

Title

Urban Waste Management and the Sustainable Development Goals: Mapping interactions and fostering policymaking

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Summary

We conducted a three-step methodology to investigate the relationship between Urban Waste Management (UWM) and the Sustainable Development Goals (SDGs) to identify potential synergies and trade-offs to foster new propositions toward systemic and priority setting to support Agenda 2030.

Our findings indicate that the UWM can facilitate and reinforce SDGs progress, creating synergistic relationships that will compensate for any trade-offs. The greatest synergetic interaction with the UWM elements is seen with SDGs 1, 11, 12, and 13. The economic-oriented SDGs are expected to have the greatest effects on all other categories (environmental, legal, health, and social).

We have discussed technocentrism and ecocentrism regarding UWM and developed novel propositions that set systemic and contextual priorities for the interactions between UWM and the SDGs. We are confident that our work will open fruitful research avenues with theoretical and practical implications for policymaking related to Agenda 2030 and its grand challenges.

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1 Introduction

Waste generation is an important grand challenge due to its impacts on the Sustainable Development (SD) domains (Burt et al., 2021; Lech, 2021; Singhal et al. 2021), including the environmental, social, economic, legal, and health aspects (De Neve & Sachs, 2020; Nobre, 2022). From 2019 to 2022, there has been an annual increase of 2 thousand kilos per inhabitant in global waste production (SENSONEO, 2019, 2022), with more than half of it being poorly managed and dumped in landfills, particularly in developing and underdeveloped countries such as Brazil (ABRELPE, 2022). This is a complex, multilevel, and multidimensional phenomenon (Nilsson et al., 2017) that requires further investigation.

Consequently, some authors have studied the impact of legislation, culture, and social acceptance on Urban Waste Management (UWM) approaches, such as the most efficient method to plan and lodge UWM strategies (Singhal et al. 2021; Younis & Mamdouh, 2021) and how to increase the social and governmental responsibility of waste generation (Shan et al., 2021; Younis & Mamdouh, 2021). Other authors have explored the relationship between UWM and the SD domains, such as how the waste chain can further economic development and environment preservation (Gomez-Sanabria et al., 2022; Lech, 2021; Magrini et al., 2021; Santos & Moreira, 2022) and the economic, social, and environmental drawbacks of poor UWM strategies (Costa & Dias, 2020; Magrini et al., 2021; Shan et al., 2021). Additionally, some authors have evaluated the impact of waste generation on the Sustainable Development Goals (SDGs), such as how UWM can favor SDGs progress (Gomez-Sanabria et al., 2022; Santos & Moreira, 2022; Younis & Mamdouh, 2021) and how local UWM can foster responsible production and consumption of natural resources (Pires & Martinho, 2019; Hassan et al., 2021).

Even though numerous studies have highlighted the importance of setting priorities to favor SD, UWM is still not optimized on a global level, resulting in persistent environmental, health, economic, and social implications (Costa & Dias, 2020; Gomez-Sanabria et al., 2022; Lech, 2021; Younis & Mamdouh, 2021). Furthermore, the analysis of the impact of a single SDG on UWM reveals its limited effectiveness, thus endangering the progress of Agenda 2030 by neglecting the interdependence between SDGs and the existence of synergies that can balance out trade-offs (Nilsson et al., 2016, 2018; Nobre, 2022).

To address the challenges outlined above, this article examines the interplay between UWM elements and the SDGs in order to generate new propositions for systemic and prioritized support of 2030 Agenda. We employed a three-step approach that utilized a seven-point scale framework and network analysis to investigate the interactions between UWM elements and the SDGs. The first step involved an integrative review of UWM literature to identify the concepts and elements that impact the progress of the SDGs. The second step entailed analyzing the potential synergies and trade-offs between UWM elements and the SDGs. In the final step, we conducted a further analysis of the interactions between the SDGs under the influence of UWM elements.

This paper is structured as follows: Section 2 provides a review of the relevant literature on UWM, SDGs, and their interactions. Section 3 presents the methodology, while Sections 4, 5, and 6 detail each approach and its results. Section 7 presents discussions and propositions, and Section 8 encompasses the conclusion, implications, and suggestions for further research.

2 Theoretical Foundation

2.1 Urban Waste Management (UWM)

The Urban Waste Management (UWM) is a set of policies and procedures designed to prioritize the reuse, recycling, and reduction of waste to avoid landfill disposal and the end of natural materials' life (Hassan et al, 2022; Pires & Martinho, 2019). This not only helps to improve people's well-being but also promotes environmental preservation (Grenville, Miller & Tsui, 2019; Lech, 2021; Pires & Martinho, 2019; Younis & Mamdouh, 2021).

Conversely, inefficient UWM strategies can lead to environmental degradation, health problems, and economic instability. For example, landfills can contribute to the greenhouse effect, and the proliferation of disease, and increase the risk of explosions, erosion, and flooding (Caldera, Desha & Dawes, 2017; Jain et al., 2016).

2.2 Sustainable Development Goals (SDG)

In 2015, the United Nations (UN) established Agenda 2030 to promote Sustainable Development (SD) globally, a process of meeting current society's needs without compromising the ability of future generations to do the same (WCDE, 1987, p.37; Reinhardt et al., 2019). This agenda contains 17 interdependent goals, divided into 169 targets (De Neve & Sachs, 2020; UN, 2015), and understanding these interdependencies is essential to create synergies that can compensate for any trade-offs (Nilsson et al., 2018; Nobre, 2022).

The Sustainable Development Goals (SDGs) are a global call to action to eradicate poverty and ensure the planet's prosperity, while also encouraging economic growth, reducing climate change, protecting the environment, and meeting social needs such as education, health, safety, and employment (UN, 2015; UN-Brazil, 2020; 2022).

