



Decision-Making Models for Circular Economy Implementation in Waste Management

Amirreza. Soleimannezhad Aliabadi¹, Mohammad Ali. Niroomand^{2*}, Fereshteh. Khalili Peykani³

¹ Faculty of Agriculture, Shiraz University, Shiraz, Iran Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Mashhad, Iran

² Faculty of Engineering, Shahrood University, Shahrood, Iran

³ Economics and Management Department, Islamic Azad University Science and Research branch, Tehran, Iran

* Corresponding author email address: am.soleymannejadaliabadi@alumni.um.ac.ir

Article Info

Article type:

Original Research

How to cite this article:

Soleimannezhad Aliabadi, A., Niroomand, M. A., & Khalili Peykani, F. (2026). Decision-Making Models for Circular Economy Implementation in Waste Management. *Journal of Resource Management and Decision Engineering*, 5(6), 1-14.

<https://doi.org/10.61838/kman.jrmd.322>



© 2026 the authors. Published by KMAN Publication Inc. (KMANPUB). This is an open access article under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

ABSTRACT

The transition from linear waste management systems to circular economy (CE) models creates the demand for advanced decision-making frameworks designed to tackle environmental, economic, social, and technical issues. This research presents the systematic literature review on decision-making models for the application of circular economy in waste management. The review processes the PRISMA framework and studies obtained from Scopus, Web of Science, and Google Scholar. Search terms included circular economy, waste management, sustainability, and MCDM, and were applied to articles from 2020 to 2026. Following the application of predefined criteria and title, abstract, and full text screenings, nine articles were chosen for qualitative synthesis. Studies were found to be moving away from classical MCDM methods, like AHP and TOPSIS, toward fuzzy-set and hybrid complex environmental system decision-making frameworks. The analyzed studies examined a variety of waste types, including medical, electronic, construction, food, organic, and plastic waste. Among these, construction and demolition waste was the most researched category. The most recent studies found that environmental factors, particularly regarding pollution, public health, and sustainability, were increasingly found among the most prominent factors of the decision-making process. Furthermore, the analysis demonstrated that hybrid and uncertainty-oriented models provide more robust and reliable support for circular economy implementation in waste management systems.

Keywords: waste management, circular economy, decision-making, AHP, TOPSIS

1. Introduction

The rapid growth of urbanization, industrialization, and changing consumption patterns has significantly intensified global waste generation in both quantity and complexity. Recent evidence demonstrates that urban systems worldwide are experiencing continuous scaling of waste production due to economic expansion, population growth, and increased material consumption (Lu et al., 2024; Voukkali et al., 2024). Traditional linear economic systems based on the “take–make–dispose” model have become increasingly unsustainable because they rely heavily on raw material extraction while generating substantial environmental pollution and resource depletion (Attri et al., 2025). Such systems contribute to greenhouse gas emissions, contamination of water and soil resources, biodiversity degradation, and growing pressure on landfill infrastructures. Consequently, policymakers, researchers, and industries are increasingly seeking sustainable approaches capable of reducing environmental burdens while maintaining economic productivity and social welfare.

Within this context, the circular economy (CE) has emerged as one of the most influential paradigms for achieving sustainability and resource efficiency. Unlike linear systems, the circular economy promotes regenerative and restorative processes through recycling, reuse, remanufacturing, waste valorization, and closed-loop material cycles (Liao, 2022). The fundamental principle of CE is the transformation of waste from an environmental liability into a valuable economic resource that can be reintegrated into production and consumption systems. Recent reviews indicate that the circular economy has become a dominant framework in sustainability discourse because it simultaneously addresses environmental protection, economic resilience, and long-term resource security (Hossain et al., 2024). The adoption of CE principles has therefore become increasingly important in waste management systems, where inefficient disposal practices continue to threaten ecological sustainability and public health.

The transition toward circular economy-based waste management systems is particularly critical because waste streams are becoming more heterogeneous, hazardous, and technologically complex. Construction and demolition waste, medical waste, electronic waste, food waste, and organic waste each present unique environmental and operational challenges that require specialized management strategies (Cook et al., 2022). For instance, medical and

electronic wastes contain hazardous materials that can create significant risks for human health and ecosystems if not managed properly. Similarly, construction and demolition waste contributes substantially to landfill accumulation and resource inefficiency, while food waste generates considerable greenhouse gas emissions and eutrophication impacts when disposed of through conventional landfilling methods (Brenes-Peralta et al., 2020). These challenges highlight the necessity of advanced waste management systems capable of balancing environmental sustainability, economic feasibility, and technical practicality.

As circular economy principles become more integrated into waste management practices, decision-making complexity has increased substantially. Waste management decisions involve multiple stakeholders, competing sustainability criteria, uncertain environmental impacts, regulatory constraints, and technological interdependencies. Consequently, selecting the most suitable waste treatment or resource recovery strategy requires comprehensive evaluation frameworks that can simultaneously address economic, environmental, technical, and social dimensions (Abu-Qdais et al., 2025). In such contexts, decision-making models and multi-criteria decision-making (MCDM) techniques have become essential tools for supporting sustainable planning and policy development.

Classical multi-criteria decision-making methods such as the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) have been widely applied in circular economy-oriented waste management studies because of their simplicity, transparency, and practical applicability. These approaches enable decision-makers to rank alternatives based on weighted evaluation criteria and to identify optimal waste treatment strategies under structured conditions. For example, studies focusing on university waste management systems and organic waste treatment have successfully used AHP and TOPSIS frameworks to prioritize recycling strategies and sustainable waste treatment options (Abu-Qdais et al., 2025; Kocak et al., 2025). Such approaches are particularly valuable when decision criteria are relatively well-defined and stakeholder preferences can be systematically quantified.

Despite their practical advantages, classical MCDM techniques face important limitations when dealing with uncertainty, vagueness, and interdependencies among criteria. Real-world waste management systems often involve incomplete information, subjective judgments, fluctuating environmental conditions, and conflicting

stakeholder priorities. These characteristics reduce the effectiveness of deterministic decision-making approaches and necessitate the development of more flexible and uncertainty-oriented frameworks. In response, recent studies have increasingly adopted fuzzy-based methodologies capable of handling ambiguity and linguistic uncertainty in decision environments (Jafarzadeh Ghoushchi et al., 2022). Fuzzy decision-making models improve robustness by allowing experts to express preferences through linguistic variables and interval-based assessments rather than precise numerical values.

