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RESEARCH TRENDS IN E-WASTE GOVERNANCE (2020–2025): A BIBLIOMETRIC AND THEMATIC REVIEW WITH IMPLICATIONS FOR URBAN SUSTAINABILITY OF SÃO PAULO, BRAZIL

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Anooshay Niazi (*), André Felipe Simões, Haroon Jan Khan
* Institute of Energy and Environment, University of São Paulo (IEE/USP)

RESUMO

Os resíduos eletrônicos (e-waste) estão entre os tipos de resíduos que mais crescem globalmente, impulsionados pela rápida evolução tecnológica, pelo encurtamento do ciclo de vida dos produtos (em geral, associável à obsolescência programada) e pelo aumento do consumo de dispositivos eletrônicos. Nesse cenário, a governança desempenha um papel estratégico, já que a eficiência dos sistemas de coleta, reciclagem e logística reversa depende da integração e da articulação entre dimensões institucionais, econômicas, tecnológicas e comportamentais, destacando-se, no contexto do presente trabalho, instrumentos regulatórios, coordenação institucional e participação de diversos setores. Este estudo, com recorte espacial centrado na cidade de São Paulo, examina as tendências de pesquisa sobre governança de resíduos eletrônicos entre 2020 e 2025, por meio de uma revisão bibliométrica e temática da literatura disponível na base Scopus; frisa-se que a busca realizada resultou na recuperação de 229 documentos. Após aplicar filtros de período, idioma e tipo de documento, além da triagem por título e resumo para verificar a relevância temática, a amostra final analisada compreendeu 101 publicações. Os resultados mostram um crescimento moderado da produção científica, com concentração das publicações em periódicos científicos voltados para sustentabilidade, gestão ambiental e sistemas de gestão de resíduos, além de um perfil interdisciplinar liderado pelas áreas de Ciências Ambientais e Sociais. A análise temática evidenciou a predominância de termos como gestão de resíduos eletrônicos, economia circular, mineração urbana, reciclagem e responsabilidade estendida do produtor, enquanto os conceitos de governança foram mais recorrentes como mecanismos facilitadores em discussões operacionais e voltadas para a sustentabilidade. Os resultados também ressaltam o papel relevante do Brazil no campo da gestão de e-waste, destacando a importância de contextos urbanos complexos como a cidade de São Paulo. O estudo, de forma conclusiva, aponta para a necessidade de maior coordenação institucional, implementação mais eficiente de mecanismos de logística reversa e melhor integração entre as dimensões sociais e operacionais para o avanço de sistemas sustentáveis de gestão de resíduos eletrônicos.

PALAVRAS-CHAVE: resíduos eletrônicos, São Paulo, governança, sustentabilidade urbana, logística reversa.

ABSTRACT

Electronic waste (e-waste) ranks among the world's fastest-growing waste streams due to the rapid pace of technological advancement, shorter product life cycles, and rising demand for electronic devices. Within this landscape, effective governance emerges as essential, as successful systems for collection, recycling, and reverse logistics rely on strong regulatory frameworks, coordinated institutions, and active involvement from multiple stakeholders. This study explores research trends in e-waste governance from 2020 to 2025 by conducting a bibliometric and thematic review of literature indexed in Scopus. The search carried out identified 229 documents. After refining the results by period, language, and document type, and screening titles and abstracts for relevance, 101 publications were included in the final analysis. The findings reveal a moderate increase in scientific output, with most publications appearing in journals focused on sustainability, environmental management, and waste systems. An interdisciplinary trend is evident, with Environmental Sciences and Social Sciences leading the field. Thematic analysis highlights the prevalence of topics such as e-waste management, circular economy, urban mining, recycling, and extended producer responsibility, while governance is often discussed as a key enabling factor within both operational and sustainability contexts. Additionally, Brazil stands out as a notable contributor, emphasizing the importance of complex urban contexts such as the city of São Paulo. Overall, the study highlights the need for enhanced institutional coordination, more robust implementation of reverse logistics, and improved integration of social and operational dimensions to promote sustainable e-waste management.

KEY WORDS: e-waste, São Paulo, governance, urban sustainability, reverse logistics.

ATENÇÃO: A área que está sombreada (em amarelo) é a que poderá ser livremente editada pelo autor do trabalho. Isto é feito para proteger o cabeçalho e o rodapé de eventuais desformatações. Posteriormente, a Comissão Organizadora retirará este sombreamento e transformará o texto em arquivo PDF.

INTRODUCTION

Electronic waste is an increasingly pressing issue in sustainability discussions, as its rise brings together technological, environmental, and institutional challenges. Rapid innovation, shorter product lifespans, growing consumption, and the widespread digitalization of daily life have all fueled a persistent increase in discarded electrical and electronic devices. The Global E-waste Monitor 2024 estimates that global e-waste generation reached around 62 million tons in 2022 and could grow to 82 million tons by 2030. However, recycling rates remain significantly lower than the pace at which this waste stream is expanding (UNITAR, 2024). This gap highlights the urgent need to enhance the management, recovery, and governance of electronic waste.