2.3 SDG categorization

Based on the studies of De Neve & Sachs (2020) and Nobre (2022), Table 1 presents an organizational framework for the SDGs into the categories of environmental, social, economic, law, and health. This categorization is a valuable resource for analyzing the impacts of UWM on the progress of SDGs and understanding their interconnections.

Categories	SDGs							
Environment								
Economic								
Social								
Law								
Health								

Table 1 SDGs categorization (Source: Nobre, 2022)

2.4 Interactions between UWM and SDG

There is a growing interest in further exploring the impacts of UWM on the progress of the SDGs, as they are essential for both social well-being and the prosperity of the ecosystem and UWM strategies can foster sustainable development in cities (Santos & Moreira, 2022).

Previous studies have concluded that inefficient urban waste management processes are a threat to SDG 3 (Good Health and Well-Being), 6 (Clean Water and Sanitation), 12 (Responsible Consumption and Production), and 13 (Climate Action), impeding the advancement of environmental and health SDGs (Hassan et al., 2021). Other authors, such as Lech (2021), suggest that urban waste management can foster synergies for SDG 11 (Sustainable Cities and Communities) progress, as cities are the major consumers of environmental resources, and thus have a greater responsibility in implementing solutions to reduce waste generation.

3 Methods

This article outlines a threefold methodology presented in Figure 1: **(a)** Integrative Review (IR); **(b)** Level 1 (L1) and **(c)** Level 2 (L2) Analyses.

For step **(a)** an IR of the international literature was conducted oriented to answer the question: *How has UWM been defined and what elements impact the SDGs categories?* Step **(b)** combined the results from **(a)** and a seven-point scale framework adapted from Nilsson et. al (2018) to map interactions to respond: *What are the interactions between UWM and the SDGs?* The last step **(c)** advanced further analysis from the previous steps through Network concepts to answer the question: *How do interactions among SDGs happen under the UWM context?*

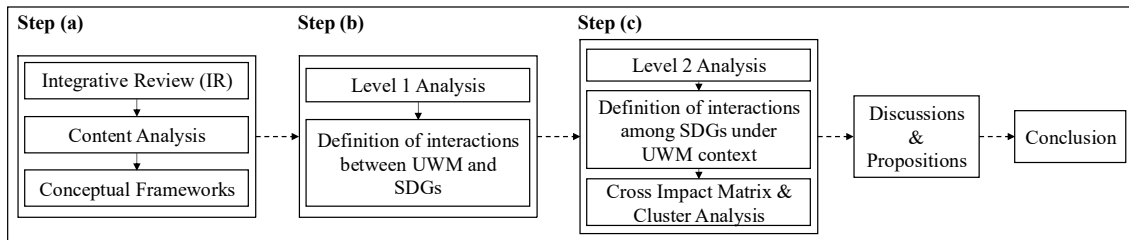


Figure 1 Synthesis of the threefold methodological approach

4 Integrative Review (IR)

The Integrative Review (IR) consisted of a three-part methodological approach, which is demonstrated in Figure 2. In the first part of the process, articles were searched for. The second part involved the selection and eligibility of the IR corpus papers. The third part of the process was a content analysis to answer the questions posed by the IR.

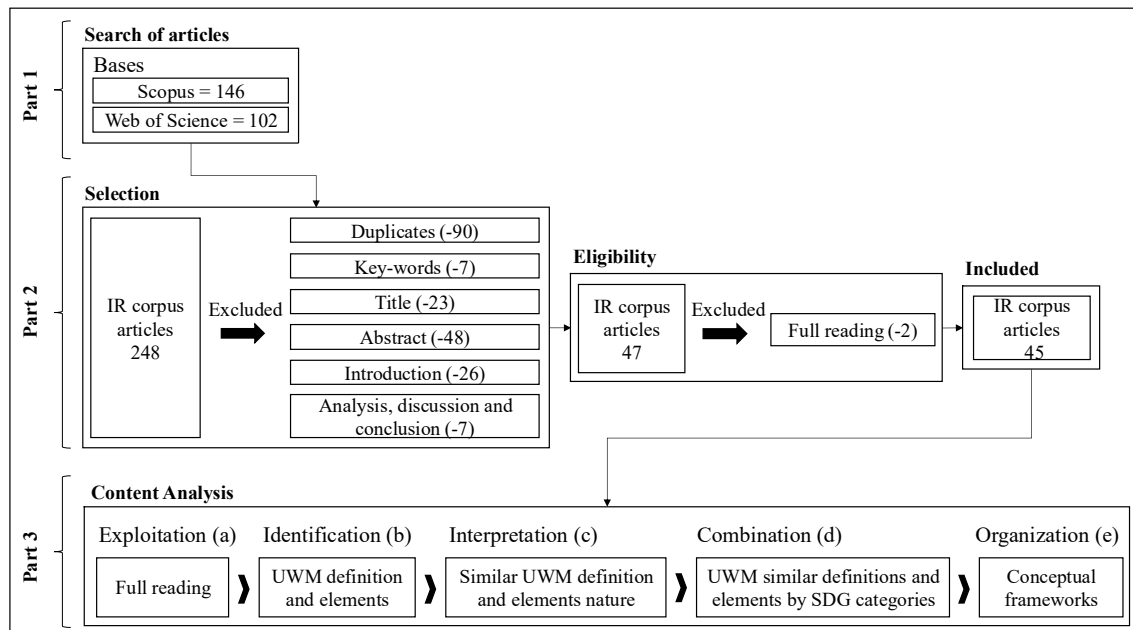


Figure 2 Synthesis of the methodological approach – Part 1: Integrative Review

Part 1 – Search for articles

A systematic search of peer-reviewed articles published in English between January 1988 and December 2022 was conducted using the Web of Science and Scopus scientific databases, which are widely used for social sciences research (De Bakker et al., 2006). The search was based on the main term “*urban waste management*”, combined with (AND) the variables of SD categories ((*environment** OR *ecolog** OR *clima**) OR *health* OR *econom** OR *law* OR *social*)) in the titles, keywords, and abstracts (Nobre, 2022). A total of 248 valuable articles were identified.