The integration of fuzzy logic into waste management decision-making has produced significant methodological advancements in recent years. Studies employing Spherical Fuzzy sets, Fermatean fuzzy linguistic systems, and Fuzzy AHP frameworks have demonstrated improved reliability in evaluating complex sustainability problems characterized by uncertain and dynamic conditions (Yazdi et al., 2024). These models are particularly useful in areas such as electronic waste management, where rapidly evolving technologies, uncertain recovery rates, and environmental risks complicate operational decision-making. Similarly, medical waste management systems require advanced decision-support models because of the high environmental sensitivity and health-related consequences associated with improper disposal practices (Jafarzadeh Ghoushchi et al., 2022). The adoption of fuzzy approaches therefore reflects a broader shift toward uncertainty-aware sustainability modeling.

In parallel with fuzzy methodologies, hybrid decision-making frameworks have become increasingly prominent in circular economy research. Hybrid models integrate multiple analytical methods in order to enhance decision accuracy, sensitivity analysis, and robustness evaluation. For example, recent studies have combined AHP, CODAS, fuzzy sets, sensitivity analysis, and optimization techniques into integrated frameworks capable of addressing complex environmental systems (Carnia et al., 2026). Such hybrid models provide more comprehensive evaluations because they simultaneously account for uncertainty, interdependencies, environmental trade-offs, and strategic priorities. The increasing popularity of hybrid frameworks demonstrates the growing recognition that waste management decisions require multidimensional and adaptive analytical approaches rather than isolated evaluation tools.

Construction and demolition waste management represents one of the most widely studied applications of MCDM and hybrid decision frameworks within the circular

economy literature. The construction sector generates massive quantities of waste globally and contributes substantially to environmental degradation and resource depletion. Consequently, researchers have focused extensively on identifying sustainable waste recovery, recycling, and reuse strategies for this sector (Cook et al., 2022). Studies integrating CE principles into construction waste management have shown that environmental criteria often receive the highest importance among sustainability dimensions, emphasizing pollution reduction, material recovery, and resource efficiency (Weerakoon et al., 2025). Decision-support systems integrating Delphi techniques, FAHP, and DSS platforms have further improved the strategic management of construction waste by enabling more accurate prioritization of waste treatment alternatives (Boonkanit & Suthiluck, 2023).

Beyond construction waste, food waste management has also received increasing attention because of its major environmental and economic consequences. Food waste contributes significantly to greenhouse gas emissions, freshwater eutrophication, and land-use inefficiencies when managed through conventional disposal systems. Circular economy strategies such as composting, anaerobic digestion, and waste-to-energy conversion offer promising alternatives capable of recovering energy and nutrients while reducing environmental burdens (Brenes-Peralta et al., 2020). Decision-making models incorporating Life Cycle Thinking (LCT), AHP, and optimization techniques have demonstrated that waste valorization strategies can substantially improve sustainability outcomes compared to traditional landfill disposal methods. These findings reinforce the importance of integrating environmental impact assessment into circular economy decision frameworks.

Electronic waste management constitutes another rapidly growing research area due to the accelerating consumption of digital technologies and the hazardous nature of electronic waste streams. E-waste contains toxic substances and valuable recoverable materials, making it simultaneously an environmental threat and a resource opportunity. Advanced decision-making systems employing fuzzy linguistic approaches and nonlinear influence models have been developed to optimize sustainable e-waste operations and circular recovery strategies (Yazdi et al., 2024). These studies highlight the increasing importance of environmental management systems, sustainability indicators, and uncertainty analysis in guiding e-waste policy and operational decisions.

Recent research has also emphasized the importance of integrating broader ecological and sustainability objectives into waste management decision-making. Studies focusing on river-basin systems and plastic pollution have linked circular economy frameworks directly to Sustainable Development Goals (SDGs), particularly goals related to clean water, responsible consumption, and marine ecosystem protection (Carnia et al., 2026). In these contexts, decision-making frameworks prioritize ecological sustainability, pollution reduction, and blue economy principles alongside traditional operational considerations. Such developments demonstrate that circular economy-based waste management is increasingly viewed not merely as a technical issue but as a comprehensive sustainability strategy involving environmental governance, public health, and long-term ecological resilience.

Another important development in the literature is the growing emphasis on organizational and institutional dimensions of circular economy transitions. Waste management decisions are influenced not only by technological and environmental factors but also by market dynamics, regulatory systems, stakeholder interactions, and governance structures. Qualitative studies examining waste treatment companies and institutional actors reveal that circular economy transitions often increase market uncertainty and operational complexity (Snellinx et al., 2021). These findings suggest that successful CE implementation requires supportive policy frameworks, stakeholder collaboration, and adaptive governance mechanisms capable of managing systemic uncertainty.

Overall, the literature demonstrates a clear methodological and conceptual evolution in circular economy-based waste management research. Earlier studies primarily relied on simple deterministic MCDM methods focused on operational efficiency and alternative selection. More recent research increasingly adopts hybrid, fuzzy, and uncertainty-oriented frameworks that prioritize environmental sustainability, resilience, and systems-level analysis (Carnia et al., 2026; Weerakoon et al., 2025). Environmental criteria such as pollution reduction, greenhouse gas mitigation, ecological protection, and public health impacts have progressively become dominant decision drivers in contemporary studies. At the same time, the increasing complexity of waste streams and sustainability challenges has accelerated the development of advanced decision-support systems capable of integrating multidimensional and uncertain evaluation environments.

Despite the growing body of research in this field, the existing literature remains fragmented regarding methodological integration, comparative evaluation of decision models, and synthesis of environmental priorities across waste streams. Many studies focus on specific waste categories or isolated methodological approaches without providing a broader understanding of evolving research trends and decision-making structures. Furthermore, limited research has systematically compared how different models address uncertainty, environmental sustainability, and circular economy implementation simultaneously. Therefore, a comprehensive synthesis of existing decision-making frameworks is necessary to identify methodological developments, dominant sustainability priorities, and emerging research gaps in circular economy-oriented waste management systems.

Accordingly, the aim of this study is to systematically review and comparatively analyze decision-making models used for circular economy implementation in waste management systems, with emphasis on methodological evolution, environmental priorities, and sustainability-oriented decision objectives.