Recent studies indicate that e-waste is not only increasing quickly in volume, but is also becoming harder to govern. Management systems differ widely between regions, collection and recycling are inconsistent, and many countries still lack strong enforcement mechanisms. As a result, effective management of Waste Electrical and Electronic Equipment (WEEE) is now closely connected to circular economy objectives, resource efficiency, and the recognition and regulation of informal recovery sectors (SHITTU; WILLIAMS; SHAW, 2021).

Inadequate management of e-waste leads to significant environmental and social consequences. Informal dismantling, open burning, and improper disposal can release toxic substances like lead, mercury, and cadmium, endangering ecosystems and public health. Simultaneously, discarded electronics are a source of valuable secondary raw materials, including strategic and rare metals, and their loss results in both environmental inefficiency and economic waste. This problem is further linked to larger discussions on climate change and resource utilization, especially when considering the energy demands of electronics manufacturing and raw material extraction (IPCC, 2022).

In Brazil, e-waste governance faces extra hurdles due to rapid urbanization, uneven waste management infrastructure, and the presence of both formal and informal recovery systems. The National Solid Waste Policy introduced important principles like shared responsibility and reverse logistics, but the application of these mechanisms is still inconsistent across regions and sectors (SANTOS; OGUNSEITAN, 2022). In major metropolitan centers such as São Paulo, the problem is intensified by fragmented institutions, limited enforcement, poor coordination among stakeholders, and the marginalization of informal recycling workers (GUERREIRO, 2025).

More broadly, research on waste governance suggests that moving toward circular systems relies not just on technical innovation, but also on coordinated policies, public engagement, and institutional strength. Obstacles in these areas can delay the shift to circular approaches, whereas greater investment in recycling infrastructure, formalizing informal labor, and improved integration of environmental and economic policies can better align waste management with overarching sustainability objectives (SHARMA et al., 2021).

At the same time, the emergence of the circular economy has expanded how e-waste is analyzed. Circular approaches prioritize reuse, repair, remanufacturing, recycling, and resource recovery, positioning electronic waste as not only an environmental issue but also a strategic aspect of urban sustainability and industrial transformation (KIRCHHERR; REIKE; HEKKERT, 2017). In this framework, governance is crucial for aligning policies, infrastructure, incentives, and stakeholder collaboration, with waste management viewed as part of a broader socio-technical system (WILSON et al., 2015).

Although research on e-waste has grown considerably in recent years, there has been less focus on how governance-related topics are organized and debated within the field. A systematic review can thus clarify how the literature has evolved, highlight key contributions, identify major themes, and uncover the main gaps in analysis. Building on this premise, this paper investigates research trends in e-waste governance from 2020 to 2025, with a special emphasis on their implications for urban sustainability in the city of São Paulo, Brazil.

After the introduction, the paper outlines its goals and research methods, and then delves into the bibliometric and thematic findings—highlighting trends in publications, leading journals, subject areas, country-by-country output, key papers, and main themes identified through keywords. The discussion then shifts to what these results mean for the city of São Paulo, finishing with a summary of the study's key insights for e-waste governance and urban sustainability debates.

OBJECTIVES

This study aims to explore how research on e-waste governance has evolved from 2020 to 2025, drawing on both bibliometric data and thematic analysis of the literature.

The research has the following specific goals: to trace changes in scientific production on the topic, pinpoint the most active journals, and spotlight key publications. It also examines the major thematic clusters within e-waste governance and considers what these findings mean for urban sustainability and governance in the city of São Paulo, Brazil.

METHODOLOGY

This research involved a bibliometric and thematic review to map out recent developments in the area of e-waste governance. Scopus served as the main database, selected for its extensive range of peer-reviewed journals and its effectiveness in supporting bibliometric research. The literature search took place utilizing an advanced search query.

TITLE ("e-waste" OR "electronic waste" OR "WEEE") AND TITLE-ABS-KEY (governance OR policy OR regulation OR "extended producer responsibility") AND TITLE-ABS-KEY (urban OR city OR municipal OR "urban sustainability")

The initial search returned 229 documents. These were narrowed down by selecting works published from 2020 to 2025, focusing only on English-language articles and review papers. The records were then exported as CSV files and reviewed by title and abstract to identify studies that specifically addressed e-waste governance, policy, regulation, and reverse logistics. After this screening, 101 publications remained in the final dataset.

During the bibliometric analysis, factors such as yearly publication numbers, document types, journal sources, country of origin, subject fields, and citation counts were examined. For the thematic analysis, author keywords from the Scopus sample were collected and manually standardized—adjusting for capitalization, spelling variations, and singular or plural forms. Similar terms such as 'e-waste', 'electronic waste', and various versions of 'WEEE' were unified to ensure accurate keyword frequency and grouping.