Part 2 – Selection of articles

First, any duplicate articles between the bases were eliminated. Second, after carefully reading each article's keywords, title, abstract, introduction, analysis, discussion, and conclusion, any papers that did not address the concept of UWM and its elements for each SDGs category were discarded. Finally, the remaining articles were read thoroughly and a corpus of 45 papers was compiled.

The following articles have been excluded from consideration: Diaz-Villavicencio, Didonet & Dodd (2017); Ghiani et al. (2013); Lupo & Cusumano (2018); and Toutouh, Rossit & Nesmachnow (2020) analyze the efficiency of UMW through Artificial Intelligence tools. Furthermore, Bruno, Bianchi & Sanchez (2022); Cruz (2007); Esposito, Dicorato & Doronzo (2021); Sternberg (2013); Wittmer (2022), and Wong (2016) investigated UWM from different perspectives, such as social behavior, feminism, and neoliberalism.

Part 3 – Content analysis

The content analysis was conducted in a five-section approach: **(a) Exploitation**, **(b) Identification**, **(c) Interpretation**, **(d) Combination**, and **(e) Organization** (Nobre & Morais-da-Silva, 2021).

To begin with, information pertinent to the IR research question was gathered from the relevant articles. Subsequently, the gathered data was tabulated by author, title, publication date, UWM definition, and its elements. Afterward, those definitions were

deciphered and the nature of the elements was allocated (synergy – promotes SDG progress – or trade-off – hinders SDG progress). Thereafter, UWM definitions were combined based on similarity, and the elements were sorted into SDGs categories in line with their effects described in Table 2. Finally, conceptual frameworks were constructed to depict the UWM concepts and the elements according to each SDGs category impact.

SDGs Category	Impact
Environmental	Ecosystem preservation, restoration, and longevity
Social	Quality of life and human rights assurance
Economic	Economic development
Law	Creation of partnerships, UWM regimentation, and coordination
Health	People's longevity and well-being

Table 2 Criteria to classify UWM elements into SDGs categories

4.1 Integrative Review Results

As a result of **Step (a)**, two conceptual frameworks were developed, presented in Tables 3 and 4. Table 3 contains nine definitions of UWM, while Table 4 classifies each UWM element based on its nature of interaction with each SDGs category.

5 Level 1 Analysis (L1)

The objective of the Level 1 Analysis was to perform an evaluation of the interactions between the UWM elements and the SDGs, based on a fourfold approach synthesized in Figure 3, a conceptual framework derived from the IR and a seven-point interaction scale adapted from Nilsson et al. (2018), to map synergies and trade-offs.

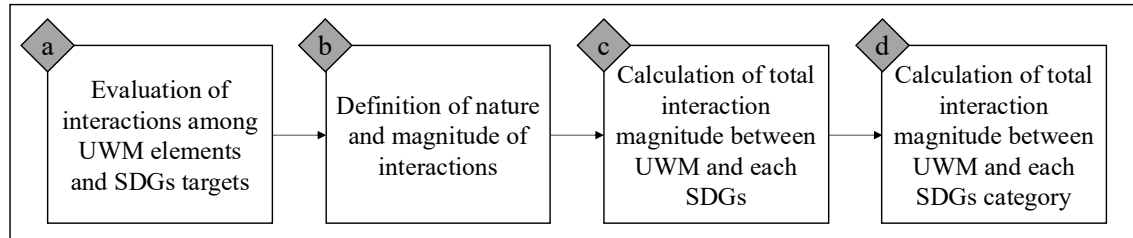


Figure 3 Synthesis of the methodological approach – Part 2: Level 1 Analysis (L1)

First, it was evaluated whether each UWM element has an impact on the achievement of SDG targets **(a)**. Second, the nature of such interactions was determined by applying a magnitude between +3 (completely synergic) and -3 (completely trade-off) based on a seven-point scale framework to map interactions, adapted from Nilsson et al. (2018), as presented in Table 5 **(b)**. Additionally, judgment was based on the results of the IR and content analysis of SDGs and their associated targets.

Magnitude	Nature	Interaction	Definition
> +2 and ≤ +3	Synergy	Very much positive	Inextricably related to SDGs progress
> +1 and ≤ +2	Synergy	Very positive	Facilitates SDGs progress
> 0 and ≤ +1	Synergy	Positive	Creates conditions for SDGs progress
0	Neutral	Consistent	No significant impact on SDGs progress
< 0 and ≥ -1	Trade-off	Negative	Limits SDGs progress
< -1 and ≥ -2	Trade-off	Very negative	Conflicts with SDGs progress
< -2 and ≥ -3	Trade-off	Very much negative	Makes SDGs progress impossible

Table 5 Seven-point scale framework to map interactions (Modified from source: Nilsson et al., 2018 and Nobre, 2022)