2. Methods and Materials

This study adopted a systematic review approach to identify and analyze existing studies related to decision-making models for circular economy implementation in waste management. The review process was conducted following a structured and transparent methodology to ensure the reliability and reproducibility of the findings. The literature search was performed using three major academic databases, including Scopus, Web of Science, and Google Scholar. The search focused on studies published between 2020 and 2026 in order to capture recent methodological developments and emerging trends in circular economy-based waste management research.

A combination of keywords and Boolean operators was used to retrieve relevant studies. The primary search terms included “decision-making model”, “circular economy”, “waste management”, “multi-criteria decision-making”, “AHP”, “TOPSIS”, “fuzzy”, and “sustainability”. Different combinations of these keywords were applied across the selected databases to maximize coverage and identify the most relevant publications.

The retrieved studies were screened according to predefined inclusion and exclusion criteria. Only peer-reviewed journal articles published in English were

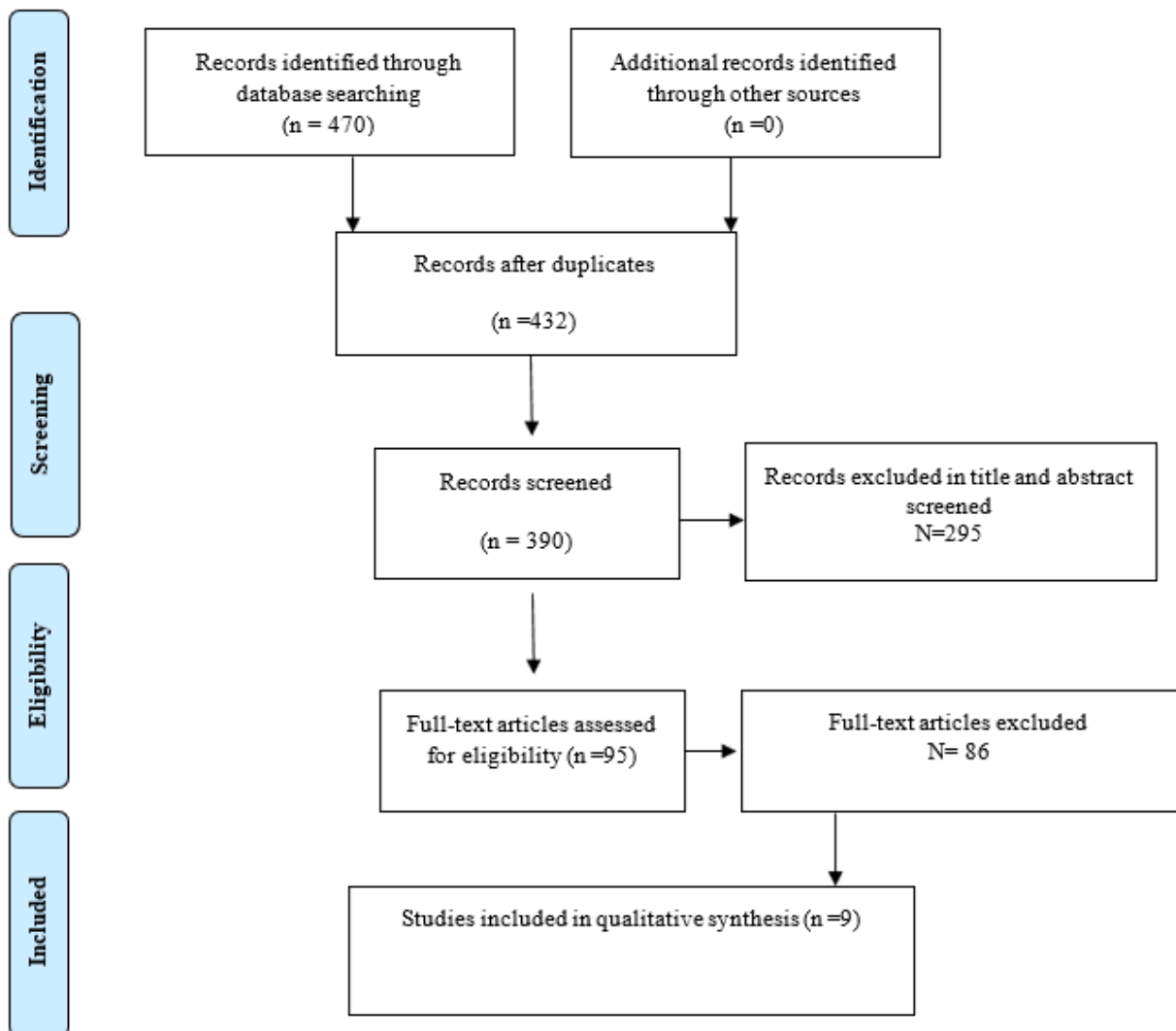
considered eligible for inclusion. In addition, the selected studies were required to focus specifically on decision-making approaches related to waste management within a circular economy framework and to include environmental or sustainability-related evaluation criteria. Conference papers, editorials, dissertations, duplicate records, and studies lacking a clear methodological framework were excluded from the review process.

After the initial search, duplicate articles were removed, and the remaining studies underwent title and abstract screening. Subsequently, full-text evaluations were

conducted to assess the relevance and methodological quality of the studies. Articles that did not directly address decision-making systems in circular economy-oriented waste management were excluded during this stage. Following the full-text assessment, a final set of nine studies was selected for qualitative synthesis and comparative analysis. The study selection process was conducted in accordance with the PRISMA framework, and the overall screening procedure is illustrated in the PRISMA flowchart presented in this study (Figure 1).

Figure 1

PRISMA flowchart



3. Findings and Results

Relevant information from the selected studies was extracted and comparatively analyzed in order to identify dominant methodological approaches, environmental priorities, and decision-making objectives in circular economy-based waste management systems. The findings demonstrated substantial variation in waste streams, analytical techniques, and sustainability evaluation structures across the reviewed literature. At the same time, several consistent research trends emerged regarding the increasing complexity of decision-making models, the growing importance of environmental considerations, and the expansion of hybrid and fuzzy-based frameworks in sustainability-oriented waste management systems.

Following the screening and eligibility assessment process, nine studies were selected for qualitative synthesis and comparative analysis. The selected studies covered a broad range of waste management contexts, including university waste systems, medical waste, food waste, electronic waste, construction and demolition waste, organic solid waste, and river-basin pollution management. Construction and demolition waste was identified as the most frequently studied waste stream among the reviewed articles, while medical waste and electronic waste were associated with the highest levels of uncertainty and methodological complexity. Table 1 summarizes the main characteristics of the included studies, including waste type, decision-making model, circular economy dimension, environmental criteria, key findings, and methodological contributions.