As outlined in Figure 1, the research followed several steps: starting with a broad search, applying filters, screening and refining the records, and finally conducting bibliometric and thematic analysis on the selected works. This process was designed to be transparent and repeatable. All further analyses were based on the final pool of 101 publications.

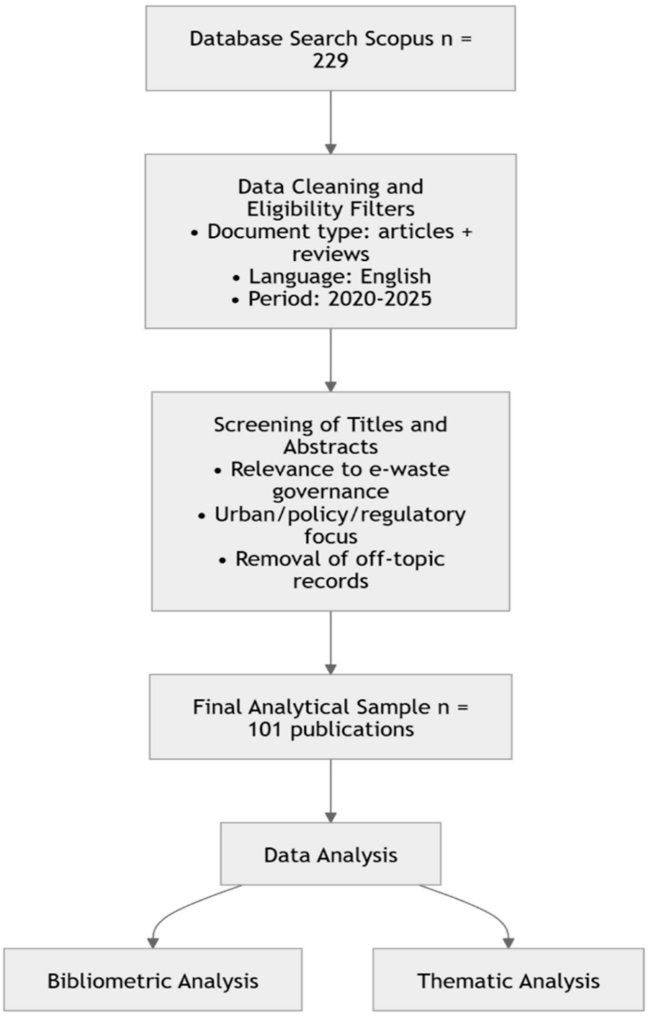

Figure 1. Methodological workflow of the bibliometric and thematic review.
Source: Elaborated by the authors from the final screened Scopus sample.

RESULTS

All bibliometric results reported below were calculated from the final screened Scopus sample used in the study (n = 101).

1. EVOLUTION OF PUBLICATIONS

The final dataset included 101 publications from Scopus covering the years 2020 to 2025. Figure 2 illustrates that, while the number of publications rose overall during this period, the increase was not perfectly steady. The total went from 15 in 2020 to 20 in 2025, with counts of 16 in 2021, 17 in 2022, 14 in 2023, and 19 in 2024. Notably, 38.6% of all publications appeared in 2024 and 2025, highlighting a concentration of research activity in these later years.

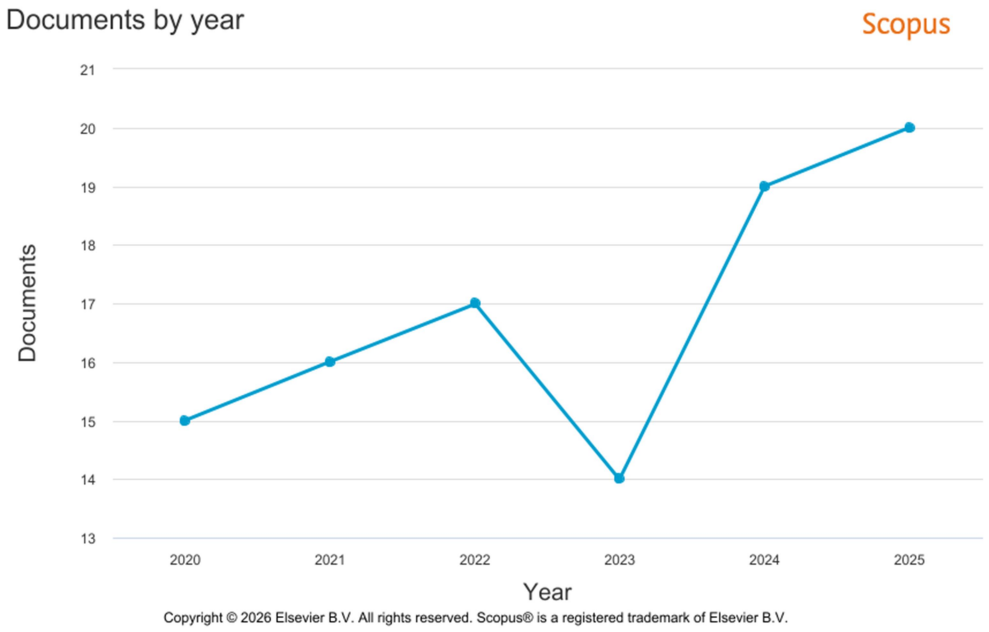

Figure 2. Annual distribution of publications on e-waste governance (2020–2025).
Source: Elaborated by the authors from the final screened Scopus sample.

