



A Conceptual Digital Platform for Integration of the Formal and Informal Sectors in E-Waste Management in India

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Abstract

Electronic waste (e-waste) generation is growing rapidly in India, yet the vast majority is handled by the informal sector, leading to environmental and health risks, resource loss, and weak circular-economy outcomes. This paper examines the dual challenge of formalising e-waste flows while integrating the informal sector, analyses the policy environment—especially the E-Waste (Management) Rules, 2022 and the Extended Producer Responsibility (EPR) regime—and proposes a platform-based model for bridging informal and formal actors. The model envisions an online exchange/marketplace for e-waste that links informal collectors, aggregators, formal recyclers and producers, enabling traceability, fair pricing, financial inclusion of informal workers, and alignment with EPR obligations. Key recommendations include stakeholder mapping, capacity building of informal actors, digital tracking of waste flows, economic incentives, regulatory coordination, and monitoring & evaluation. The paper argues that integrating informal and formal sectors is essential for a sustainable, inclusive, circular e-waste ecosystem in India.

Keywords: e-waste, informal sector, formal sector, India, Extended Producer Responsibility (EPR), circular economy, platform model, e-waste policy

1. Introduction

Electronic and electrical equipment (EEE) consumption in India has accelerated due to rapid urbanisation, rising incomes, shorter product lifecycles and digitisation. As a result, e-waste has emerged as one of the fastest growing waste streams. For instance, one study estimated that by 2019 India generated over 3.23 million tonnes of e-waste. [2] However, formal recycling systems capture a very small share of this stream—less than 10% of the waste is processed by established, authorised recyclers. [2] In practice, the informal sector—comprised of scrap dealers, rag-pickers, local dismantlers, repair shops and unregistered recyclers—handles the bulk of collection and dismantling. [1]

This dichotomy creates several problems: hazardous and unscientific recycling practices, low resource recovery, weak traceability, tax and revenue losses, and lost opportunities for circular economy. [6] Therefore, integrating informal actors into the formal ecosystem but not simply by replacing them—is both a challenge and an opportunity. This paper explores how such integration can be achieved in the Indian context, especially through the lens of policy (EPR) and via a digital/market platform model.

The objectives are as follows:

1. To review the formal and informal e-waste sectors in India, their roles, strengths and limitations.
2. To examine the current policy framework with emphasis on EPR in the 2022 Rules.
3. To propose a platform model for linking informal and formal actors in e-waste management.
4. To discuss benefits, challenges, and policy/operational recommendations for such integration.

2. Literature Review

2.1 Formal vs Informal E-Waste Management in India

Several studies indicate that more than 90 % (or even up to 95 %) of e-waste in India is handled by the informal sector [1], [5]. The informal sector has inherent advantages: flexibility, low operational cost, proximity to waste sources (households, small businesses), strong existing networks and workforce. However, major limitations include lack of protective equipment, hazardous processes (acid leaching, open burning), lack of regulatory oversight, low resource recovery efficiency and weak traceability [2].

The formal sector, conversely, has authorised recyclers with certified processes, better technology, environmental compliance and traceability. But formal entities face severe constraints: weak collection networks, limited access to waste streams (because informal actors dominate), high operational cost, inadequate volumes to run plants at capacity, and insufficient linkages to producers or markets [5]. Thus, the literature emphasises the gap between collection (dominated by informal) and high-end processing (dominated by formal), and the risk that formalisation could inadvertently displace livelihoods without addressing systemic issues [5].