Table 1

Characteristics of Included Studies

Study	Waste Type / Context	Decision-Making Model	Circular Economy Aspect	Environmental Criteria	Key Findings	Contribution / Notes
Koçak et al. (2025)	University waste management system	AHP + TOPSIS	Sustainable circular waste management, recycling, resource efficiency	Environmental, economic, social, and technical sustainability criteria	Reduced environmental impact; improved recycling prioritization	Practical AHP-TOPSIS framework
Jafarzadeh Ghouschi et al. (2022)	Medical waste management	FMEA + Spherical Fuzzy MOORA + TOPSIS comparison	Identification and prioritization of CE implementation barriers in medical waste systems	Sustainability and environmental protection considerations under uncertainty	Reliable prioritization of CE barriers under uncertainty	Fuzzy MOORA-FMEA integration
Brenes-Peralta et al. (2020)	Food waste management in universities	Linear Programming + Life Cycle Thinking (LCT) + AHP	Waste-to-energy and food waste valorization	Global Warming Potential, Freshwater Eutrophication, Land Use, environmental trade-offs	Landfilling showed highest environmental burden	LCT-AHP integrated evaluation
Yazdi et al. (2024)	E-waste management in the UK (London Metropolitan area)	Step-wise weighted influence nonlinear gauge system + Fermatean fuzzy linguistic sets	Sustainable e-waste operations, recycling, redesign, CE contributing factors	Environmental management systems, sustainability, uncertainty analysis	Environmental management systems identified as key driver	Advanced fuzzy MCDM framework
Snellinx et al. (2021)	Waste treatment companies across the EU	Qualitative decision-making analysis (semi-structured interviews, workshops, focus groups)	Organizational transition toward circular economy in waste markets	Indirect environmental sustainability considerations through CE transition	CE transition increases uncertainty and market complexity	Stakeholder-oriented qualitative insights
Boonkanit & Suthiluck (2023)	Construction and demolition waste (concrete) waste	Delphi technique + Fuzzy AHP (FAHP) + Decision Support System (DSS)	Smart transition toward CE in construction waste management	Sustainability-related waste management criteria	Optimal concrete waste strategy identified	DSS with FAHP integration
Weerakoon et al. (2025)	Construction and demolition waste (CDW) in Sri Lanka	AHP + TOPSIS + WSM + WPM + sensitivity analysis	Integration of CE principles into construction waste management	Environmental, economic, social, and technological criteria	Environmental criteria ranked most important	Multi-method validated MCDM model
Abu-Qdais et al. (2025)	Organic solid waste management in Jordan	AHP + sensitivity analysis	Transition from linear waste systems to CE-based organic waste treatment	Environmental and public health impacts	Composting selected as most sustainable option	Policy-oriented AHP framework
Carma et al. (2026)	River-basin waste management (Citarum River Basin, Indonesia)	Weighted Fuzzy N-Soft Set + CODAS + AHP + sensitivity analysis	CE-based waste prioritization using 10R strategies supporting blue economy goals	Pollution reduction, ecological sustainability, SDGs (6, 12, 14)	Single-use plastics prioritized for intervention	Hybrid fuzzy CODAS decision model

The methodological comparison of decision-making systems revealed a clear progression from traditional deterministic methods toward more sophisticated hybrid and uncertainty-oriented frameworks. Classical MCDM approaches such as AHP, TOPSIS, WSM, and WPM were frequently used in studies involving relatively structured and measurable waste management systems. These methods were particularly common in university waste management systems, organic waste treatment, and construction waste management contexts. However, the findings showed that more recent studies increasingly integrate fuzzy logic, sensitivity analysis, and hybrid decision-support systems in order to improve decision robustness and uncertainty handling.

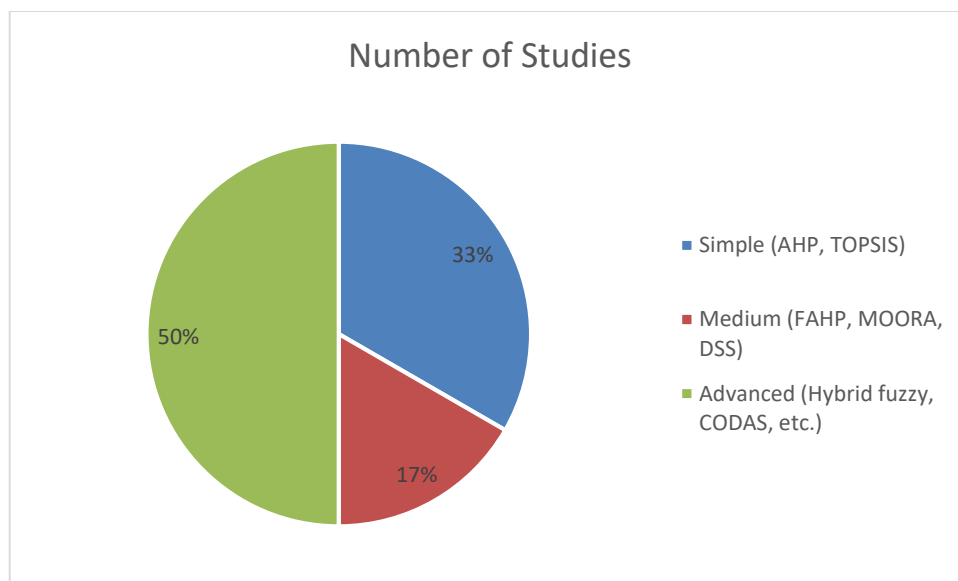
The findings demonstrated that fuzzy-based extensions, including Fuzzy AHP, Spherical Fuzzy sets, and Fermatean fuzzy linguistic systems, were increasingly adopted in studies characterized by environmental ambiguity and interdependent evaluation criteria. Medical waste

management, electronic waste systems, and river-basin pollution management exhibited the highest levels of methodological sophistication because these waste streams involve hazardous materials, uncertain environmental impacts, and dynamic operational conditions. In addition, hybrid frameworks integrating multiple analytical techniques were found to provide more comprehensive evaluations by combining prioritization, uncertainty analysis, and sensitivity testing within a unified structure.

The comparative analysis further revealed that optimization-based models and life cycle-oriented approaches were commonly applied in food waste and waste-to-energy systems. These models emphasized environmental trade-offs such as greenhouse gas emissions, freshwater eutrophication, and land-use impacts. In contrast, qualitative approaches focusing on organizational and institutional transitions were primarily used to analyze market complexity, stakeholder interactions, and governance-related challenges within circular economy implementation processes.