Taken together, these results reflect a rising academic interest in e-waste governance and its associated topics, particularly toward the end of the study period. Despite a moderate overall number of publications, the uptick after 2023 signals that the topic has become more prominent in discussions about sustainability, circular economy, reverse logistics, and changes in waste management practices.

As shown in Figure 3, most publications are articles (89 of 101), while review papers account for only 12. However, review articles tend to receive more attention, averaging nearly 90 citations each, compared to about 24 citations for research articles. This pattern points to the influential role of review papers, which help shape the field by summarizing concepts, highlighting key trends, and guiding future research directions, even though original research is more common.

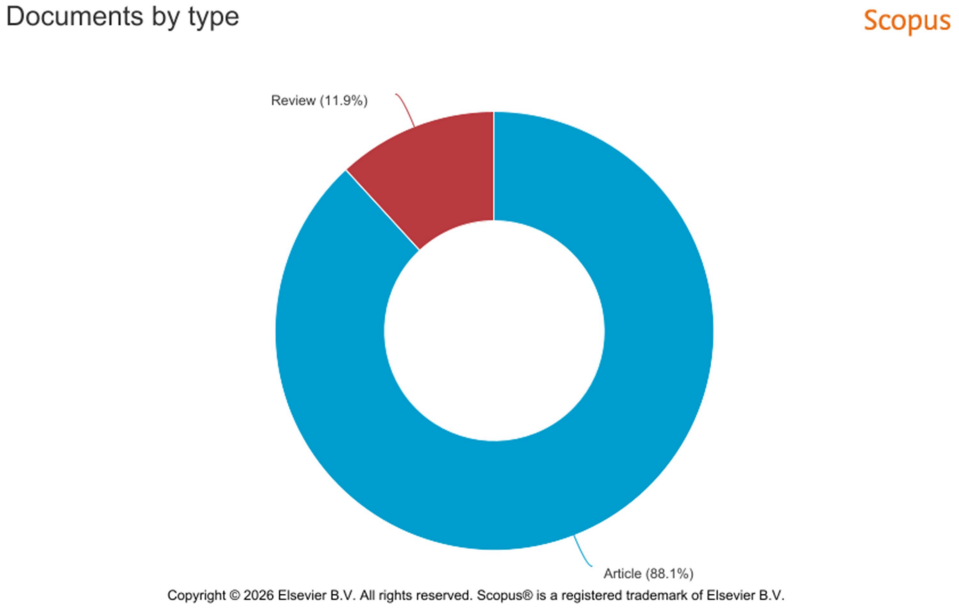

Figure 3. Distribution of publications by document type in the final screened sample.
Source: Elaborated by the authors from the final screened Scopus sample.

2. MAIN JOURNALS AND PUBLICATION OUTLETS

Table 1 highlights where most of the studies in the final sample were published, showing that a significant portion appears in journals focused on sustainability, environmental management, and waste management. The journal Sustainability (Switzerland) leads with 11 articles, followed by the Journal of Cleaner Production with 9, Waste Management with 6, and Cleaner Waste Systems with 4. Other frequently appearing titles include the Journal of Material Cycles and Waste Management and Environmental Science and Pollution Research, each with 3 articles. In total, the top ten journals published 44 of the included studies, making up 43.6% of the final dataset.

This spread of publications shows that research on e-waste governance goes beyond law or public administration journals, appearing mainly in interdisciplinary outlets focused on sustainability, environmental management, circular economy, and the performance of waste systems. This pattern suggests that governance is typically viewed as one facet of larger social, technical, and organizational systems, not as a standalone institutional concern.

Table 1. Main journals publishing on e-waste governance and related topics (2020–2025)

Rank	Journal	No. of publications
1	Sustainability (Switzerland)	11
2	Journal of Cleaner Production	9
3	Waste Management	6
4	Cleaner Waste Systems	4
5	Journal of Material Cycles and Waste Management	3
6	Environmental Science and Pollution Research	3
7	Resources, Conservation and Recycling	2
8	Recycling	2
9	Journal of Environmental Management	2
10	Urban Geography	2

Figure 4 builds on the information in Table 1 by showing how publication numbers changed each year across the main journals in the study sample from 2020 to 2025. While Table 1 provides a summary of total publications, the figure tracks how different journals contributed over time. This approach helps to spot which journals were influential in the early years, which maintained a steady output, and which saw increased attention more recently.

