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Waste Management: A Bibliometric Review and Future Research Agenda

Dr. Richa Kalpesh Saxena[1], Sonia Rajpurohit[2], Simran Pinglay[3], Soham Chawla[4], Soumya Kothari[5]

[1]Assistant Professor, Marketing & Operations, NMIMS, Anil Surendra Modi School of Commerce, Mumbai Campus, India

[2,3,4,5]BBA, NMIMS, Anil Surendra Modi School of Commerce, Mumbai Campus, India

Abstract

Waste management is an increasingly complex planning problem involving collection, transportation, segregation, treatment, recycling, resource recovery and final disposal. Operations Research (OR) can support these activities through optimisation, simulation, forecasting and decision-support models, but research is distributed across environmental science, engineering, energy, sustainability and management. This study examines the development and thematic direction of waste-management research with particular attention to optimisation and OR-related decision-making. A bibliometric dataset retrieved from Scopus was screened using stated year, document-type, language and source criteria. The final dataset comprised 1,022 journal records for the 2014–2026 period. Biblioshiny outputs and an annual publication series available for 2014–2025 were interpreted alongside a narrative synthesis of relevant literature. The dashboard reported 441 sources, 3,663 authors, annual growth of 21.19%, an average document age of 3.21 years, 25.52 citations per document and international co-authorship of 34.05%. Annual production increased from 24 papers in 2014 to 201 in 2025, although the dashboard period and annual series do not end in the same year. Prominent themes included municipal solid waste, recycling, sustainable development, optimisation, decision-making, life-cycle assessment, energy recovery and the circular economy. The synthesis identifies a need for integrated models that connect waste prevention, household behaviour, collection routing, treatment, material markets, emissions, equity and uncertainty. Because metadata completeness was limited, the results should be interpreted as a descriptive mapping rather than a complete citation-network analysis.

Keywords: operations research; waste management; bibliometric analysis; optimisation; circular economy; sustainability; decision support

1. Introduction

Waste management includes the collection, segregation, transportation, treatment and disposal of waste, as well as the recovery of materials and energy. Population growth, urbanisation, consumption patterns and inadequate segregation place pressure on infrastructure and can contribute to pollution, greenhouse-gas emissions and landfill demand. Effective waste systems therefore need to balance service reliability, cost, public health, environmental protection and resource recovery (Kaza et al., 2018; Ferronato & Torretta, 2019). The circular-economy perspective further encourages systems to retain materials in use through prevention, reuse, recycling and recovery rather than relying predominantly on disposal (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

Operations Research is concerned with using mathematical modelling, statistics, optimisation and analytical methods to support decisions under constraints. In waste management, these methods can help determine collection routes, locate treatment facilities, allocate waste among technologies, plan capacity and evaluate trade-offs between costs and environmental outcomes. The field spans strategic decisions, such as facility location and capacity, and tactical or operational decisions, such as vehicle routing and collection schedules (Ghiani et al., 2014; Beliën et al., 2014). Classical models can, however, simplify real-world conditions by assuming fixed waste quantities, stable material composition, a single decision-maker or a single objective.

Recent research increasingly connects optimisation with machine learning, geographic information systems, life-cycle assessment, circular-economy principles and digital monitoring. These developments broaden the range of decisions that can be supported, but they also introduce concerns about data quality, interpretability, technology cost and implementation capacity. A review that maps the field and identifies gaps can help researchers and decision-makers understand where evidence is concentrated and where integrated approaches are still needed.

1.1 Research objectives

1. To identify broad publication and thematic trends in waste-management research.
2. To synthesise findings on the methods and applications relevant to waste-management optimisation and decision-making.
3. To identify research gaps and propose a future research agenda for Operations Research in waste management.

2. Literature Review

2.1 From disposal to circular and sustainable systems

The literature increasingly frames waste management as a system of material flows, resource recovery and governance rather than as a disposal problem alone. Zaman (2026) discusses the relationship between industrial ecology, circular economy and zero-waste approaches. Omokaro et al. (2026) identify institutional fragmentation, weak enforcement and data scarcity as barriers to sustainable waste management in Nigeria, while noting opportunities in decentralised organics management, inclusive recycling and selected waste-to-energy applications. Reviews of plastic waste similarly emphasise that contamination, heterogeneous material streams, market conditions and regulation limit the effectiveness of single-pathway solutions (Alex & Devipriya, 2026; Ali et al., 2026). These studies imply that optimisation models should incorporate institutional and market conditions alongside technical constraints.