Table 1: Comparison of Informal and Formal E-Waste Systems

Criteria	Informal Sector	Formal Sector
Collection Reach	Extensive, household-level	Limited to authorized centers
Technology Level	Manual dismantling, open burning	Automated, certified recycling
Worker Protection	Low	High
Cost Efficiency	High	Moderate
Traceability	Weak	Strong
Compliance	Minimal	High
Integration Readiness	High potential with training	High with collaboration

2.2 Integration Approaches & Circular Economy

Recent research has proposed models for integration of informal and formal sectors within a circular economy framework. For instance, the study “Circular economy and household e-waste management in India: Integration of formal and informal sectors” presents a modified EPR model linking informal collectors to formal recyclers [2]. Another piece identifies building blocks such as federating informal workers into collectives, capacity building, supportive framework conditions, business structures that leverage both sectors, and monitoring & evaluation.[5]

2.3 Policy and Regulatory Framework

India’s policy on e-waste has evolved over time. The earlier E-Waste (Management) Rules, 2016 provided basic definitions, collection targets and responsibilities. The newer 2022 Rules strengthen obligations, expand product coverage, introduce digitalisation of registration, and leverage EPR more robustly. [7]&[4]

Key features include:

- Inclusion of 106 categories of EEE under Schedule-I (versus only 21 earlier). [7]
- Mandated registration of producers, recyclers, refurbishers and dismantlers via a digital portal. [8]
- Producers required to meet annual recycling targets (through registered recyclers) and submit annual/quarterly returns. [4]

- Introduction of EPR certificates that recyclers generate based on processed volume; producers can purchase these certificates to fulfil obligations. Overall, the regulatory regime is moving toward traceability, formalisation, transparency and circular-economy orientation.

2.4 Gaps and Unaddressed Issues

Despite the policy advances, major gaps remain:

- The informal sector is not explicitly recognised/registered in many policies and formal actors still struggle to access actual waste flows. [9]
- Collection infrastructure is inadequate compared to generation volumes; consumer awareness is low. [2],[3]
- Digital infrastructure and traceability mechanisms are nascent.
- Economic incentives for informal actors to transition or integrate are weak.
- Monitoring, enforcement and data quality are challenged (e.g., paper-trading, false certificates) [8]

These indicate the need for operational models that link informal network strengths with formal system requirements, within the policy framework.

3. Research Methodology

This study uses a qualitative, exploratory research method to analyze how formal and informal sectors come together in India's e-waste management system. It also suggests a digital platform model that follows the E-Waste (Management) Rules, 2022. The methodology aims to combine existing evidence, assess policy frameworks, find gaps in the sectors, and create an operational solution for integration.

3.1 Research Design

The research employs an exploratory and descriptive design. This approach helps in understanding complex systems like e-waste flows, supply chains, policy mechanisms, and interactions among stakeholders. Since the study looks at systemic challenges and proposes a model for integration, it mainly relies on analyzing secondary data and creating conceptual models.

3.2 Data Sources

This study is based entirely on secondary data, collected from:

- Peer-reviewed journal articles and conference papers, such as Minerals Engineering and the International Journal of Development Research.
- Government publications, including CPCB guidelines, the E-Waste (Management) Rules from 2016 and 2022, along with documents from MoEFCC.
- Reports from international organizations like GIZ, TERI, and industry white papers.
- Respected national sources such as Economic Times, Vision IAS, and Insights IAS for statistical updates, sector analysis, and policy commentary.
- Case studies of existing digital e-waste platforms, such as IIT Madras's "e-Source."
- All references used in this paper can be found in the reference section.

3.3 Data Collection Method

A structured literature review approach was used to gather and classify relevant information. The steps included:

I. Identification of keywords:

"e-waste management India," "informal sector," "formal sector," "EPR," "circular economy," "platform model," "digital traceability."

II. Screening documents based on relevance criteria:

- Published after 2016
- Focused on India
- Directly discussing roles of informal/formal sectors, policy gaps, EPR challenges, or digital integration

III. Data extraction focused on:

- Current e-waste flows
- Roles and limitations of formal and informal actors
- Policy provisions in the E-Waste Rules 2022
- Barriers in collection, tracing, and recycling
- Best practices in digital waste-management platforms

3.4 Analytical Framework

The analysis followed three major frameworks:

(a) Sectoral Analysis Framework

This framework compared the informal and formal sectors in terms of:

- Collection reach
- Technology use
- Regulatory compliance
- Worker safety
- Cost efficiency
- Integration potential

This helped identify structural gaps that the proposed platform needs to address.