UWM short definition	UWM detailed definition	References
Policies for waste management	The UWM is a set of policies, processes, and methodologies designed to manage waste from its source to its final destination. The primary aim of UWM is to ensure the preservation of society, the environment, and the economy. However, its viability and effectiveness can be impacted by a variety of legal, financial, operational, technological, and social factors.	Aleluia & Ferrão, 2016; Bajçinovci, 2018; Bruni et al., 2020; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Filho et al., 2016.; Lech, 2021; Lee-Gailler & Kutting, 2021; Mukhtar et al., 2016; Romano & Molinos-Senante, 2020; Rutkowski & Rutkowski, 2015; Zand & Heir, 2021
The process to reduce threats	UWM involves distinct processes such as collection, transport, treatment, reuse, disposal, recycling, and educational activities, which enable communities and companies to avoid wastage practices that threaten society and the environment while improving pollution reduction from waste treatment cycles and energy efficiency.	Agarwal, Bardhan & Das, 2021; Aleluia & Ferrão, 2016; Bajçinovci, 2018; Bruni et al., 2020; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Cialani & Mortazavi, 2020; El-Fadel, 2005; Filho et al., 2016; Gastaldi et al., 2020; Lech, 2021; Lee-Gailler & Kutting, 2021; Magrini et al., 2021; Magrini, Pozzo & Bonoli, 2022; Romano & Molinos-Senante, 2020; Romano et al., 2022; Rutkowski & Rutkowski, 2015; Song et al., 2022; Tong and Tao, 2016
Circular economy articulator	The primary goal of UWM is to eliminate the production and disposal of waste in the environment. UWM seeks to transform the concept of waste from “garbage” to “feedstock” through waste reuse, conversion to high-quality material, and the encouragement of waste markets. In doing so, UWM promotes the circular economy and integrates society into its processes.	Agarwal, Bardhan & Das, 2021; Bruni et al., 2020; Cherubini, Bargigle & Ulgiati, 2008; Filho et al., 2016; Gastaldi et al., 2020; Lech, 2021; Reis, Mattos & Silva, 2018; Song et al., 2022
Waste Hierarchy articulator	UWM strategies should be aligned with the Waste Hierarchy, aiming for zero emissions through reuse and recycling processes. This approach can help to avoid the incineration of waste and its landfill disposal.	Agarwal, Bardhan & Das, 2021; Aleluia & Ferrão, 2016; Bruni et al., 2020; Cherubini, Bargigle & Ulgiati, 2008; Cialani & Mortazavi, 2020; Filho et al., 2016; Mukhtar et al., 2016; Shan, 2021
Sustainable development propeller	UWM seeks to develop and implement policies, techniques, and processes that will support the sustainable development of cities and have a positive effect on the environment and society.	Agarwal, Bardhan & Das, 2021; Aleluia & Ferrão, 2016; Bajçinovci, 2018; Bruni et al., 2020; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Hornsby et al., 2017; Lech, 2021; Magrini, Pozzo & Bonoli, 2022; Reis, Mattos & Silva, 2018; Romano & Molinos-Senante, 2020
Economic competitiveness, public health, and environmental quality generator	UWM is regarded as a crucial public and economic activity that is essential for generating market competitiveness, public health, and social well-being. Thus, strategies for utilizing waste materials must be economically viable, environmentally efficient, and socially acceptable to create a sustainable economy.	Bajçinovci, 2018; Cialani & Mortazavi, 2020; Gastaldi et al., 2020; Hornsby et al., 2017; Lee-Gailler & Kutting, 2021; Magrini et al., 2021; Magrini, Pozzo & Bonoli, 2022.; Mukhtar et al., 2016; Romano & Molinos-Senante, 2020; Rutkowski & Rutkowski, 2015
Integrated, holistic, multidimensional, and multi-stakeholder system	UWM involves operational and managerial activities with a diversity of formal and informal actors. In order to ensure an organized, impartial, and transparent manner of action, it is essential that all stakeholders involved act in a unified, multidimensional, and multi-stakeholder system.	Aleluia & Ferrão, 2016; Bajçinovci, 2018; Filho et al., 2016; Hornsby et al., 2017; Lech, 2021; Lee-Gailler & Kutting, 2021; Magrini, Pozzo & Bonoli, 2022.; Ramaswami, Baidwan & Nagpure, 2016; Romano et al., 2022; Rutkowski & Rutkowski, 2015; Tong and Tao, 2016
Management of waste from distinct sources	UWM has the goal of managing the flux of liquid and solid waste from a variety of sources, including domestic, commercial, industrial, agricultural, and public services.	Aleluia & Ferrão, 2016; Filho et al., 2016; Gastaldi et al., 2020; Mukhtar et al., 2016
Socio-ecologic system component	UWM is an integral part of the larger socio-ecological system and is influenced by external factors such as economic development, population size, resource availability, individual identity, human behavior, culture, corruption, and personal development. Consequently, UWM should be planned and implemented following local conditions to add value to the waste chain.	Aleluia & Ferrão, 2016; Bajçinovci, 2018; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Filho et al., 2016; Saldivia-Gonzatti, Jannes & Barreal, 2022.; Hornsby et al., 2017; Mukhtar et al., 2016; Romano et al., 2022; Song et al., 2022