2.2 Optimisation, facility location and collection logistics

Collection routing and facility location are established Operations Research applications in solid waste management. Beliën et al. (2014) review municipal collection and management problems, while Ghiani et al. (2014) survey strategic and tactical OR issues in solid-waste systems. Location decisions are often combined with geographic information systems and multi-criteria decision analysis. Alhassan et al. (2026) review GIS–MCDA approaches for waste-to-energy facility siting and identify the need to better integrate spatial planning with other decision methods. These approaches can support cost and distance reduction, but they need to account for environmental exposure, local acceptance, transport conditions and uneven distribution of service burdens.

2.3 Digital technologies, forecasting and data-driven optimisation

Digital tools are increasingly applied to waste generation forecasting, sorting, monitoring and operational planning. Handoyo and Sueb (2026) identify artificial intelligence and the Internet of Things as frequently discussed technologies in circular-economy chains. Golafshani et al. (2026) examine data-driven modelling of municipal solid-waste generation, while Loni et al. (2026) discuss integrated sewage-sludge treatment, resource recovery and AI-enabled optimisation. Gegana et al. (2026) review explainable ensemble machine learning for wastewater-treatment modelling and highlight interpretability as a concern. These studies point towards a useful division of labour: predictive models estimate future waste volumes or composition, while OR models use those forecasts to select routes, capacities, treatment allocations and schedules. Such systems should be evaluated against simpler baselines and should account for the costs of data collection, maintenance and implementation.

2.4 Waste-to-energy and environmental-economic trade-offs

Waste-to-energy technology selection is a multi-criteria decision problem because economic performance, emissions, energy output, feedstock composition and local infrastructure can point towards different options. Saif and Zoroufchi Benis (2026) examine technology selection and capacity planning across a multi-facility system, while Golkar et al.

(2026) compare waste-to-energy options for plastic waste. Nsekela et al. (2026) review biogas optimisation using municipal solid waste in Sub-Saharan Africa and identify financing, technical capacity and policy support as implementation constraints. Life-cycle assessment can help compare environmental effects, but results depend on assumptions about displaced energy, substituted materials and system boundaries (Laurent et al., 2014). OR models should therefore avoid treating environmental impacts as fixed or secondary when these assumptions materially affect the preferred solution.

2.5 Research gap

The reviewed literature shows substantial methodological breadth, but many studies still focus on individual stages or objectives. Collection routing, facility siting, treatment selection, recycling allocation and recovered-material markets are often analysed separately. Moreover, models may treat waste quantities as fixed inputs even though policy and household behaviour influence generation and separation. There is a need for integrated and uncertainty-aware models that link operational efficiency with emissions, resource recovery, service quality, worker safety and equity. This study responds by combining descriptive bibliometric indicators with a thematic synthesis and a structured future research agenda.

3. Research Methodology

3.1 Research design

The study uses a bibliometric review supported by narrative synthesis. Bibliometric analysis is useful for mapping publication growth, sources, authors, keywords and relationships across a large body of literature; a narrative synthesis helps interpret these patterns in relation to Operations Research applications. The design follows the general logic of systematic screening but should not be interpreted as a full systematic review with independent duplicate screening or formal quality appraisal, as those procedures were not documented in the supplied materials.

3.2 Data source and search

Scopus was used as the primary bibliographic source. The search was conducted on 16 September 2026 using the terms “Waste Management Optimization” and “Policy” across title, abstract and keyword fields, as recorded in the project methodology. The initial search returned 1,745 records covering 1971–2027. Records published before 2014 were excluded, leaving 1,418 records for the selected period. No subject areas were excluded in order to retain the interdisciplinary character of the field.

3.3 Screening and inclusion criteria

Screening proceeded by publication year, document type, language and source type. Restricting the document types to articles and reviews reduced the set to 1,074 records. Restricting the language to English produced 1,027 records. Finally, only journal publications were retained, resulting in a final dataset of 1,022 records. The supplied PRISMA diagram is reproduced as Figure 1. The screening counts are reported as provided by the project files.