Figure 2

Distribution of Decision-Making Model Complexity Across the Reviewed Studies



The analysis of waste streams demonstrated that different waste categories were associated with distinct environmental priorities and analytical requirements. Construction and demolition waste emerged as the most dominant research area among the reviewed studies. This waste stream was generally associated with structured sustainability indicators and measurable operational alternatives, making it highly suitable for MCDM

applications. Several studies focusing on construction waste integrated AHP, TOPSIS, FAHP, and DSS frameworks in order to optimize recycling strategies and improve resource efficiency.

Medical waste and electronic waste represented the most complex waste streams in terms of decision-making requirements. These systems involved high levels of uncertainty, regulatory sensitivity, and public health risk.

Consequently, studies examining these waste categories predominantly employed advanced fuzzy and hybrid methodologies capable of addressing interdependencies and ambiguous evaluation conditions. Food waste management systems were primarily analyzed from an environmental impact perspective, with particular emphasis on waste valorization, waste-to-energy conversion, and the environmental burden of landfill disposal.

Another major finding concerned the emergence of river-basin and plastic pollution management as environmentally critical areas within circular economy research. These studies emphasized ecological sustainability, pollution reduction, and alignment with Sustainable Development Goals. Single-use plastics were consistently identified as high-priority intervention targets because of their persistence in ecosystems and their contribution to marine and freshwater pollution.

The structure of decision-making criteria represented another important dimension identified in the comparative analysis. Three major patterns of criteria design were observed across the reviewed studies. The first and most common structure consisted of classical multidimensional sustainability frameworks integrating environmental,

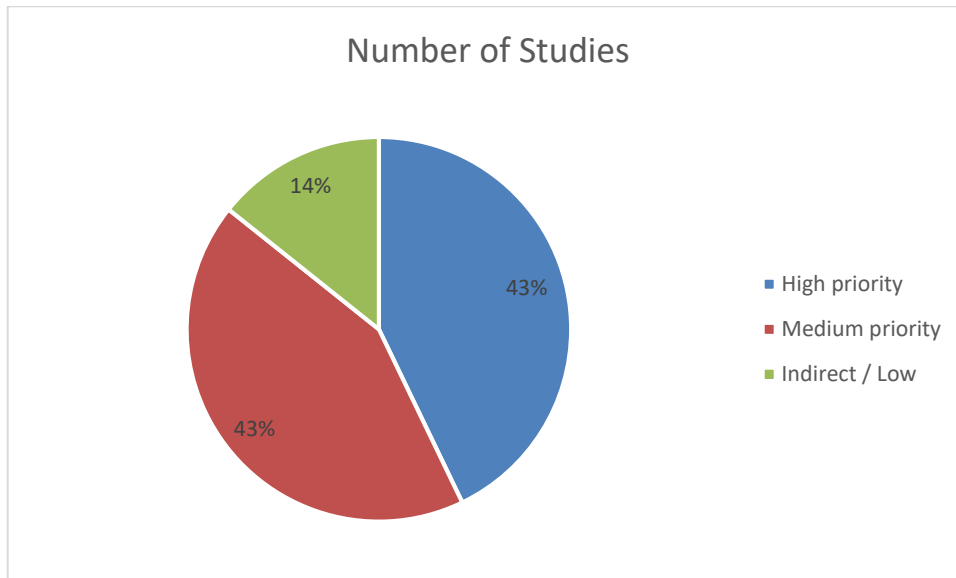
economic, social, and technical criteria. These balanced evaluation structures were particularly common in construction waste management and university waste systems, where multiple stakeholder priorities had to be simultaneously considered.

The second pattern involved environmentally focused criteria structures emphasizing measurable ecological indicators such as pollution reduction, greenhouse gas emissions, land use, eutrophication, and public health impacts. Studies using this approach typically prioritized environmental performance over broader sustainability balancing. Such frameworks were especially prominent in food waste, organic waste, and river-basin management systems.

The third pattern consisted of system-oriented and policy-driven criteria structures emphasizing institutional complexity, uncertainty, governance constraints, and interdependencies among actors and variables. These frameworks extended beyond traditional technical evaluations and focused on understanding broader systemic characteristics influencing circular economy implementation.

Figure 3

Level of Environmental Priority in Decision-Making Frameworks



The findings additionally revealed a substantial increase in the importance of environmental considerations within decision-making systems. Environmental criteria were increasingly identified as the dominant evaluation dimension across recent studies. Pollution reduction,

ecological sustainability, greenhouse gas mitigation, public health protection, and resource efficiency emerged as the most frequently prioritized environmental objectives.

The reviewed studies could be classified into three environmental priority levels. At the high-priority level,

environmental factors represented the dominant decision driver and received the greatest weighting within evaluation systems. River-basin management, organic waste treatment, and construction waste studies frequently belonged to this category. At the medium-priority level, environmental criteria remained important but were evaluated alongside economic, operational, and technical considerations within balanced sustainability frameworks. At the indirect-priority level, environmental considerations were embedded within broader organizational or institutional discussions rather than being directly quantified as evaluation indicators.

The findings also demonstrated that the methodological complexity of decision-making models increased substantially in more recent studies. Three levels of model sophistication were identified across the reviewed literature: simple deterministic frameworks, intermediate fuzzy-enhanced systems, and advanced hybrid-integrated models.