Table 3 Urban Waste Management (UWM) definitions

SDGs categories	UWM elements		Reference
	Synergy	Trade-off	
Environmental (1)	(1) Development and implementation of modern infrastructures to manage and treat waste reducing environmental degradation; (2) Formal integration of workers in the waste chain to improve UWM efficiency and reduction of ecosystem's degradation; (3) Strategies to extend organic material's life cycle to foster sustainable agricultural practices; (4) Strategies to maximize resources usage, avoid waste disposal and environmental contamination; (5) Strategies to extend recyclable material's life to minimize natural resource extraction; (6) Generation and prioritization of clean energy in UWM processes to reduce the greenhouse effect.	(7) Landfills usage to dispose of material that implicates air, water, and soil pollution; (8) Secondary pollution from waste treatment that worsens the greenhouse effect.	Agarwal, Bardhan & Das, 2021; Akrou, Moore & Grimes, 2021; Aleluia & Ferrão, 2016; Bajcinovci, 2018; Bruni et al., 2020; Chan, 2016; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Cialani & Mortazavi, 2020; El-Fadel, 2005; Ezekwe & Arokoyu, 2017; Gastaldi et al., 2020; Hornsby et al., 2017; Indrosaptono & Syahbana, 2017; Lech, 2021; Lee-Gailler & Kutting, 2021; Lissah et al., 2021; Maclaren, 1988; Magrini, Pozzo & Bonoli, 2022; Mukhtar et al., 2016; Oduro-Appiah et al., 2020; Park & Gupta, 2015; Ramaswami, Baidwan & Nagpure, 2016; Randhawa et al., 2020; Reis, Mattos & Silva, 2018; Romano et al., 2022; Rutkowski & Rutkowski, 2015; Serrona & Yu, 2006; Shan, 2021; Song et al., 2022; Viva et al., 2020; Yu, Liu & Song, 2022.; Zand & Heir, 2021
Social (2)	(1) Strategies to generate local employment and foster the opportunity to propel higher living standards; (2) Development and implementation of modern infrastructures to manage and treat waste reducing drawbacks to people's quality of life; (3) Development of clear, enveloping, and transparent implementation strategies to spread sustainable UWM practices amongst the society; (4) Foment of interactions, responsibility awareness, and partnerships creation among actors in the waste chain to reach all citizens.	(5) Landfills usage to dispose of material threatening peoples' safety environment and disseminating diseases; (7) Prioritization of high society and urban areas needs causing class segregation of UWM strategies; (8) Lack of strategies to integrate and fulfill the needs of a diversity of actors in the waste chain.	Agarwal, Bardhan & Das, 2021; Akrou, Moore & Grimes, 2021; Aleluia & Ferrão, 2016; Bajcinovci, 2018; Bruni et al., 2020; Cervantes & Castellanos, 2022; Chan, 2016; Chaturvedi, 2003; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Cialani & Mortazavi, 2020; El-Fadel, 2005; Ezekwe & Arokoyu, 2017; Filho et al., 2016; Garcés et al, 2002; Gastaldi et al., 2020; Saldivia-Gonzatti, Jannes & Barreal, 2022.; Haastrup et al, 1998; Hornsby et al., 2017; Indrosaptono & Syahbana, 2017; Lech, 2021; Lee-Gailler & Kutting, 2021; LISSAH et al., 2021; Maclaren, 1988; Magrini et al., 2021; Magrini, Pozzo & Bonoli, 2022; Mukhtar et al., 2016; Oduro-Appiah et al., 2020; Ramaswami, Baidwan & Nagpure, 2016; Randhawa et al., 2020; Reis, Mattos & SILVA, 2018; Romano & Molinos-Senante, 2020; Romano et al., 2022; Romano, Masserini & Lombardi, 2021; Rutkowski & Rutkowski, 2015; Shan, 2021; Song et al., 2022; Tong and Tao, 2016; Tvedten & Candiracci, 2018; Viva et al., 2020; Yu, Liu & Song, 2022; Zand & Heir, 2021
Economic (3)	(1) Strategies to extend recyclable material's life cycle such as reuse of materials to foment circular economy; (2) Generation and prioritization of clean energy in UWM processes to reduce local costs; (3) Strategies to maximize resources usage such as the selective collection of waste to produce high-quality second-hand feedstock; (4) Strategies to generate employment and foster local economy; (5) Efficient coordination and control of processes at every point of the waste chain to avoid corruption and economic inflation; (6) Foment of interactions, responsibility awareness, and partnership creation amongst actors in the waste chain to increase UWM efficiency and reduce local costs.	(7) Landfills usage to dispose of material increasing transportation, maintenance, and drawbacks costs; (8) Secondary pollution from waste treatment processes increases costs to preserve communities' well-being.	Agarwal, Bardhan & Das, 2021; Akrou, Moore & Grimes, 2021; Aleluia & Ferrão, 2016; Bajcinovci, 2018; Bruni et al., 2020; Chan, 2016; Chaturvedi, 2003; Chifari et al., 2018; Cherubini, Bargigle & Ulgiati, 2008; Cialani & Mortazavi, 2020; Ezekwe & Arokoyu, 2017; Filho et al., 2016; Gastaldi et al., 2020; Saldivia-Gonzatti, Jannes & Barreal, 2022.; Haastrup et al, 1998; Hornsby et al., 2017; Indrosaptono & Syahbana, 2017; Lech, 2021; Lee-gailler & Kutting, 2021; Lissah et al., 2021; Maclaren, 1988; Magrini et al., 2021; Magrini, Pozzo & Bonoli, 2022; Mukhtar et al., 2016; Oduro-appiah et al., 2020; Park & Gupta, 2015; Ramaswami, Baidwan & Nagpure, 2016; Randhawa et al., 2020; Reis, Mattos & Silva, 2018; Romano & Molinos-senante, 2020; Romano et al., 2022; Romano, Masserini & Lombardi, 2021; Rutkowski & Rutkowski, 2015; Serrona & Yu, 2006; Shan, 2021; Song et al., 2022; Tong and Tao, 2016; Tvedten & Candiracci, 2018; Viva et al., 2020; Yu, Liu & Song, 2022
Law (4)	(1) Planning and implementation of efficient and all classes embracing waste regulations and legislations; (2) Efficient coordination and control of processes at every point of the UWM chain; (3) Foment of interactions, responsibility awareness, and partnership creation among actors in the waste chain.	(4) Lack of control and efficient regulations on waste markets to avoid corruption.	Akrou, Moore & Grimes, 2021; Aleluia & Ferrão, 2016; Bajcinovci, 2018; Bruni et al., 2020; Cervantes & Castellanos, 2022; Chan, 2016; Chaturvedi, 2003; Chifari et al., 2018; Cialani & Mortazavi, 2020; El-fadel, 2005; Ezekwe & Arokoyu, 2017; Filho et al., 2016; Garcés et al, 2002; Gastaldi et al., 2020; Saldivia-Gonzatti, Jannes & Barreal, 2022.; Haastrup et al, 1998; Hornsby et al., 2017; Indrosaptono & Syahbana, 2017; Lech, 2021; Lee-gailler & Kutting, 2021; Lissah et al., 2021; Maclaren, 1988; Magrini et al., 2021; Mukhtar et al., 2016; Oduro-appiah et al., 2020; Park & Gupta, 2015; Ramaswami, Baidwan & Nagpure, 2016; Randhawa et al., 2020; Reis, Mattos & Silva, 2018; Romano & Molinos-senante, 2020; Romano et al., 2022; Romano, Masserini & Lombardi, 2021; Rutkowski & Rutkowski, 2015; Serrona & Yu, 2006; Shan, 2021; Tong and Tao, 2016; Tvedten & Candiracci, 2018; Yu, Liu & Song, 2022; Zand & Heir, 2021
Health (5)	(1) Assuring practices that promote labor safety for all in the waste sector; (2) Strategies to efficiently collect waste in urban and rural areas, reducing waste accumulation and diseases; (3) Strategies to extend recyclable material's life cycle such as the reuse of materials to preserve the social environment and society's quality of life.	(4) Secondary pollution from waste treatment is a low efficient process that aggravates health problems.	Aleluia & Ferrão, 2016; Astaldi et al., 2020; Bajcinovci, 2018; Chan, 2016; Ezekwe & Arokoyu, 2017; Lee-gailler & Kutting, 2021; Lissah et al., 2021; Oduro-appiah et al., 2020; Ramaswami, Baidwan & Nagpure, 2016; Randhawa et al., 2020; Reis, Mattos & Silva, 2018; Romano, Masserini & Lombardi, 2021; Rutkowski & Rutkowski, 2015; Serrona & Yu, 2006; Tong and Tao, 2016.; Tvedten & Candiracci, 2018; Zand & Heir, 2021