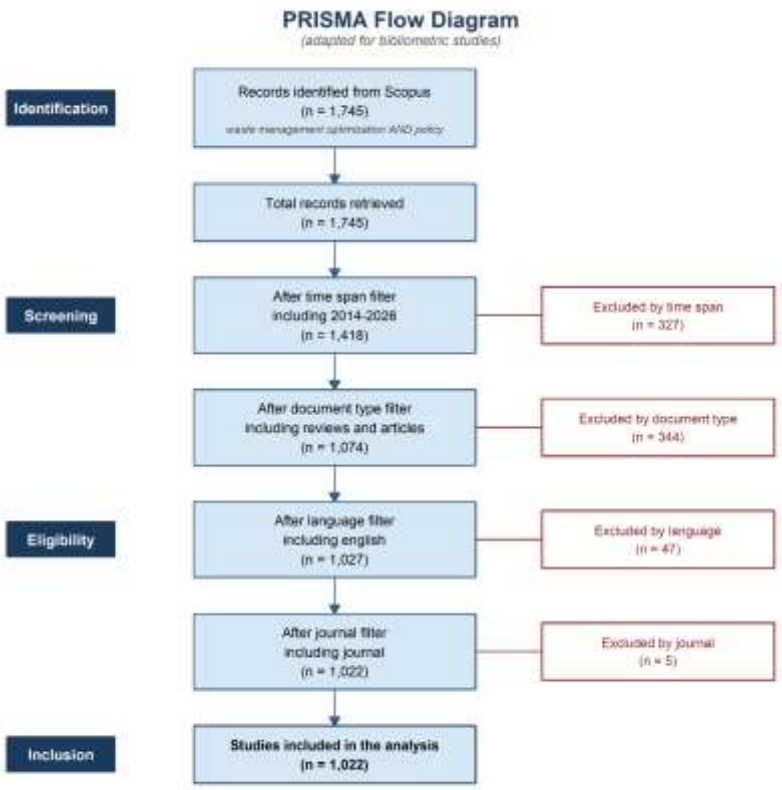


Figure 1. PRISMA-style flow diagram for record screening (reproduced from the supplied methodology file).

3.4 Analytical tools and procedure

Microsoft Excel was used to organise the annual publication series. R and RStudio were used to access Biblioshiny for descriptive bibliometric analysis. The supplied outputs included the main-information dashboard, annual scientific production, source production over time, most relevant sources, geographical distribution and a country–author–keyword Sankey diagram. VOSviewer was also used for a keyword co-occurrence map in the literature-review work. Because the export did not contain complete keyword, abstract and citation fields, detailed co-citation and keyword-network results were treated cautiously. The analysis therefore relies primarily on descriptive indicators, visual interpretation and title-based/thematic reading rather than claiming complete network coverage.

3.5 Data limitations and consistency decisions

The dashboard reports 1,022 documents for 2014–2026, whereas the supplied annual-production series contains values only through 2025. These are reported separately rather than treated as identical time series. The 2026 data may be incomplete because the search was conducted during that year. The dashboard also reports zero references; this is treated as a metadata/export limitation, not evidence that the source articles have no references. The introductory draft contained earlier counts and a claim that no 2024 records were present; those statements conflict with the final analysis report and annual-production table, so the final report's 1,022-record dataset and its 2014–2025 annual series are used here.

4. Results and Data Analysis

4.1 Dataset profile

The Biblioshiny main-information dashboard reports 1,022 documents published through 441 sources and involving 3,663 authors. The annual growth rate is 21.19%, the average document age is 3.21 years, and the average citation count is 25.52 per document. The dashboard reports 38 authors of single-authored documents, an international co-authorship rate

of 34.05%, an average of 4.46 co-authors per document and 9,699 author keywords. These values suggest a recent, collaborative and interdisciplinary research field. Because metadata completeness varies, the indicators should be read as descriptive characteristics of the supplied export.

4.2 Annual scientific production

The annual series increased from 24 publications in 2014 to 201 publications in 2025. Growth was gradual through 2019, accelerated in 2020, and expanded further in 2022 and 2024–2025. Production rose from 77 papers in 2023 to 135 in 2024 and 201 in 2025. The increase from 2023 to 2024 was approximately 75.3%, followed by a further increase of approximately 48.9% from 2024 to 2025. The series shows substantial growth in scholarly attention, although changes in search coverage and the partial 2026 period should be considered when interpreting the trend.