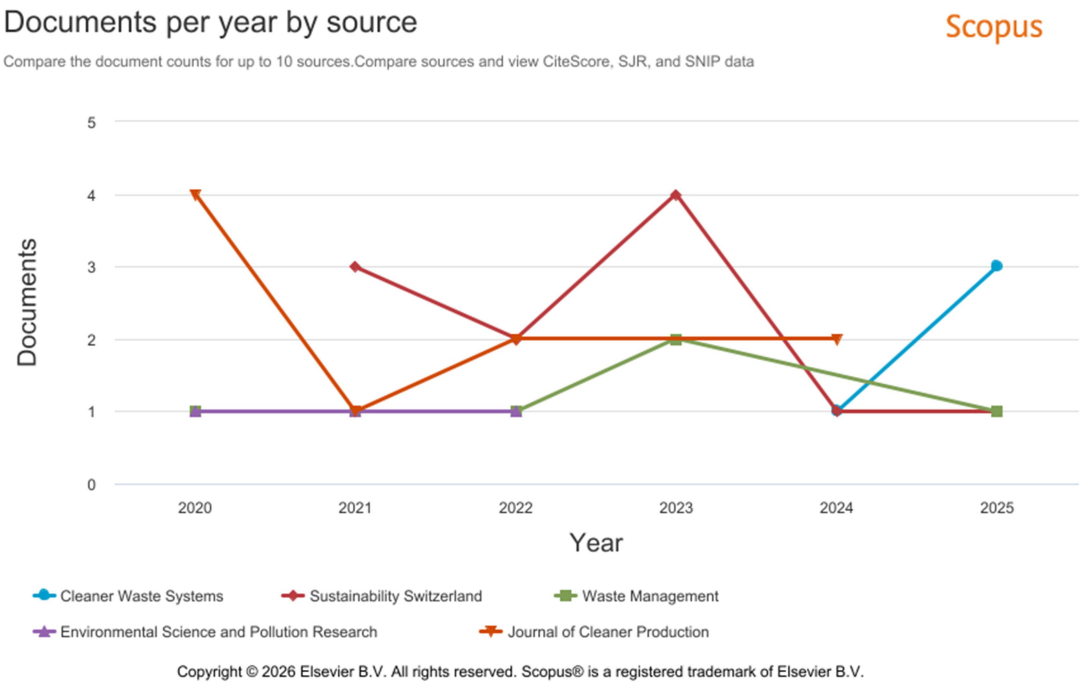

Figure 4. Distribution of publications by main journal sources (2020–2025).
Source: Elaborated by the authors from the final screened Scopus sample.

When considered together, Table 1 and Figure 4 show that most research on e-waste governance is rooted in broader discussions about environmental management, resource use, the circular economy, and changes in waste systems. This trend suggests that governance is usually explored as part of larger system dynamics such as recycling, circular practices, industrial processes, and environmental evaluation rather than as a strictly legal or institutional topic. Although this interdisciplinary approach enriches the analytical landscape, it can make it harder to spot work that focuses specifically on governance as its primary theme.

3. SUBJECT AREA DISTRIBUTION

Figure 5 presents the distribution of publications by subject area within the final screened sample. This classification delineates the primary disciplinary domains of e-waste governance in the literature and highlights the field's interdisciplinary nature.

The subject-area distribution shows a clear predominance of Environmental Science, accounting for 35.6% of the publications, followed by Social Sciences (15.4%), Energy (11.5%), and Engineering (8.2%). Additional relevant areas include Business, Management, and Accounting (7.2%), Computer Science (6.7%), and a residual category labeled as Other (7.7%). Smaller proportions are observed in Decision Sciences, Earth and Planetary Sciences, Economics, Econometrics and Finance, and Medicine, each comprising 1.9% of the sample.