(b) Policy Analysis Framework

The study examined the E-Waste (Management) Rules, 2022, and Extended Producer Responsibility (EPR) guidelines to understand:

- Stakeholder obligations
- Compliance needs
- Certificate systems
- Limitations in traceability and monitoring

(c) Platform Conceptualization Framework

Based on insights from real-world digital platforms (e.g., e-Source), the study developed a conceptual “E-Waste Exchange Platform (EEP)” using:

3.5 Model Development Procedure

The proposed platform model was created using these steps:

1. Mapping all stakeholders in both formal and informal supply chains.
2. Identifying integration gaps, such as data inaccuracy, informal dominance in collection, low formal recycling volumes, and weak traceability.
3. Aligning platform components with policy needs under EPR (certificate management, recycler-producer connections, registration).
4. Designing data and material flow, where e-waste moves from generators to informal actors, then to formal recyclers, and finally to producers, while data and incentives move through the digital system.
5. Creating incentives for informal workers, including training, digital payments, health benefits, and fair pricing.

6. Evaluating challenges and strategies to address them, such as the digital divide, regulatory alignment, and trust issues.

3.6 Scope of the Study

This study focuses on:

- India's urban and semi-urban e-waste systems
- E-waste covered under the E-Waste (Management) Rules, 2022
- Roles of collectors, recyclers, refurbishers, producers, and regulators
- Feasibility of integration using a nationwide digital platform

3.7 Limitations

This study is conceptual and based on secondary data. It does not include:

- Field surveys
- Empirical cost-benefit analysis
- Pilot deployment results
- Primary stakeholder interviews

Future research could include validation through field studies and prototype testing.

4. India's EPR Policy for E-Waste

4.1 What is EPR?

Recent research has proposed models for integration of informal and formal sectors within a circular economy framework. For instance, the study presents a modified EPR model linking informal collectors to formal recyclers [2]. Another piece identifies building blocks such as federating informal workers into collectives, capacity building, supportive framework conditions, business structures that leverage both sectors, and monitoring & evaluation [5].

4.2 EPR under the 2022 Rules

Under the E-Waste (Management) Rules, 2022:

- Producers of EEE must register and meet annual recycling targets via registered recyclers. [7]
- Producers can fulfil obligations through purchase of EPR certificates from authorised recyclers. [4]
- Refurbishers can generate refurbishing certificates that defer recycling liability by extending product life. [7]
- The rules enable the Central Government to establish platforms for trading/transferring EPR certificates. [9]
- Non-compliance may trigger environmental compensation, audit and prosecution [7].

Table 2: Last three years recycling target.

Financial Year	Target Recycling %*
2023-24	approx. 60%
2024-25	approx. 70%
2025-26	approx. 80%

*Illustrative; actual targets vary by category and year. These provisions aim to ensure the "polluter pays" principle and foster circularity by recovering valuable materials from e-waste.

4.3 Implications for Formal and Informal Sectors

The EPR regime strengthens formal recycling supply chains—registered recyclers become key nodes. For informal actors, this policy creates both opportunity and risk: they might be excluded if unable to register or join formal value chains, but conversely they may be integrated as collectors or aggregators under producer/recycler networks. Scholars argue that the informal sector's inclusion is essential for meeting targets and unlocking resource flows [2].

4.4 Challenges in Implementation

- Data accuracy and verification of e-waste collected, dismantled and recycled remain weak. [8]
- Many informal flows bypass authorised structures, reducing volume available to formal recyclers [5].
- Broader structural issues (low awareness, weak collection logistics, high cost of formal recycling) hamper achievement of targets. Thus, EPR policy alone is insufficient—it needs enabling infrastructure, stakeholder engagement and innovative business models.

5. Proposed Platform for Managing E-Waste: Integrating Informal and Formal Sectors

5.1 Rationale for a Platform Approach

Given the structural fragmentation of e-waste flows in India—with informal collectors dominating collection and formal recyclers focusing on end-processing—a digital platform can act as an intermediary that links all stakeholders, ensures traceability, enables fair pricing, and aligns flows with EPR obligations. In Indian developing a marketplace that aims to connect formal and informal actors in the e-waste value chain solve the problem effectively.