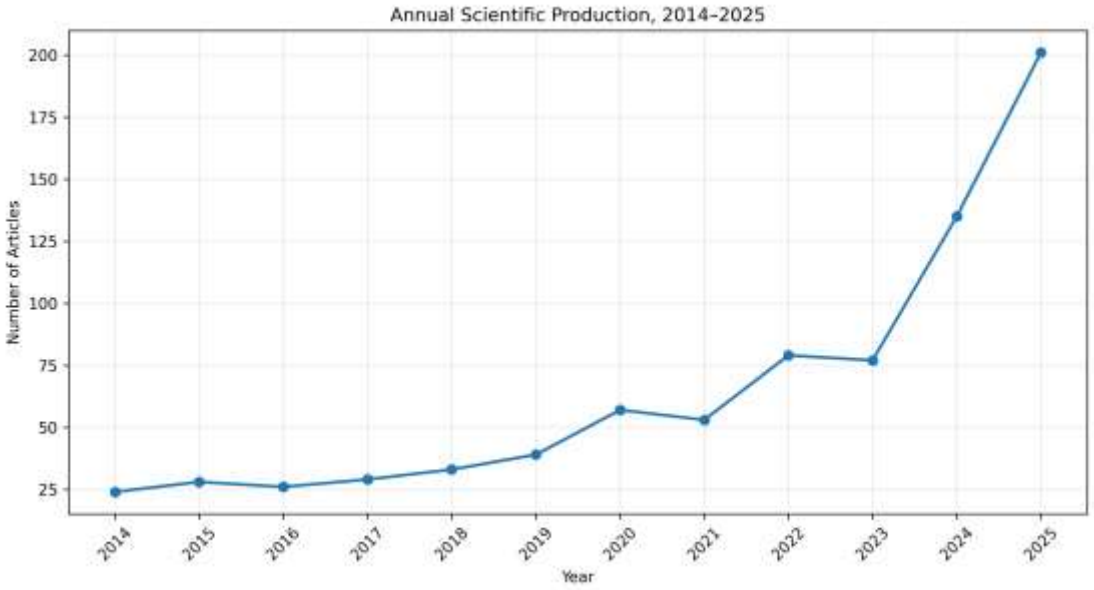


Figure 2. Annual scientific production in the supplied dataset, 2014–2025.

Year	Articles	Change from previous year
2014	24	—
2015	28	+4 (16.7%)
2016	26	−2 (−7.1%)
2017	29	+3 (11.5%)
2018	33	+4 (13.8%)
2019	39	+6 (18.2%)
2020	57	+18 (46.2%)
2021	53	−4 (−7.0%)
2022	79	+26 (49.1%)
2023	77	−2 (−2.5%)
2024	135	+58 (75.3%)
2025	201	+66 (48.9%)

Table 1. Annual publication production based on the supplied Excel dataset.

4.3 Publication sources

Figures 3 and 4 show that publication activity is distributed across journals covering cleaner production, sustainability, waste management, environmental management, resource conservation, energy and pollution. The cumulative source graph reports 57 documents for the Journal of Cleaner Production, 53 for Sustainability (Switzerland), 43 for Waste Management, 38 for Journal of Environmental Management and 34 for Resources, Conservation and Recycling. The source-ranking output also includes Science of the Total Environment, Energies, Energy, Environmental Science and Technology, and Environmental Science and Pollution Research. The distribution supports the interdisciplinary character of waste-management research.