Table 4 UWM elements by SDGs categories

As an example, the interaction between Element (1) from the Environmental SDGs category and Target 2.1 (SDG 2 - Zero Hunger) was assigned a magnitude of +2, based on authors such as Filho et al. (2016) who claim that modern infrastructure to manage and treat waste can be utilized as local tools to benefit the economy, environment, and society by reducing hunger, promoting sustainable production, and conserving the ecosystem. Finally, the total magnitude of interactions between UWM and each SDG was determined using Equation 1 (c) and UWM and each SDGs category through Equation 2 (d).

$$TMG_{sdg=1,...,17} = \frac{\sum_{e_{sdg}=1,...,E_{sdg}}^{E_{SDG}} \frac{\sum_{sg=1,...,SG}^{SG} MG_e(sg)}{SG}}{E_{sdg}}$$

$TMG_{SDG=1,...,17}$ = Total magnitude of interaction between UWM and each SDG ($sdg=1,...,17$)

MG_e = Magnitude of interaction between each UWM element and each SDGs target

SG = Total target of analyzed SDG

sg = Target sg ($sg=1,...,SG$) of analyzed SDG

E_{SDG} = Total UWM elements of analyzed SDGs category

e_{SDG} = UWM elements ($e_{SDG}=1,..., E_{SDG}$) of analyzed SDGs category

Equation 1 Total Magnitude (TMG_{SDG}) of interaction among UWM elements and each SDG

$$TMG_{ca=1,...,5} = \frac{\sum_{SDG_{ca}=1,...,SDG_{CA}}^{SDG_{CA}} TMG_{SDG}}{SDG_{CA}}$$

$TMG_{ca=1,...,5}$ = Total magnitude of interaction between UWM and each SDGs category ($ca=1,...,5$)

$TMG_{SDG=1,...,17}$ = Total magnitude of interaction between UWM and each SDG ($sdg=1,...,17$)

SDG_{CA} = Total SDGs of analyzed category

SDG_{ca} = SDG ($SDG_{ca}=1,..., SDG_{CA}$) from the analyzed category

Equation 2 Total magnitude (TMG_{ca}) of interaction between UWM and each SDGs category

5.1 Level 1 Analysis Results

Through the Level 1 Analysis, it was possible to determine the interactions between UWM and SDGs synthesized in Table 6. The SDGs categories are presented in the first column, along with their respective oriented SDGs in the second column. Following this, there are the magnitude, nature, specification, and definition of each interaction. The total impact of UWM on each SDGs category results from the average calculation of its SDGs magnitudes. For instance, for the law category, the total interaction is the average of the magnitudes of SDGs 16 and 17.

6 Level 2 Analysis (L2)

By using the conceptual framework of UWM elements from the IR and the SDGs interactions results from Level 1, Level 2 Analysis aimed to understand how the internal SDGs of each category (SDGs-L1) interact with the external SDGs of each category (SDGs-L2) under the context of the UWM. Figure 4 presents a synthesized fivefold approach for this analysis.