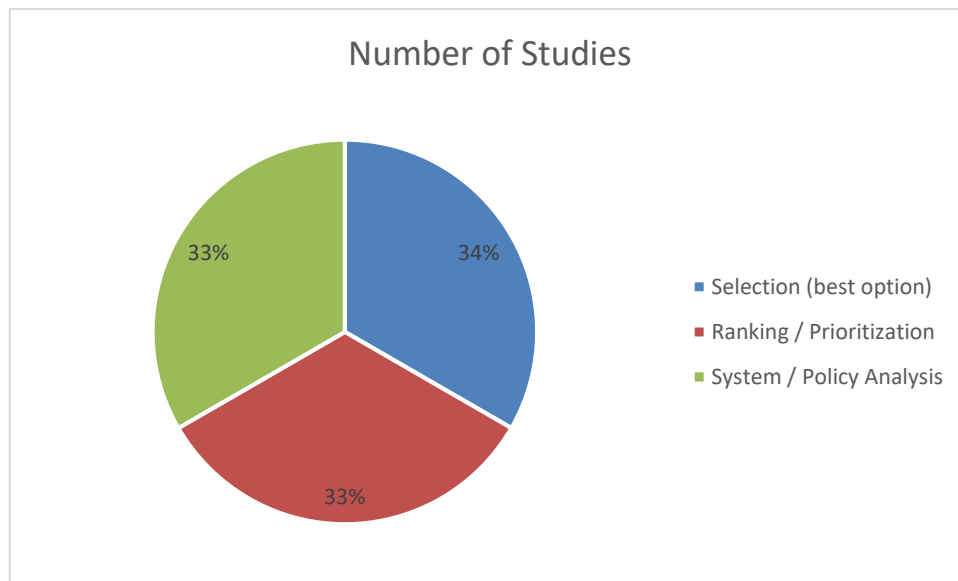
Simple frameworks were dominated by classical AHP and TOPSIS methods and were generally applied in

structured decision environments characterized by clearly defined alternatives and measurable sustainability criteria. Intermediate models incorporated fuzzy logic, MOORA techniques, and decision-support systems in order to improve flexibility and uncertainty management. Advanced frameworks integrated multiple analytical methods such as fuzzy logic, CODAS, AHP, and sensitivity analysis within unified hybrid systems capable of handling high levels of uncertainty and system interdependency.

The results further indicated that advanced hybrid frameworks demonstrated stronger analytical capabilities compared to standalone techniques because they enabled multi-layered evaluation, uncertainty management, ranking stability assessment, and sensitivity testing simultaneously. These models were particularly prevalent in environmentally sensitive and operationally complex waste management systems.

Figure 4

Classification of Decision Objectives in Circular Economy Waste Management Studies



The comparative analysis of decision-making objectives revealed three dominant categories within the reviewed literature. The first category focused on selecting the most suitable waste management alternative among competing options. These studies commonly evaluated alternatives such as composting, recycling systems, and integrated waste treatment strategies using structured MCDM approaches.

The second category focused on ranking and prioritization objectives. Instead of identifying a single

optimal solution, these studies aimed to prioritize waste streams, environmental interventions, or sustainability strategies according to relative importance. This approach was especially common in studies involving environmental risk reduction and resource allocation planning.

The third category involved system-level and policy-oriented analysis. These studies emphasized institutional dynamics, governance structures, market complexity, and organizational transitions associated with circular economy

implementation. Rather than producing operational rankings, these approaches generated strategic insights concerning systemic barriers, enabling conditions, and long-term sustainability transitions.

Overall, the findings demonstrated a substantial methodological evolution within circular economy-based waste management research. The reviewed literature showed a progressive shift from simple deterministic decision-making techniques toward advanced hybrid and uncertainty-aware frameworks. Environmental sustainability emerged as the dominant decision priority across most recent studies, while construction waste, medical waste, electronic waste, and plastic pollution were identified as the most significant waste management domains within the reviewed literature. The findings further indicated that modern waste management systems increasingly require integrated and adaptive decision-support frameworks capable of simultaneously addressing environmental, economic, technical, social, and institutional dimensions.

4. Discussion and Conclusion

The findings of this systematic review demonstrate that decision-making models have become increasingly important in supporting circular economy implementation within waste management systems. The reviewed studies collectively indicate a clear methodological transition from traditional deterministic decision-making approaches toward advanced hybrid and uncertainty-oriented frameworks. One of the most important findings of the present review is that classical methods such as AHP and TOPSIS remain widely used because of their transparency, simplicity, and practical applicability in structured decision environments. Studies conducted in university waste management systems and organic waste treatment contexts showed that these models provide effective support for selecting sustainable waste management alternatives and improving recycling prioritization (Abu-Qdais et al., 2025; Kocak et al., 2025). These findings suggest that classical MCDM approaches continue to offer substantial value for operational-level decision-making, especially in contexts where criteria and alternatives are clearly defined.

However, the results also revealed that recent studies increasingly favor fuzzy and hybrid frameworks capable of managing uncertainty, ambiguity, and interdependent sustainability criteria. This trend reflects the growing complexity of modern waste management systems and the limitations of deterministic approaches in dealing with

uncertain environmental conditions and subjective expert evaluations. The findings are strongly aligned with the work of Yazdi et al. (Yazdi et al., 2024), who demonstrated that fuzzy linguistic frameworks substantially improve decision robustness in e-waste management systems characterized by uncertain operational variables and rapidly changing technological conditions. Similarly, Jafarzadeh Ghoushchi et al. (Jafarzadeh Ghoushchi et al., 2022) found that integrating FMEA with fuzzy MOORA approaches enabled more reliable prioritization of circular economy barriers in medical waste management under uncertain conditions. These studies support the present review's conclusion that uncertainty-aware methodologies are increasingly becoming essential for sustainable waste management decision-making.

Another important finding of the present study is the increasing methodological sophistication observed in the literature. Hybrid frameworks integrating fuzzy logic, CODAS, AHP, optimization techniques, and sensitivity analysis were identified as the most advanced approaches among the reviewed studies. The integration of multiple techniques allows decision-makers to address several dimensions simultaneously, including uncertainty management, environmental trade-offs, ranking stability, and strategic prioritization. This finding is strongly supported by the study of Carnia et al. (Carnia et al., 2026), which proposed an integrated weighted fuzzy N-soft set-CODAS framework capable of supporting circular economy-based waste prioritization within the environmentally sensitive Citarum River Basin. Their findings demonstrated that hybrid models provide more resilient and comprehensive evaluations than standalone techniques. Likewise, Weerakoon et al. (Weerakoon et al., 2025) showed that combining AHP, TOPSIS, WSM, WPM, and sensitivity analysis significantly improved the reliability and consistency of construction waste management decisions. These findings collectively indicate that hybrid decision-making frameworks are increasingly viewed as the most effective tools for addressing complex sustainability problems in waste management systems.

The findings also revealed substantial differences among waste streams regarding methodological complexity and environmental sensitivity. Construction and demolition waste emerged as the most extensively studied waste category in the reviewed literature. This result is likely attributable to the enormous volume of construction waste generated globally and the relatively structured nature of decision criteria in this sector. Studies such as those

conducted by Boonkanit and Suthiluck (Boonkanit & Suthiluck, 2023) and Weerakoon et al. (Weerakoon et al., 2025) demonstrated that construction waste management systems are highly compatible with structured MCDM approaches because waste alternatives, sustainability indicators, and operational criteria are comparatively measurable and well-defined. These findings are also consistent with the systematic review by Cook et al. (Cook et al., 2022), which emphasized the significant environmental and public health risks associated with construction and demolition waste, thereby explaining the strong research attention directed toward this waste stream.