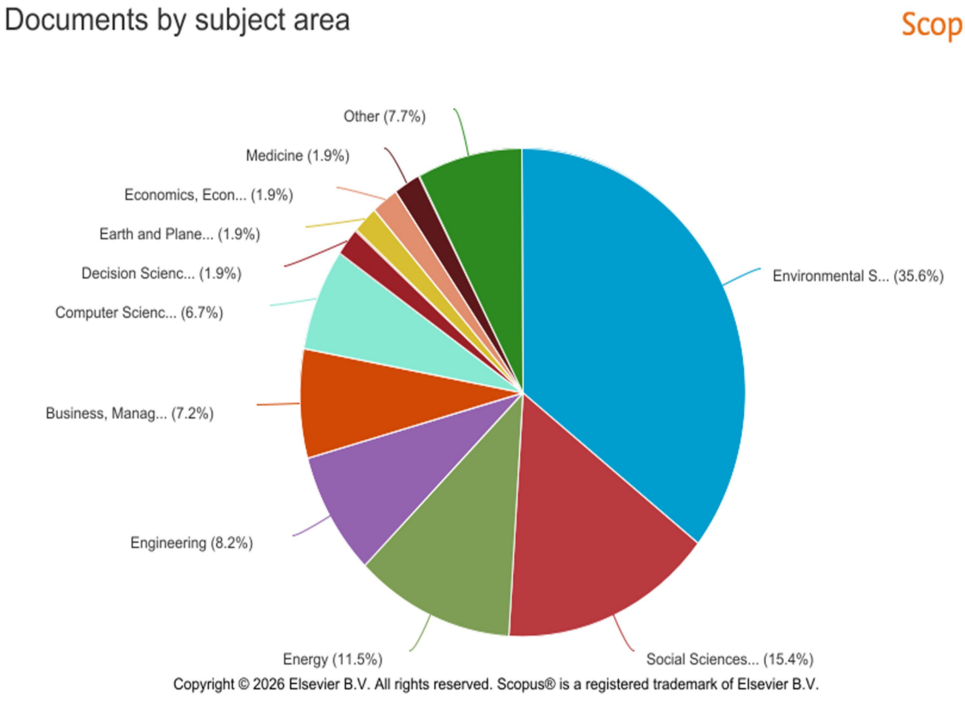

Figure 5. Distribution of publications by subject area in the final screened sample.
Source: Elaborated by the authors from the final screened Scopus sample.

This trend highlights how research on e-waste governance brings together multiple fields. The dominance of Environmental Science shows that much of the work is tied to environmental impacts, waste management, and sustainability topics. The involvement of Social Sciences points to an interest in institutional, behavioral, and policy aspects. Additionally, the presence of Energy and Engineering reveals the importance of technological systems, material recovery, and changes in urban and industrial infrastructure.

Overall, the findings make it clear that e-waste governance is a multi-faceted topic, sitting at the crossroads of environmental management, policy, technology, and sustainability. Because of this wide-ranging disciplinary mix, understanding governance in this area calls for approaches that weave together environmental, social, regulatory, and technical perspectives.

4. COUNTRY DISTRIBUTION

Figure 6 demonstrates that a handful of countries account for most of the published research on e-waste governance. China tops the list with 22 studies, followed by Brazil (16), the UK (9), India (8), and Australia (7). Indonesia contributed 6 publications, while Canada, Ghana, the US, and Vietnam each produced 5.

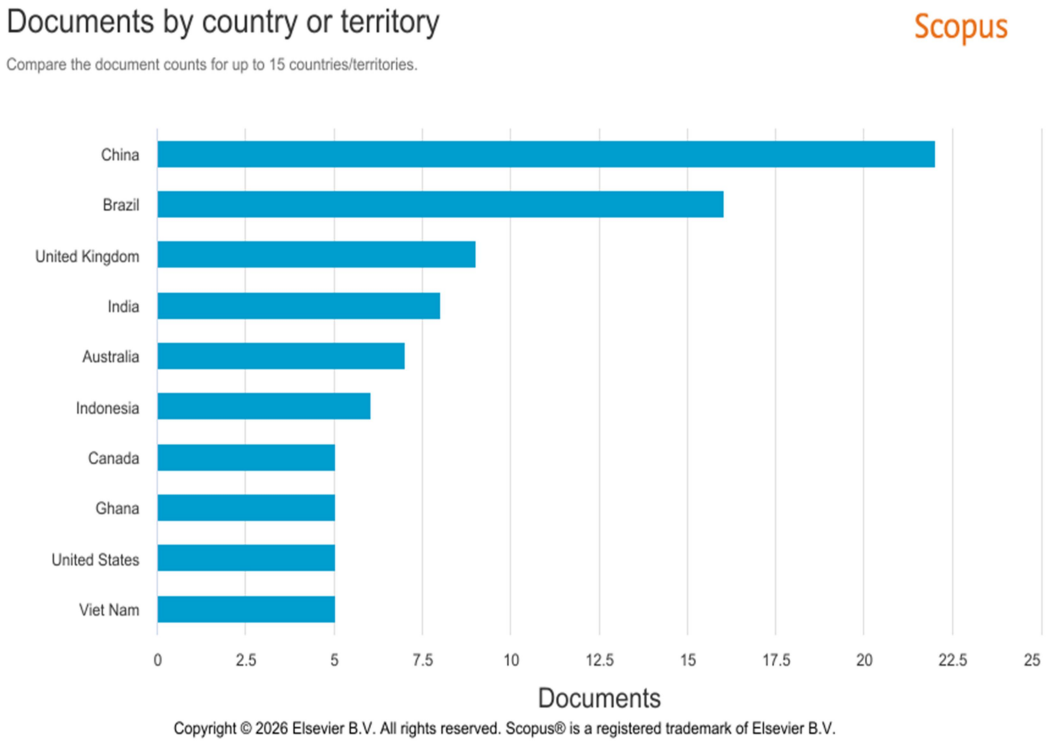

Figure 6. Distribution of publications by country or territory.
Source: Elaborated by the authors from the final screened Scopus sample.