Category	SDGs	Magnitude	Nature	Interaction	Definition
Environmental	2	+1.01	Synergy	Very positive	UWM environmental elements <i>facilitate</i> SDG 2 progress
	6	+0.93	Synergy	Positive	UWM environmental elements <i>create conditions</i> for SDG 6 progress
	7	+0.91	Synergy	Positive	UWM environmental elements <i>create conditions</i> for SDG 7 progress
	11	+1.48	Synergy	Very positive	UWM environmental elements <i>facilitate</i> SDG 11 progress
	12	+1.45	Synergy	Very positive	UWM environmental elements <i>facilitate</i> SDG 12 progress
	13	+1.04	Synergy	Very positive	UWM environmental elements <i>facilitate</i> SDG 13 progress
	14	+0.61	Synergy	Positive	UWM environmental elements <i>create conditions</i> for SDG 14 progress
	15	+0.71	Synergy	Positive	UWM environmental elements <i>create conditions</i> for SDG 15 progress
	Average	+1.02	Synergy	Very positive	UWM <i>facilitates</i> progress on environmental-oriented SDGs
Social	4	+1.11	Synergy	Very positive	UWM social elements <i>facilitate</i> SDG 4 progress
	8	+1.02	Synergy	Very positive	UWM social elements <i>facilitate</i> SDG 8 progress
	9	+1.04	Synergy	Very positive	UWM social elements <i>facilitate</i> SDG 9 progress
	Average	+1.06	Synergy	Very positive	UWM <i>facilitates</i> progress on social-oriented SDGs
Economic	1	+1.45	Synergy	Very positive	UWM economic elements <i>facilitate</i> SDG 1 progress
	5	+0.99	Synergy	Positive	UWM economic elements <i>create conditions</i> for SDG 5 progress
	10	+1.35	Synergy	Very positive	UWM economic elements <i>facilitate</i> SDG 10 progress
	Average	+1.17	Synergy	Very positive	UWM <i>facilitates</i> progress on economic-oriented SDGs
Law	16	+0.31	Synergy	Positive	UWM law elements <i>create conditions</i> for SDG 16 progress
	17	+0.47	Synergy	Positive	UWM law elements <i>create conditions</i> for SDG 17 progress
	Average	+0.39	Synergy	Positive	UWM <i>creates conditions</i> for progress on law-oriented SDGs
Health	3	+1.04	Synergy	Very positive	UWM health elements <i>facilitate</i> SDG 3 progress
	Average	+1.04	Synergy	Very positive	UWM <i>facilitates</i> progress on health-oriented SDG

Table 6 L1 results synthesis – UWM impact on SDGs and their categories

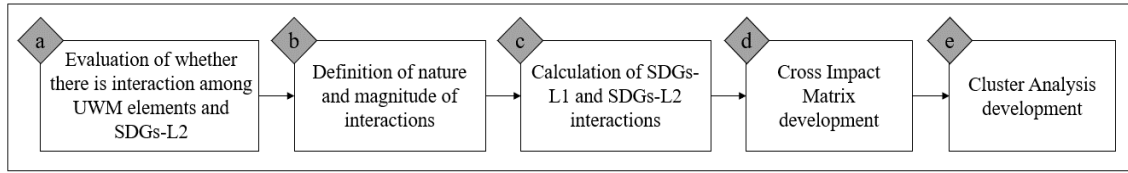


Figure 4 Synthesis of the methodological approach – Part 3: Level 2 Analysis (L2)

To evaluate the interactions between UWM elements and SDGs-L2 targets, a judgment was made based on IR results and content analysis of the SDGs and their targets **(a)**. For example, the UWM element (1) from the environmental category interacts with target 1.1 (SDG 1 – No Poverty), as Bruni et al. (2020) and Song et al. (2022) suggest that modern infrastructures to manage and treat waste can increase communities' quality of life and well-being by creating employment and reducing landfills usage, pollution, and diseases.

When no interaction between UWM elements and SDGs-L2 targets was detected, the magnitude was set to zero, otherwise, it was calculated using Equation 3. With this definition of UWM and SDGs-L2 interaction magnitude, the total interaction between each SDGs-L1 and SDGs-L2 could be determined using Equation 4 **(b)**.

Following this, Network concepts were used to develop a cross-impact matrix that highlighted the main impacts of SDGs-L1 on SDGs-L2 **(d)**, and cluster analysis was used to evaluate the interdependence behavior of SDGs categories under UWM context **(e)**.

$$MGEL_{ods=1,...,17} = \frac{\sum_{sg=1,...,SG} MG_e(sg)}{SG}$$

$MGEL_{sdg=1,...,17}$ = Magnitude of interaction between each UWM element and SDGs-L2 ($sdg=1, ..., 17$)

MG_e = Magnitude of interaction between each UMW element and each SDGs-L1 target

SG = Total targets of SDGs-L1

sg = Target sg ($sg=1, ..., SG$) of SDGs-L1

Equation 3 Interaction magnitude of each UWM element and SDGs-L2

$$MGL_{sdg=1,...,17} = \frac{\sum_{e_{SDG}=1,...,E_{SDG}}^{E_{SDG}} MGEP_{sdg}}{E_{SDG}}$$

$MGL_{sdg=1,...,17}$ = Magnitude of interaction between each SDGs-L1 and SDGs-L2 ($sdg=1, ..., 17$)

$MGEL_{sdg=1,...,17}$ = Magnitude of interaction between each UWM element and SDGs-L2 ($sdg=1, ..., 17$)

E_{SDG} = Total UWM elements from the analyzed category for SDGs-L2

e_{SDG} = UWM elements ($e_{SDG}=1, ..., E_{SDG}$) from the analyzed category for SDGs-L2

Equation 4 Interaction magnitude between each SDGs-L1 and SDGs-L2 under UWM context

6.1 Level 2 Analysis Results

Through Level 2 Analysis, it was possible to compile two main results: the magnitude of interactions between the SDGs (cross-impact matrix) and the interdependency behavior among the SDGs and their categories (cluster analysis).

The cross-impact matrix (Table 7) contains the SDGs-L1 in its lines and SDGs-L2 in its columns. For each crossing point, there is a magnitude of the interaction between the two SDGs, where grey indicates neutrality, blue indicates a positive interaction, and green indicates a very positive interaction. Additionally, the diagonal has no interaction since it represents the SDGs' impact on itself (Weitz et al., 2017). Furthermore, the purple

sum of magnitudes highlights the most synergistic interactions for the successful implementation of Agenda 2030.