5.2 Key Features of the Platform

The proposed platform (“E-Waste Exchange Platform (EEP)”) would include the following components:

1. Stakeholder registration module

- Register informal collectors/aggregators with minimal paperwork; certify them to ensure baseline health/safety standards.
- Register formal recyclers, dismantlers, producers in system.
- Link producer EPR obligations with platform flows.

2. Collection & aggregation module

- Informal collectors bring e-waste to aggregation centres or directly into platform network; platform tracks volumes, categories, origin, condition.
- Provide real-time inventory of collected e-waste, prices based on category/value.
- Enable scheduling of pickups by households/businesses via app/web.

3. Traceability & documentation

- Digital tracking from source → collector → aggregator → recycler.
- Unique identifier/QR code for batches of e-waste.
- Link to EPR certificate issuance: when recyclers process and certify, platform records volume and generates certificates that producers can purchase.

4. Marketplace/Price discovery

- Transparent pricing for materials/scrap categories (PCBs, plastics, metals).
- Informal collectors can see current rates, incentivised to bring materials into formal stream rather than informal scrap channels.

5. Incentives & financial inclusion

- Payments to informal collectors via digital means (UPI, bank transfer).
- Certification, training programmes included; insurance/health benefit schemes.
- Performance-based rewards for meeting collection/segregation KPIs.

6. Analytics & reporting

- Data dashboard for producers (EPR status), recyclers (processing capacity/volume), regulators (compliance).
- Geographic heat-maps of e-waste generation/collection, informal sector flows, gaps in network.

5.3 Integration Mechanism: Connecting Informal and Formal

- Informal collectors feed into the platform: they act as first-mile collection agents and become formalised through registration and training.
- Aggregators handle bulk volumes and forward to authorised recyclers; platform allows matching of supply (collected e-waste) with capacity (recyclers) and demand (producers needing certificates).
- Formal recyclers process and issue certificates; platform ensures transparent flows and reduces leakage into purely informal/unregistered processing.
- Producers purchase certificates and meet their EPR obligations; platform aggregates certificate inventory and enables trading/exchange among producers if needed (once rules permit).

5.4 Alignment with Policy and EPR

- The platform forms a digital traceability chain which complements the 2022 Rules' requirement for registrations, digital returns and EPR certificate management.
- By formalising flows from informal collectors via the platform, the system supports meeting the targets set under EPR.
- The marketplace feature can help price discovery and incentivisation of collection which is critical to achieve high collection rates.

5.5 Potential Benefits

- Improved collection volumes from households, institutions and businesses.
- Better resource recovery (metals, plastics) and less leakage to unscientific recycling.
- Inclusion of informal workers—improved livelihoods, safer working conditions, shift towards formal economy.
- Enhanced policy compliance, traceability, data-driven decision-making.
- Moves the system towards a circular economy: reuse, refurbish, recover.

5.6 Challenges and Mitigation

Challenges include:

- Informal sector resistance/fear of formalisation. Overcome by incentives, trust building, minimal burden of registration.
- Digital divide and low technology adoption among informal actors. Mitigation: mobile-friendly apps, training, aggregator support.
- Ensuring that collected e-waste is processed by authorised recyclers and not diverted. Mitigation: strict platform rules, audits, blockchain or secure ledger system.
- Ensuring sufficient volumes and financial viability of formal recyclers. Mitigation: aggregation of waste, guaranteed flows via platform, price stability.
- Ensuring consumer awareness and engagement (digital collection solutions). Mitigation: marketing campaigns, incentives for consumers to drop off e-waste.
- Regulatory/operational integration across states, municipalities and central government requires coordination.

6. Case Example & Implementation Roadmap

6.1 Example: “e-Source” Platform by IIT Madras

As noted, IIT Madras is developing an open-source platform called “e-Source” to serve as an online marketplace linking formal and informal sectors of e-waste in India. This illustrates that the model is not purely theoretical but has active development, giving credibility to the proposed platform.