In contrast, the present review found that medical waste and electronic waste management systems require significantly more advanced decision-support methodologies because of their hazardous nature, technological uncertainty, and regulatory complexity. These findings align closely with previous studies emphasizing the multidimensional risks associated with hazardous waste streams. Jafarzadeh Ghoushchi et al. (Jafarzadeh Ghoushchi et al., 2022) demonstrated that medical waste management decisions involve substantial uncertainty because environmental protection, operational feasibility, and public health concerns must be evaluated simultaneously. Similarly, Yazdi et al. (Yazdi et al., 2024) highlighted the complexity of e-waste management systems due to the rapid evolution of electronic technologies and the environmental risks associated with toxic materials. The present review therefore confirms that the complexity of waste streams directly influences the methodological sophistication required for effective decision-making.

A further important result concerns the growing dominance of environmental considerations within decision-making frameworks. The reviewed studies clearly showed that environmental criteria have evolved from secondary evaluation factors into central decision drivers in contemporary circular economy research. Environmental priorities such as pollution reduction, greenhouse gas mitigation, ecological sustainability, public health protection, and resource efficiency were consistently identified as dominant criteria across recent studies (Abu-Qdais et al., 2025; Carnia et al., 2026; Weerakoon et al., 2025). This finding reflects a broader shift in sustainability research toward stronger ecological orientation and aligns with global sustainability agendas emphasizing climate action, ecosystem preservation, and responsible resource consumption.

The increasing prominence of environmental considerations is particularly evident in studies focusing on food waste, plastic pollution, and organic waste management systems. Brenes-Peralta et al. (Brenes-Peralta et al., 2020) demonstrated that landfill disposal of food waste creates significantly greater environmental burdens than valorization alternatives such as composting and waste-to-energy systems. Similarly, Abu-Qdais et al. (Abu-Qdais et al., 2025) identified composting as the most sustainable treatment option for organic waste because of its favorable environmental and public health outcomes. The present review supports these conclusions by demonstrating that recent decision-making frameworks increasingly prioritize environmental impact reduction over purely economic considerations. This trend is also consistent with the broader theoretical understanding of circular economy systems as regenerative models designed to minimize ecological degradation while maximizing resource recovery (Hossain et al., 2024; Liao, 2022).

The findings additionally revealed that policy-oriented and system-level analyses are becoming increasingly important in circular economy research. Unlike operational decision models focused primarily on alternative selection or prioritization, these approaches aim to understand broader institutional, organizational, and governance-related dynamics influencing circular economy transitions. Snellinx et al. (Snellinx et al., 2021) showed that waste treatment companies operating within circular economy markets experience increased uncertainty and market complexity because of evolving regulations, stakeholder interactions, and changing resource flows. The present review supports this perspective by highlighting that successful circular economy implementation depends not only on technical optimization but also on adaptive governance systems, institutional coordination, and supportive policy frameworks.

Another noteworthy finding concerns the role of urbanization and increasing waste generation as major drivers for methodological innovation in waste management decision-making. The reviewed studies collectively suggest that rapid urban expansion and industrial growth are intensifying the need for efficient and sustainable waste management systems. Voukkali et al. (Voukkali et al., 2024) emphasized that urbanization significantly accelerates municipal waste production and creates major environmental and infrastructural challenges. Similarly, Lu et al. (Lu et al., 2024) demonstrated that waste generation scales systematically with urban growth worldwide. These

trends explain why researchers are increasingly developing advanced decision-support systems capable of optimizing resource allocation, environmental sustainability, and waste recovery within highly dynamic urban systems.

The findings of this review also reinforce the conceptual importance of circular economy principles in transforming waste management systems from disposal-oriented models into resource-oriented systems. Earlier linear systems treated waste primarily as a burden requiring elimination, whereas circular economy approaches emphasize material recirculation, value recovery, and long-term sustainability (Attri et al., 2025). The reviewed studies collectively demonstrate that decision-making frameworks are increasingly designed to support this transition by integrating sustainability objectives directly into operational and strategic planning processes. Atstaja et al. (Atstaja et al., 2024) similarly argued that waste-to-energy systems and resource-efficient business models represent critical components of circular economy transitions because they simultaneously address environmental and economic sustainability objectives.

Moreover, the review revealed that uncertainty management has become one of the defining characteristics of modern circular economy decision-making frameworks. Real-world waste management systems involve fluctuating environmental conditions, changing market structures, incomplete data, and subjective expert judgments. Consequently, advanced fuzzy and hybrid frameworks have emerged as highly valuable tools for improving decision reliability under uncertain conditions. The increasing emphasis on uncertainty-oriented methodologies reflects a broader recognition that sustainability problems cannot be effectively addressed through rigid deterministic models alone (Carnia et al., 2026; Yazdi et al., 2024). This methodological evolution represents a major advancement in sustainability decision science and demonstrates the growing maturity of circular economy research.

Overall, the findings of the present study indicate that circular economy-based waste management research is undergoing substantial methodological and conceptual transformation. Classical MCDM methods remain valuable for structured operational problems, but recent literature increasingly favors hybrid, fuzzy, and uncertainty-aware frameworks capable of addressing complex environmental systems. Environmental sustainability has become the dominant decision priority across most contemporary studies, while system-level and policy-oriented analyses highlight the importance of governance and institutional

adaptation. The reviewed studies collectively demonstrate that integrated, flexible, and environmentally oriented decision-support systems are essential for achieving sustainable waste management and successful circular economy transitions (Hossain et al., 2024; Liao, 2022).

One of the primary limitations of this study is that the review was restricted to peer-reviewed English-language articles published between 2020 and 2026, which may have excluded relevant studies published in other languages or earlier periods. In addition, the review focused mainly on methodological and comparative analysis rather than quantitative meta-analysis, limiting the ability to statistically compare the effectiveness of different decision-making models. Another limitation concerns the relatively small number of final studies included in the synthesis, which reflects the still-emerging nature of research specifically integrating circular economy principles with advanced waste management decision-making systems. Furthermore, because many reviewed studies used different evaluation criteria, waste streams, and contextual conditions, direct comparison among findings was occasionally difficult.