This distribution shows that most research comes from countries dealing with major challenges in electronic consumption, waste generation, recycling, and institutional coordination. China's leading role matches its massive scale in production and waste management. Brazil's strong showing as the second-largest contributor stands out, highlighting the value of focusing on the Brazilian context - especially in large cities like São Paulo - for studies on e-waste governance.

Brazil's important place in the research record indicates that discussions about e-waste governance in the country are gaining international consideration. This significance is further reinforced by recent studies that highlight Brazil's growing role in e-waste governance. As the largest generator of electronic waste in Latin America, the country faces significant challenges in formalizing and scaling its management organizations, particularly in urban regions. At the same time, ongoing efforts to build up reverse logistics and institutional coordination illustrate a transition toward more structured governance models. These dynamics position Brazil as a critical case for understanding how emerging economies address e-waste within the broader context of circular economy and urban sustainability (SCHNEIDER et al., 2024; GIGLIO et al., 2023). This finding supports the center of attention on São Paulo in this study, not only due to the city's size and waste difficulties, but also because Brazil is already a key player in global debates on the subject.

5. MOST CITED PAPERS AND INFLUENTIAL TOPICS

By examining citation counts, it is possible to spot the most influential studies and see which topics have drawn the most scholarly interest. According to Table 2, the top-cited work is "Global E-waste management: Can WEEE make a difference? A review of e-waste trends, legislation, contemporary issues and future challenges," published in Waste Management in 2021, with 428 citations. Next is "E-waste in India at a glance: Current trends, regulations, challenges and management strategies" from the Journal of Cleaner Production (2020), which has 269 citations. In third place is "A Review on Global E-Waste Management: Urban Mining towards a Sustainable Future and Circular Economy," published in Sustainability (Switzerland) in 2022, with 235 citations.

The other highly cited works help map out the main themes in the field. For example, "Electronic waste, an environmental problem exported to developing countries: The good, the bad and the ugly" was cited 199 times, and "Electronic waste collection systems using Internet of Things (IoT): Household electronic waste management in Malaysia" received 156 citations. These findings show that the most impactful papers often focus on major governance

topics, including laws and regulations, management strategies, international and development issues, urban mining, circular economy, and ways to organize collection systems.

It's also worth noting that many of the most frequently cited publications are reviews or syntheses, rather than case-specific studies. This suggests that broad, integrative works have played a key role in connecting e-waste governance to larger discussions about regulation, sustainability, the circular economy, and changes in waste management.

Table 2. Top 5 most cited papers in the final screened sample

Rank	Title	Year	Journal	Citations
1	Global E-waste management: Can WEEE make a difference? A review of e-waste trends, legislation, contemporary issues and future challenges	2021	Waste Management	428
2	E-waste in India at a glance: Current trends, regulations, challenges and management strategies	2020	Journal of Cleaner Production	269
3	A Review on Global E-Waste Management: Urban Mining towards a Sustainable Future and Circular Economy	2022	Sustainability (Switzerland)	235
4	Electronic waste, an environmental problem exported to developing countries: The good, the bad and the ugly	2021	Sustainability (Switzerland)	199
5	Electronic waste collection systems using Internet of Things (IoT): Household electronic waste management in Malaysia	2020	Journal of Cleaner Production	156

6. THEMATIC ANALYSIS

The keyword analysis reveals that most of the published work focuses on practical management issues and circular economy themes, rather than treating governance as its own distinct topic. After adjusting for differences in spelling and capitalization, the most common keywords were: e-waste (56), circular economy (19), urban mining (15), WEEE (15), e-waste management (14), extended producer responsibility (13), and recycling (11).

From this refined list of keywords, six major themes emerged, as outlined in Table 3. The most prominent group centers on waste management and recycling, reflected by keywords like e-waste, e-waste management, WEEE, recycling, waste management, and disposal. The next theme, circular economy and resource recovery, includes circular economy and urban mining. Governance, policy, and regulation form another group, captured in terms such as extended producer responsibility, reverse logistics, policy, public policy, and system dynamics. Other themes identified were environmental assessment and sustainability, social behavior and informal-sector issues, and regional or developmental aspects.

This breakdown is noteworthy from an analytical standpoint. Even though the search was designed to capture governance-related topics, the final collection of studies mostly focuses on practical aspects like collection systems, recycling, resource recovery, and circular approaches. Governance does appear, but more as a supporting framework for wider technical, social, and organizational initiatives than as the main subject of study. This pattern reinforces the idea that research on e-waste governance is highly interdisciplinary and closely linked to the actual workings of waste systems.