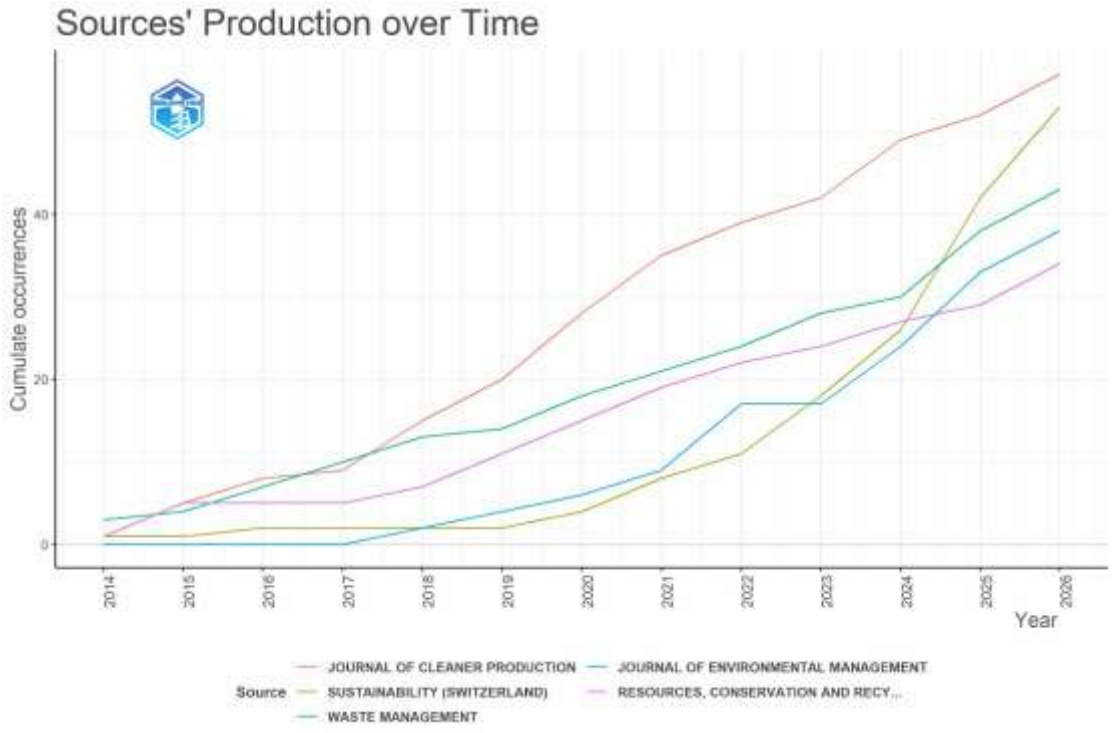


Figure 3. Cumulative source production for selected publication outlets.

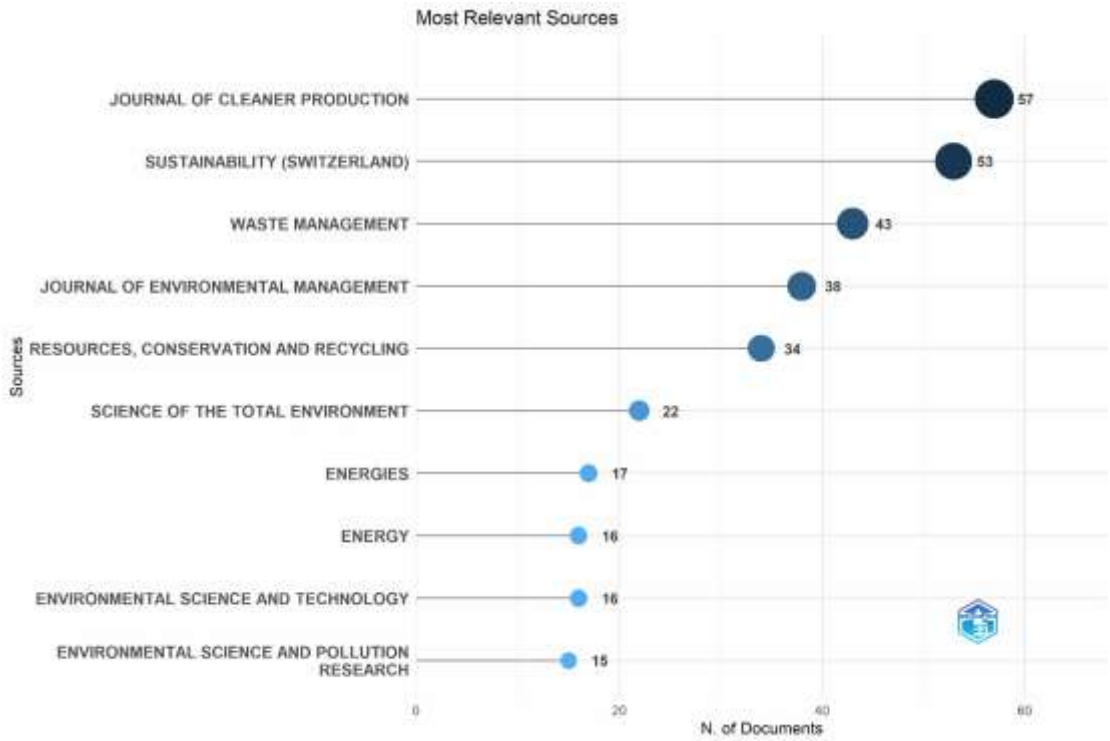


Figure 4. Most relevant publication sources in the supplied dataset.