Future research should focus on developing more integrated and adaptive decision-making frameworks capable of incorporating real-time environmental, economic, and operational data into circular economy waste management systems. Researchers should also investigate the application of artificial intelligence, machine learning, and big-data analytics in improving sustainability-oriented decision-support systems. Comparative empirical studies examining the practical implementation of hybrid and fuzzy models across different countries and waste sectors would further strengthen understanding of methodological effectiveness. Additionally, future studies should explore governance structures, stakeholder collaboration mechanisms, and policy integration strategies that can facilitate successful circular economy transitions in complex urban and industrial environments.

From a practical perspective, policymakers and waste management practitioners should prioritize the adoption of integrated and environmentally oriented decision-support systems when designing sustainable waste management strategies. Organizations should increasingly utilize hybrid and uncertainty-aware models capable of balancing environmental, economic, technical, and social considerations simultaneously. Governments and municipal authorities should also strengthen regulatory frameworks supporting circular economy practices such as recycling, waste valorization, and resource recovery. Furthermore,

investment in digital technologies, environmental monitoring systems, and stakeholder collaboration platforms can significantly improve the effectiveness of circular economy implementation in modern waste management systems.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

References

- Abu-Qdais, H., Al-Omouh, S., Jalalipour, H., & Nassour, A. (2025). Towards a Circular Economy in Jordan: Selecting Organic Waste Treatment Options Using a Multi-Criteria Decision-Making Approach. *Sustainability*, 17(5), 2146. <https://doi.org/10.3390/su17052146>
- Atstaja, D., Cudecka-Purina, N., Koval, V., Kuzmina, J., Butkevics, J., & Hrinchenko, H. (2024). Waste-to-Energy in the Circular Economy Transition and Development of Resource-Efficient Business Models. *Energies*, 17(16), 4188. <https://doi.org/10.3390/en17164188>
- Attri, S., Chauhan, A., Saklani, A., Pandey, G., Chauhan, A., Amirdzhanov, F. F., & Redouane, K. (2025). Challenges in Linear Waste Systems: A Critical Look at Conventional Models and Their Environmental Effects. In *Sustainable Urban Future: Embracing Circular Economy in Waste Management* (pp. 115-132). Springer Nature Singapore. https://doi.org/10.1007/978-981-95-2976-6_6
- Boonkanit, P., & Suthiluck, K. (2023). Developing a Decision-Making Support System for a Smart Construction and Demolition Waste Transition to a Circular Economy. *Sustainability*, 15(12), 9672. <https://doi.org/10.3390/su15129672>
- Brenes-Peralta, L., Jimenez-Morales, M. F., Campos-Rodriguez, R., De Menna, F., & Vittuari, M. (2020). Decision-Making Process in the Circular Economy: A Case Study on University Food Waste-to-Energy Actions in Latin America. *Energies*, 13(9), 2291. <https://doi.org/10.3390/en13092291>
- Carnia, E., Saputra, M. P. A., Mashadi, Sukono, Hs, A. A. S. I., Lestari, M., & Azahra, A. S. (2026). An Integrated Weighted Fuzzy N-Soft Set-CODAS Framework for Decision-Making in Circular Economy-Based Waste Management Supporting the Blue Economy: A Case Study of the Citarum River Basin, Indonesia. *Mathematics*, 14(2), 238. <https://doi.org/10.3390/math14020238>
- Cook, E., Velis, C. A., & Black, L. (2022). Construction and Demolition Waste Management: A Systematic Scoping Review of Risks to Occupational and Public Health. *Frontiers in Sustainability*, 3, 924926. <https://doi.org/10.3389/frsus.2022.924926>
- Hossain, M., Park, S., Suchek, N., & Pansera, M. (2024). Circular Economy: A Review of Review Articles. *Business Strategy and the Environment*, 33(7), 7077-7099. <https://doi.org/10.1002/bse.3867>
- Jafarzadeh Ghouschi, S., Memarpour Ghiaci, A., Rahnamay Bonab, S., & Ranjbarzadeh, R. (2022). Barriers to Circular Economy Implementation in Designing of Sustainable Medical Waste Management Systems Using a New Extended Decision-Making and FMEA Models. *Environmental Science and Pollution Research*, 29(53), 79735-79753. <https://doi.org/10.1007/s11356-022-19018-z>
- Kocak, A. B., Almarestani, A., & Tirkolaei, E. B. (2025). A Decision-Making Approach to Establish a Sustainable-Circular Waste Management System: A Case Study of Istinye University. *Spectrum of Mechanical Engineering and Operational Research*, 2(1), 204-218. <https://doi.org/10.31181/smeor21202539>
- Liao, A. (2022). Circular Economy. In *Warranty Chain Management: Digitalization and Sustainability* (pp. 375-399). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-2104-9_15
- Lu, M., Zhou, C., Wang, C., Jackson, R. B., & Kempes, C. P. (2024). Worldwide Scaling of Waste Generation in Urban Systems. *Nature Cities*, 1(2), 126-135. <https://doi.org/10.1038/s44284-023-00021-5>
- Snellinx, S., Van Meensel, J., Farahbakhsh, S., Bourgeois, L., Mertens, A., Lauwers, L., & Buysse, J. (2021). Waste Treatment Company Decision-Making in a Complex System of Markets Influenced by the Circular Economy. *Journal of Cleaner Production*, 328, 129672. <https://doi.org/10.1016/j.jclepro.2021.129672>
- Voukkali, I., Papamichael, I., Loizia, P., & Zorpas, A. A. (2024). Urbanization and Solid Waste Production: Prospects and Challenges. *Environmental Science and Pollution Research*, 31(12), 17678-17689. <https://doi.org/10.1007/s11356-023-27670-2>
- Weerakoon, T. G., Zvirgzdins, J., Lapuke, S., Wimalasena, S., & Drukis, P. (2025). Integrating Circular Economy (CE) Principles into Construction Waste Management (CWM) through Multiple Criteria Decision-Making (MCDM).

Sustainability, 17(17), 7770.
<https://doi.org/10.3390/su17177770>

Yazdi, M., Moradi, R., Nedjati, A., Ghasemi Pirbalouti, R., & Li, H. (2024). E-Waste Circular Economy Decision-Making: A Comprehensive Approach for Sustainable Operation Management in the UK. *Neural Computing and Applications*, 36(22), 13551-13577. <https://doi.org/10.1007/s00521-024-09754-3>