Table 3. Keyword-based thematic groups identified in the final screened sample

S. No.	Theme	Representative keywords	What this theme means
1.	Waste management and recycling systems	e-waste (56), e-waste management (14), WEEE (15), recycling (11), waste management (5), disposal (4)	Focus on collection, treatment, recycling, and disposal systems for electronic waste
2.	Circular economy and resource recovery	circular economy (19), urban mining (15), reuse (2), industrial ecology (2)	Focus on material recovery, value retention, and circular use of resources

3.	Governance, policy, and regulation	extended producer responsibility (13), reverse logistics (6), policy (3), public policy (2), system dynamics (2)	Focus on regulatory instruments, institutional coordination, and responsibility-sharing mechanisms
4.	Environmental assessment and sustainability	sustainability (8), heavy metals (5), environmental impact (4), life cycle assessment (2)	Focus on environmental risks, impacts, and sustainability outcomes
5.	Social behavior and informal-sector dynamics	informal sector (5), knowledge (4), willingness to pay (3), awareness (2), consumer behavior (2)	Focus on behavior, participation, and the role of informal recovery systems
6.	Regional and development dimensions	developing countries (4), Bangladesh (2), India (2), Brazil (2), urban planning (2)	Focus on territorial concentration, urban context, and governance challenges in developing regions

IMPLICATIONS FOR THE CITY OF SÃO PAULO

The center of attention on the city of São Paulo is accounts by its role as the largest urban center in Brazil and one of the most economically and demographically significant cities in Latin America. The city focusses a high level of electronic consumption, ensuring in substantial e-waste generation and making it a critical point of attention for examining urban waste governance. Moreover, São Paulo introduces a complex institutional landscape in which public authorities, private actors, and informal recyclers interact within often fragmented governance structures. This complexity provides a valuable setting to analyze the challenges and opportunities associated with applying reverse logistics and circular economy strategies at the urban scale. Recent studies also give attention that São Paulo has been a key site for the development and assessment of e-waste recycling networks and reverse logistics systems, reinforcing its relevance as an empirical case (GIGLIO et al., 2023; OLIVEIRA NETO et al., 2023). Therefore, centering on the city enables a more detailed and context-specific understanding of e-waste governance, gives rise to insights that are applicable to other large urban centers facing similar sustainability challenges.

These results offer important insights for addressing e-waste governance in the city of São Paulo. The strong focus on management, recycling, and reverse logistics points to the fact that effective governance relies not just on regulations, but also on the ability to put plans into action, coordinate operations, and connect different institutions. Additionally, the significance of terms related to the informal sector, public awareness, and community involvement shows that successful governance should move past legal structures and include efforts to shape social behavior, support collection practices, and bring informal recyclers into the system.

Furthermore, the emphasis on circular economy and urban mining indicates that e-waste management in big cities shouldn't be seen merely as a matter of disposal. Instead, it should fit within a wider strategy for urban sustainability, one that brings together resource recovery, social inclusion, environmental safeguards, and better reverse logistics. In São Paulo's case, this means closer collaboration among local governments, manufacturers, vendors, recyclers, and the wider community to build a system that is both environmentally effective and institutionally strong.

CONCLUSION

This study mapped out how research on e-waste governance developed from 2020 to 2025, drawing on a carefully selected set of 101 publications from Scopus. The analysis shows that interest in this area is on the rise, with the topic gaining ground in larger conversations about sustainability, the circular economy, reverse logistics, and changes in waste management. Even though growth from year to year wasn't perfectly steady, the overall number of studies grew, picking up pace in the later years.

The review of publication data revealed that most research appears in journals dedicated to sustainability, environmental management, and waste systems, with titles like Sustainability (Switzerland), Journal of Cleaner Production, and Waste Management leading the way. The most cited works tend to be broad reviews or syntheses that tackle big questions such as e-waste laws, management approaches, urban mining, international issues, and collection methods. This points to a field influenced by both in-depth case studies and comprehensive analyses linking e-waste governance to broader environmental and sustainability discussions.

Looking at the keywords, it's clear that most studies focus on waste management, recycling, and circular economy topics rather than treating governance as a separate field of study. While ideas like extended producer responsibility,

policies, and reverse logistics are still significant, they usually show up as part of larger debates about how systems work, how institutions cooperate, and what outcomes are achieved. This pattern highlights how research in this area cuts across different disciplines and is closely tied to real-world management issues.

The breakdown by country adds another layer to the story. China comes out on top in terms of research output, but Brazil's strong showing as the second most active country makes the Brazilian context especially relevant. This is particularly meaningful when considering São Paulo, as it demonstrates that the city's governance challenges are central to emerging international debates rather than being on the sidelines.

In practical terms, the results underline the importance of better coordination between institutions, stronger reverse logistics, and closer links between social and operational aspects of e-waste governance. For São Paulo, this means going beyond just having rules on paper, it requires building effective systems that connect manufacturers, government agencies, recyclers, the public, and informal workers. Achieving sustainable e-waste management in big cities depends not just on policy, but on the ability to bring together environmental aims, day-to-day operations, and inclusive approaches to urban management.

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