e-waste management, circular economy practices, and sustainable approaches beneficial for stakeholders, policymakers, and environmental conservation.

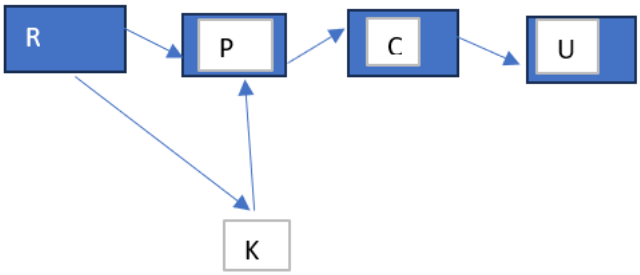

Figure 1. Linear Economy Model (Cristian et al., 2018)

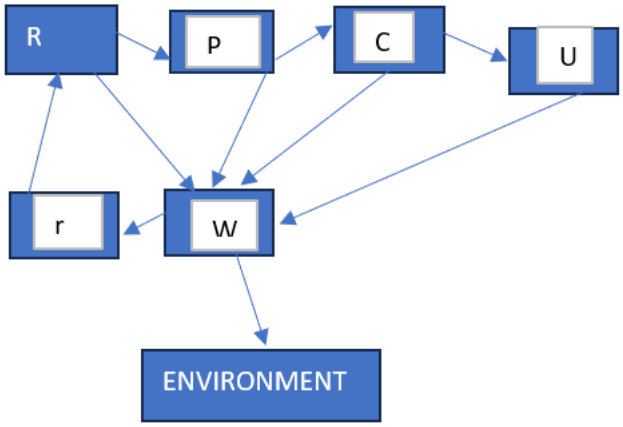

Figure 2. Circular Economy Model (Cristian et al., 2018)

Informal sector

The e-waste management sector in India is primarily handled by local scrap vendors, who are responsible for collecting electronic waste. The methods used in recycling include basic approaches like taking apart electronic devices, manually breaking down printed circuit boards, recovering metals by cutting cables, breaking or melting plastics, sweeping toner, and using open acid leaching to extract metals from e-waste. (Tyagi et al., 2015). The lack of education and skills among most scrap vendors and their workers contributes to the use of outdated and hazardous methods, including burning products to extract metals, without adequate awareness of the associated health risks.

These extraction methods lead to the emission of toxic elements into the atmosphere, causing environmental pollution, and contaminate water sources due to improper disposal of e-waste residues. The leftover waste frequently ends up in illegal landfills, worsening the environmental consequences. Moreover, workers in this sector lack adequate ventilation or personal protective gear, resulting in direct exposure to hazardous elements, leading to chronic health problems.

Despite its significant contribution to providing livelihoods, especially for marginalized sections of society, the sector's unscientific and unsafe practices pose risks to the workers' health and impose potential environmental and health costs on society at large. Urgent action is required to address these challenges and implement safe and sustainable e-waste management practices.

Formal System

To address the prevalent non-regulatory handling of e-waste in India, the implementation of effective policies is essential to establish a formal system that ensures environmentally friendly management. Formal recyclers employ the latest technologies to manage and recover resources efficiently. However, sustaining these measures demands substantial cost investment, posing challenges for formal recyclers as they face competition from the informal sector (Tyagi et al., 2015).

Within the formal system, electronic devices are gathered and sorted based on their intended purpose. These categorized items are then either refurbished or dismantled as necessary. Reusable components from refurbishment are reintroduced into the market, while the remaining parts move through the dismantling phase. During dismantling, strict adherence to environmentally safe disposal methods is maintained. This involves separating and categorizing various components to recover valuable materials for market use, with the number of cycles adjusted according to specific needs.

The coexistence of the informal sector and its exclusion from existing regulations poses a significant challenge. Despite playing a crucial role in e-waste management, the informal sector remains unrecognized and unacknowledged. This situation has created a competitive dynamic with the formal sector, especially regarding waste access and value

extraction within the waste trade. Producers often use the presence of the informal sector as an excuse to evade their mandated Extended Producer Responsibility (EPR) obligations, making EPR compliance more challenging. Extended Producer Responsibility (EPR) is a policy approach that holds producers responsible for the environmental impact of their products throughout their entire life cycle, from design and production to disposal and end-of-life management (MoEFCC), Government of India (2016)). The concept aims to shift the burden of managing and recycling waste from consumers and local governments to the producers, encouraging them to take responsibility for the environmental implications of their products. Additionally, the informal sector's robust collection logistics further complicate the achievement of EPR goals.

RESEARCH RESULTS AND DISCUSSION

The existing e-waste management infrastructure in India

The management of e-waste encounters significant hurdles and issues. Key among these is the insufficient awareness among consumers and manufacturers regarding appropriate e-waste disposal methods. Furthermore, there's a notable absence of efficient oversight and regulation regarding the generation and recycling of e-waste. The informal sector holds a pivotal position in e-waste processing, employing outdated techniques that contribute to environmental contamination. Workers in this sector lack sufficient knowledge about the health risks linked to e-waste, and the absence of modern technologies impedes effective resource extraction.

A notable drawback is the absence of specific rules and regulations governing e-waste handling. Partially dismantled products are often left to be landfilled, further exacerbating the problem (Tyagi et al., 2015).

The distinctive makeup of e-waste, encompassing both valuable and hazardous elements, leads to diverse paths of waste movement. In many developing nations, e-waste is perceived as a valuable commodity, incentivizing customers through payments made by collectors (Islam et al., 2016). Conversely, developed countries have implemented stringent regulations to prevent illegal channels and dumping of e-waste. Understanding the various routes of this waste stream, including both overt and unlawful channels, emerges as a critical focus for all nations. This understanding is pivotal in conserving resources, managing cross-border movement, and safeguarding human well-being (Nazmul Huda et al., 2019). Tackling these complexities is imperative to establish a sustainable and conscientious e-waste management framework.