4.4 Geographical distribution and collaboration

Figure 5 identifies China as the most prominent contributor in the supplied geographical visualisation, with substantial activity also visible in the United States, India, Australia, Canada, the United Kingdom, South Korea and several European countries. The dashboard's international co-authorship rate of 34.05% indicates that more than one-third of documents involve cross-country collaboration. The average of 4.46 co-authors per document is consistent with a collaborative field that brings together environmental science, engineering, economics, policy, sustainability and decision sciences. These observations are based on the supplied visual outputs; country-level rankings should be verified against complete metadata before being treated as exact publication counts.

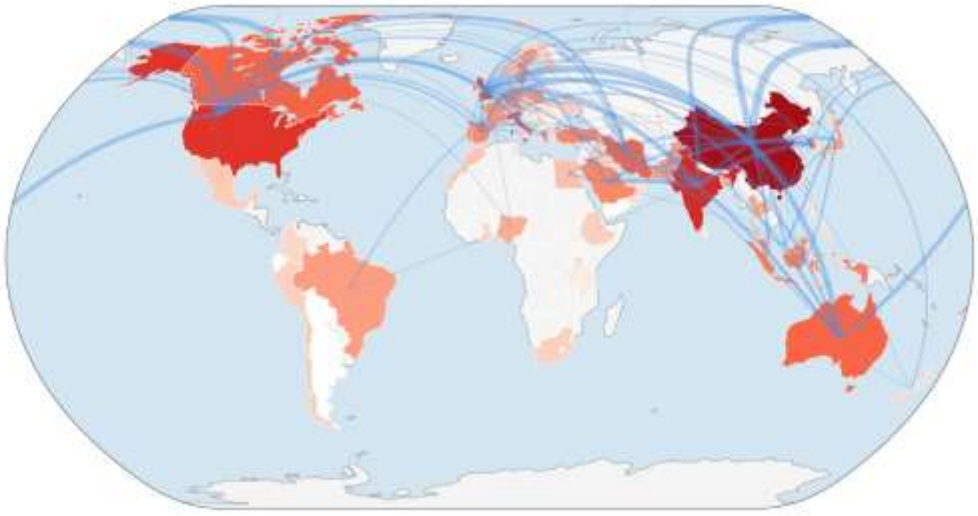


Figure 5. Geographical distribution and international collaboration represented in the supplied output.

4.5 Keyword and thematic relationships

Figure 6, the country–author–keyword Sankey diagram, links geographical contributions, researchers and research themes. Prominent terms include waste management, optimisation, sustainable development, recycling, municipal solid waste and waste disposal. Other visible themes include carbon, life-cycle analysis, environmental management, economics, environmental impact, decision-making, process optimisation, energy policy, circular economy and sustainability. The prominence of optimisation and decision-making supports the relevance of an Operations Research perspective, while the associated environmental and economic terms indicate that decisions are increasingly framed as multi-objective problems.

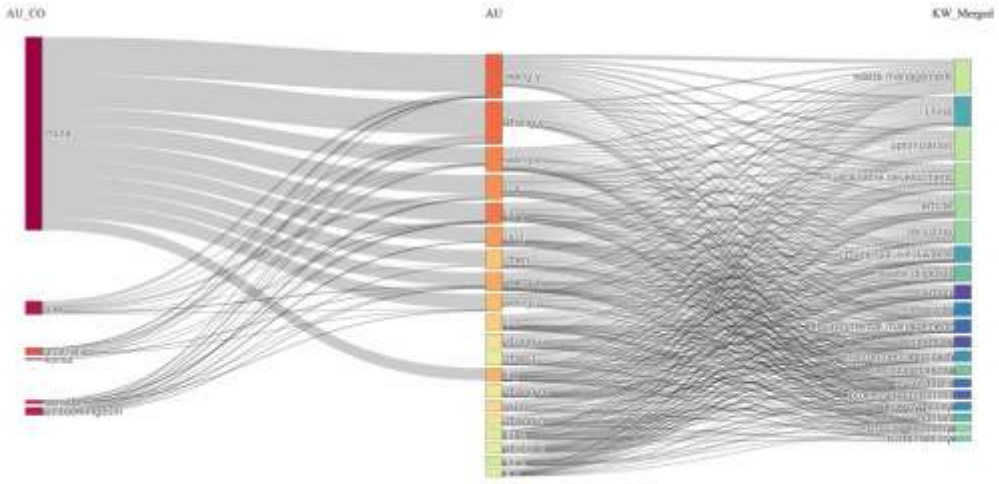


Figure 6. Country–author–keyword relationships in the supplied bibliometric output.