6.2 Roadmap for Implementation

Phase 1: Pilot & Stakeholder Engagement

- Map the informal e-waste ecosystem in a selected urban region (collectors, aggregators, repair shops).
- Register informal actors, provide training and baseline equipment.
- Develop platform MVP (mobile + web) and onboard a formal recycler and producer partner.
- Run pilot for 6–12 months, monitor flows, user adoption, data capture.

Phase 2: Scaling & Institutionalisation

- Expand across city / region. Link multiple recyclers, aggregators, producers.
- Integrate with municipal waste collection systems, citizen apps for e-waste drop-off.
- Enable marketplace pricing, incentive schemes for collectors, certified refurbishers, and link to EPR certificate issuance.

Phase 3: Policy Integration & National Roll-out

- Work with regulators (Central Pollution Control Board / state pollution control boards) to align platform data with official portals, reporting.
- Integrate certification/trading of EPR certificates via platform.
- Incorporate refurbishing/repair networks, map circular economy flows (reuse first, then recycle).
- Monitor KPIs: collection rate (% of generation), formal recycling rate, informal sector worker inclusion, traceability coverage.

7. Discussion

7.1 Why Integration Matters

Integration of informal and formal sectors is not simply a matter of formalising or eliminating informal actors. Informal networks are entrenched, efficient in collection and localised distribution, and they hold immense potential to feed waste flows into the formal system. Rather than adversarial, a partnership approach leverages their strengths and mitigates their risks. The formal sector brings technology, standards, environmental compliance and links with producers under EPR. The platform model helps bridge the two.

7.2 Policy Levers and Institutional Mechanisms

The success of the integration model depends on enabling policy, institutional alignment and incentives. Key levers include:

- Strong enforcement of EPR obligations and credible penalties for non-compliance.
- Registration and accreditation systems for informal actors (collectors, aggregators) under municipal/state schemes.
- Financial incentives such as subsidies, tax breaks, preferential contracts for formal recyclers receiving platform-aggregated waste.
- Capacity building, upskilling, health/insurance benefits for informal workers.
- Digital infrastructure (portal, apps, dashboards) for traceability and decision-making.
- Public awareness campaigns and consumer incentives for drop-off or collection of e-waste.

7.3 Towards Circular Economy

By improving collection, processing and resource recovery of e-waste, India moves towards a circular economy: materials are reused and recycled, reducing dependence on virgin resources and reducing environmental/human health burdens. Integration of informal networks is particularly strategic in this context given the large volumes they already handle. The platform model aligns with circular-economy principles of transparency, traceability, reuse/refurbish, and stakeholder inclusion.

7.4 Limitations and Research Gaps

- Empirical data on the exact flows of e-waste through informal networks is limited. More field research is needed.
 - The economic viability of aggregators and formal recyclers in different geographies needs assessment.
 - The social dimension of informal sector transition (livelihoods, social security) requires deeper study.
 - The role of digital technologies (IoT, blockchain) in large-scale deployment remains to be validated.
- These gaps suggest future research directions.

8. Conclusion

E-waste management in India presents a major challenge due to rapid urbanization, growing EEE consumption, and the dominance of informal recycling practices. While the informal sector excels in collection and dismantling, its unsafe methods lead to environmental and health risks. The formal sector, despite its technological strengths and regulatory compliance, struggles with insufficient waste inflow and weak integration with informal networks.

A coordinated approach that connects both sectors is essential. The proposed digital, platform-based model offers a transparent and traceable system that links informal collectors, formal recyclers, producers, and regulators. It aligns with the E-Waste (Management) Rules, 2022 and supports Extended Producer Responsibility (EPR) compliance through digital tracking and certificate management.

By enabling financial inclusion, training, and safer working conditions for informal workers, the model strengthens social equity while advancing circular economy goals such as reuse, refurbishing, and resource recovery. Successful implementation will require collaboration among producers, recyclers, policymakers, and local authorities, supported by incentives and phased deployment.

In summary, integrating informal and formal actors through a structured, technology-driven platform can transform India's e-waste landscape, promoting environmental sustainability, resource efficiency, and inclusive growth.

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