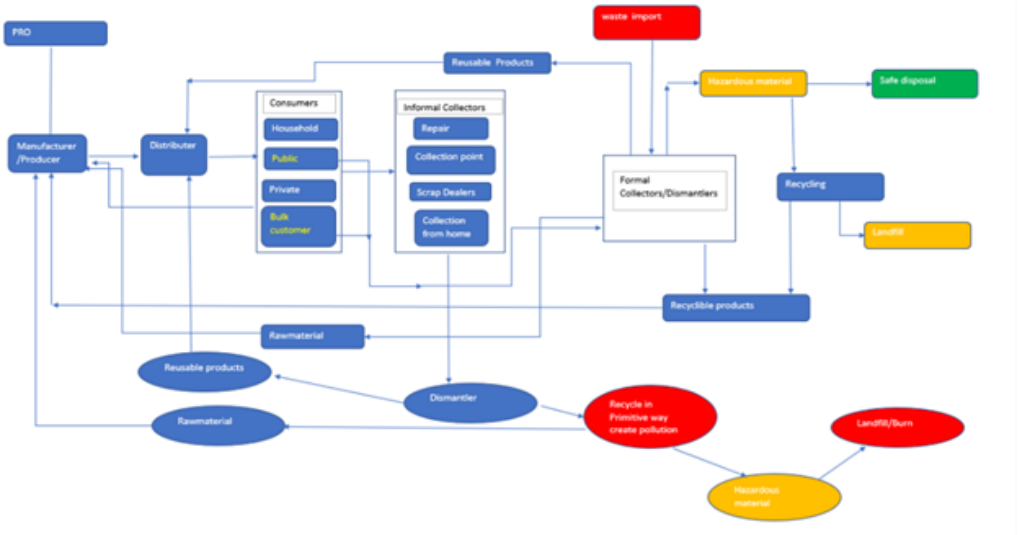

Figure 5. The existing e-waste management infrastructure in India (made by author)

Proposed e-waste model adopting cradle-to-cradle approach

The research question seeks to explore how the informal sector's negative environmental impact, associated with its cradle-to-grave methodology, can be transformed into a positive force through a formal-informal cooperation model based on the cradle-to-cradle (C2C) approach. The objective is to create a sustainable and mutually beneficial system that preserves the environment while supporting the livelihoods of the marginalized individuals who depend on the informal sector's extensive logistics. By examining and implementing the proposed C2C-based model developed by Anahide Bondolf et al., this study aims to identify ways to harness the existing informal sector's potential for positive environmental change and social well-being. A formal-informal collaboration paradigm is the one that has been put out. It won't pose a threat to those whose livelihoods depend on the unorganized sector, and it will lessen its negative environmental effects. Circular economy principles are used.

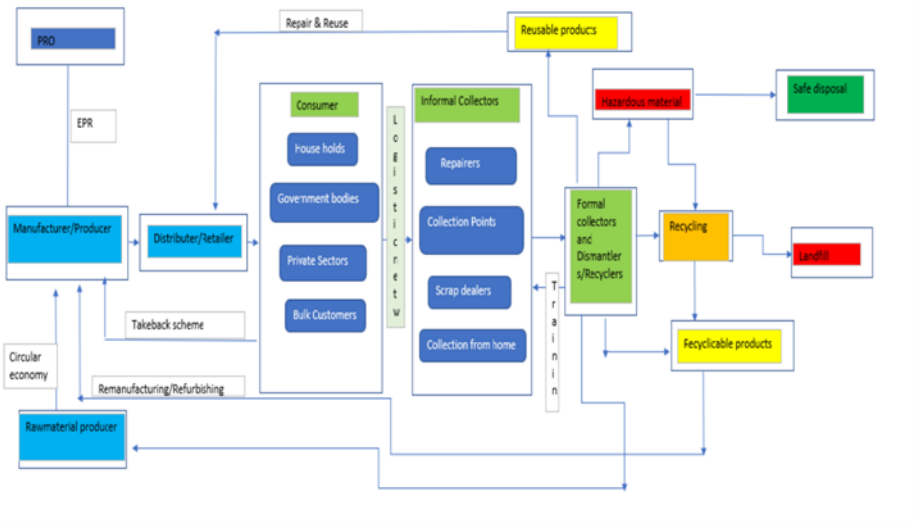

Figure 6. Proposed e-waste model adopting Cardle-to-cradle approach (made by author)

CONCLUSION

In summary, the persistence of informal e-waste treatment and management practices in numerous developing nations is primarily attributed to insufficient awareness and the ineffective enforcement of existing regulatory frameworks. The imperative for establishing an effective e-waste management system necessitates the development of a sustainable roadmap that strategically addresses the disparities between formal and informal recycling sectors. Such an approach is pivotal in fostering the resilience of ecosystems, advancing occupational health and safety standards, and catalyzing the emergence of fresh business prospects and employment avenues.

Implementing the Cradle-to-Cradle (C2C) e-waste model shows significant potential in advancing multiple sustainable development objectives. Incorporating this model can contribute to promoting universal good health and well-being, creating employment prospects and economic advancement, and cultivating sustainable urban and community development.

To address the challenges associated with e-waste management, collaborative efforts between governments, industries, and communities are imperative. Raising awareness about the hazards of improper e-waste disposal, enforcing regulations, and promoting responsible recycling practices can significantly contribute to the creation of a resilient and sustainable ecosystem. By adopting a C2C approach and embracing innovation, we can pave the way for a brighter and healthier future, where the management of e-waste becomes an opportunity for positive economic, environmental, and social impact.

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