4.6 Integrated interpretation

Taken together, the results suggest that waste-management research is expanding in volume, increasingly collaborative and broad in thematic scope. Optimisation sits alongside circular economy, resource recovery, emissions, life-cycle thinking and energy policy. This pattern is important for OR because waste systems involve interdependent decisions across collection, sorting, treatment, disposal and recovered-material markets. A route that minimises distance may not minimise emissions or improve recycling quality; a treatment option that maximises energy recovery may not be best under carbon, cost or feedstock constraints. The literature therefore supports models that make trade-offs explicit and evaluate multiple outcomes.

5. Discussion

The findings are consistent with the view that waste management is no longer adequately represented as a sequence of isolated disposal activities. The source distribution and keyword relationships point to a field in which engineering, environmental accounting, energy systems, public policy and data-driven decision-making increasingly intersect. For OR, this creates an opportunity to move from single-stage optimisation towards integrated decision models.

First, forecasting and optimisation should be connected. Machine-learning models can estimate waste quantities or composition, but predictions become operationally useful only when translated into decisions about vehicle capacity, collection frequency, facility allocation and treatment selection. Second, environmental impacts should be incorporated transparently. Life-cycle assessment can inform emissions and resource-recovery parameters, while sensitivity analysis can test whether a preferred solution depends on uncertain assumptions. Third, model design should reflect institutional and social realities. Municipal authorities, private operators, producers, informal collectors and households can have different objectives and constraints.

The dataset also illustrates why bibliometric findings need cautious interpretation. Publication counts and keyword maps describe the supplied export, not the whole universe of waste-management research. Missing reference fields constrain citation analysis, and the 2026 period is incomplete. The broad search may also include papers on waste management that do not make substantial use of OR. Future bibliometric work should therefore use a transparent search string that combines waste-management terms with explicit OR methods, document each screening stage and validate the export before conducting advanced network analysis.

6. Future Research Agenda

The analysis points to eight priorities for future work. These directions are intended to connect operational decisions with behavioural, environmental, economic and institutional conditions.

Research direction	Proposed focus
1. Waste prevention as a decision variable	Model waste generation as responsive to policy, packaging design, deposit schemes and extended producer responsibility; link forecasts to robust optimisation.
2. Household behaviour and routing	Jointly optimise collection routes and incentives such as bin design, collection frequency, pay-as-you-throw pricing and source separation.
3. Environmental accounting under uncertainty	Test uncertain emissions factors and substitution assumptions; report Pareto trade-offs and consider rebound effects.
4. Multiple actors and equity	Represent municipalities, producers, private operators, informal collectors and citizens; include service fairness, worker safety and workload.
5. Digital technology evaluation	Compare smart bins, sensors, AI sorting and tracking with simpler baselines; include capital, energy, maintenance and data costs.
6. End-to-end system models	Integrate collection, sorting, treatment and recovered-material markets instead of optimising each stage independently.
7. Context-specific models	Develop models for emerging markets, dense settlements and informal recovery systems, accounting for funding and infrastructure constraints.
8. Better data and reporting	Publish open benchmark instances and anonymised operational data; standardise metadata, search terms, country counts and complete-year reporting.

Table 2. Summary of proposed future research directions.

6.1 Waste generation and prevention as decision outcomes

Many models treat waste quantity and composition as fixed inputs. Future work should model these outcomes as responsive to policy, consumer behaviour and product design. Forecasts can be incorporated into stochastic or distributionally robust optimisation, with decisions spanning prevention, reuse, recycling, recovery and disposal (Kaza et al., 2018; Geissdoerfer et al., 2017; Kirchherr et al., 2017).

6.2 Integrating household behaviour with collection routing

Collection models should connect route design with participation, source separation, bin design and collection frequency. Dynamic routing based on actual fill levels may improve efficiency, but benefits should be compared with the costs of sensors and data systems (Beliën et al., 2014; Fullerton & Kinnaman, 1996).

6.3 Credible environmental accounting

Future models should test the sensitivity of decisions to emissions factors, energy substitution and life-cycle boundaries. Multi-objective formulations and Pareto-front reporting can make environmental and economic trade-offs more transparent (Laurent et al., 2014).

6.4 Strategic actors, citizens and equity

Models should recognise multiple decision-makers and consider how facility siting and service quality affect different communities. Behavioural evidence should inform assumptions, and worker safety, workload and equitable service can be represented as constraints or objectives.

6.5 Digital technologies judged against simple baselines

Digital tools should be evaluated by their incremental benefit relative to existing practice. Cost, energy use, maintenance, interoperability and data governance should be included alongside technical performance (Esmaeilian et al., 2018).

6.6 End-to-end collection, sorting, treatment and markets

Integrated models should connect household contamination, sorting costs, treatment capacity and market prices for recovered materials. Comparing integrated and stage-by-stage optimisation can show whether local improvements create system-wide benefits.

6.7 Context-specific models for emerging markets and informal actors

Research should account for uncollected waste, open dumping, irregular settlements, limited financing and the role of informal collectors. The informal sector should be represented as a stakeholder or partner where appropriate, rather than treated only as an external parameter (Ferronato & Torretta, 2019; Wilson et al., 2006).

6.8 Data, methods and reporting

Future studies should use reproducible search strings, validate records, remove irrelevant indexing keywords, complete reference fields and report all screening decisions. A focused OR search would help distinguish general waste-management publications from studies that directly apply optimisation or decision-science methods (Aria & Cuccurullo, 2017).

7. Implications

7.1 Implications for managers

Managers can use optimisation, geographic information systems, simulation, forecasting and decision-support methods to improve collection routes, facility locations, resource allocation and treatment planning. Decisions should be evaluated not only by cost but also by emissions, resource recovery, service quality, reliability and the consequences for workers and communities.

7.2 Implications for society

Better-planned waste systems can contribute to cleaner communities, more efficient resource use and reduced environmental impacts. Circular-economy approaches can treat some waste streams as sources of materials and energy, provided recovery choices are assessed against environmental and social outcomes rather than assumed to be beneficial in every context.

7.3 Implications for policymakers

Policy frameworks should support data-driven, sustainable and context-specific planning. Population density, waste composition, infrastructure, local regulations and market conditions vary, so universal models may not transfer well across jurisdictions. Comparative studies and models that explicitly represent environmental, operational and social outcomes can strengthen policy design.

8. Limitations

4. The bibliometric export did not contain complete reference, keyword and abstract information. This limited the reliability of detailed co-citation and keyword-network analyses.
5. The dashboard covers 2014–2026, while the annual production series provided for this study ends in 2025; the 2026 data are therefore not a complete year.
6. The search and screening counts are taken from the supplied project files. Independent duplicate screening, inter-rater agreement and formal study-quality appraisal were not documented.
7. Terminology varies across the literature, making it difficult to consolidate related themes consistently.
8. The dataset covers a broad waste-management field and may include records that do not directly apply Operations Research methods. A more targeted OR-specific search would improve precision.
9. The results depend on the supplied Scopus export and analysis outputs; they should not be interpreted as a complete census of all global waste-management research.

9. Conclusion

This study mapped waste-management research using a Scopus-derived dataset of 1,022 journal records for 2014–2026 and a supplied annual production series extending from 2014 to 2025. The descriptive results show substantial growth in publication activity, a broad range of publication outlets and meaningful international collaboration. The themes most relevant to Operations Research include optimisation, decision-making, municipal solid waste, recycling, life-cycle assessment, energy recovery and circular economy.

The review suggests that the next stage of research should connect prediction with optimisation and integrate collection, sorting, treatment and material recovery decisions. Models should account for uncertainty, environmental impacts, household behaviour, multiple stakeholders and equity. At the same time, the limitations of the bibliometric export mean that the findings should be treated as a descriptive map rather than definitive evidence of all research activity. More complete metadata, transparent search strategies and reproducible benchmarks would support stronger future analysis. Overall, integrated and context-sensitive OR models offer a promising basis for improving the efficiency, resilience and sustainability of waste-management systems.

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