	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17	SDGs-L1 Foster interactions
SDG 1		0.82	0.41	0.21	1.25	0.63	0.84	0.04	0.27	1.37	1.15	0.94	1.07	0.21	0.57	0.30	0.00	10.1
SDG 2	0.96		0.38	0.09	0.27	0.96	0.83	0.54	0.08	0.36	1.17	1.16	1.06	0.69	0.70	0.15	0.00	9.4
SDG 3	1.05	0.32		0.05	0.41	0.32	0.39	0.32	0.13	0.40	0.62	0.40	0.60	0.10	0.29	0.09	0.00	5.5
SDG 4	0.84	0.49	0.21		0.44	0.44	0.59	1.22	1.26	0.61	0.59	0.82	0.94	0.12	0.33	0.25	0.05	9.2
SDG 5	0.99	0.50	0.29	0.17		0.44	0.45	0.01	0.24	0.89	0.75	0.65	0.74	0.14	0.37	0.21	0.00	6.8
SDG 6	0.91	0.79	0.35	0.05	0.21		0.93	0.48	0.11	0.35	1.10	1.15	1.07	0.70	0.71	0.16	0.00	9.1
SDG 7	0.85	0.74	0.31	0.01	0.17	0.93		0.46	0.14	0.28	1.03	1.02	0.94	0.73	0.67	0.18	0.00	8.5
SDG 8	0.78	0.46	0.20	1.08	0.42	0.40	0.51		1.12	0.56	0.55	0.74	0.84	0.12	0.30	0.22	0.08	8.4
SDG 9	0.79	0.47	0.24	1.12	0.38	0.50	0.62	1.12		0.51	0.60	0.76	0.86	0.13	0.35	0.23	0.06	8.7
SDG 10	1.35	0.74	0.35	0.16	1.15	0.61	0.77	0.03	0.34		1.03	0.91	1.08	0.22	0.57	0.31	0.00	9.6
SDG 11	1.39	1.20	0.58	0.13	0.39	1.40	1.20	0.78	0.11	0.55		1.72	1.59	1.02	1.03	0.21	0.00	13.3
SDG 12	1.35	1.18	0.55	0.10	0.35	1.40	1.20	0.76	0.13	0.51	1.67		1.54	1.03	1.03	0.22	0.00	13.0
SDG 13	0.99	0.84	0.40	0.09	0.28	1.01	0.90	0.56	0.10	0.38	1.21	1.22		0.75	0.73	0.16	0.00	9.6
SDG 14	0.61	0.53	0.21	0.03	0.14	0.65	0.66	0.32	0.09	0.22	0.74	0.79	0.71		0.48	0.11	0.00	6.3
SDG 15	0.66	0.60	0.24	0.01	0.13	0.73	0.69	0.36	0.08	0.24	0.83	0.86	0.78	0.54		0.12	0.00	6.9
SDG 16	0.31	0.20	0.12	0.04	0.19	0.16	0.29	0.18	0.22	0.23	0.23	0.30	0.38	0.07	0.16		0.23	3.3
SDG 17	0.46	0.31	0.15	0.06	0.23	0.25	0.44	0.25	0.32	0.34	0.36	0.44	0.54	0.11	0.24	0.21		4.7
SDGs-L2 Receiver interactions	14.3	10.2	5.0	3.4	6.4	1.8	11.3	7.4	4.7	7.8	13.6	13.9	14.7	6.7	8.5	3.1	0.4	

Table 7 Cross impact matrix – SDGs interactions under UWM context (Modified from source: Weitz et al., 2017).

Figure 5 graphically depicts the most synergistic interactions between SDGs-L1 and SDGs-L2. The arrows signify the direction of impact between the SDGs, the circle size indicates the magnitude and the colors follow the same rules as the matrix.

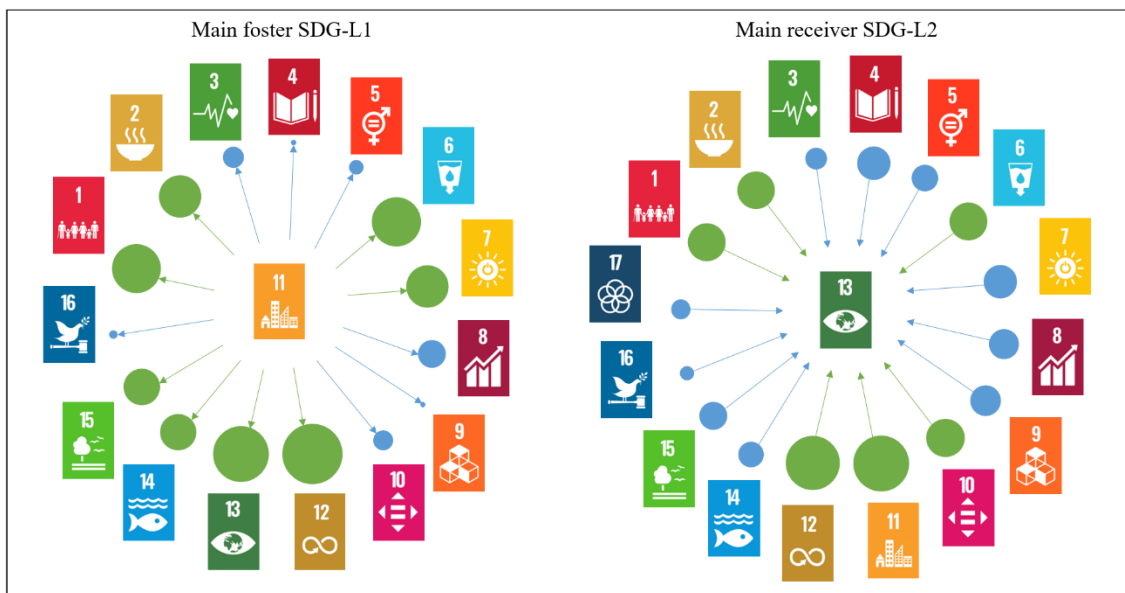


Figure 5 Graphic representation of most synergistic interactions between SDGs under UWM context

Finally, Figure 6 is a network multigraph that presents the SDGs divided into clusters based on their similar interaction behavior towards others from Agenda 2030. The arrows' colors indicate the nature of the interactions, where grey is neutral, blue is positive and green is very positive. Furthermore, the size of the SDGs indicates its total impact on others.

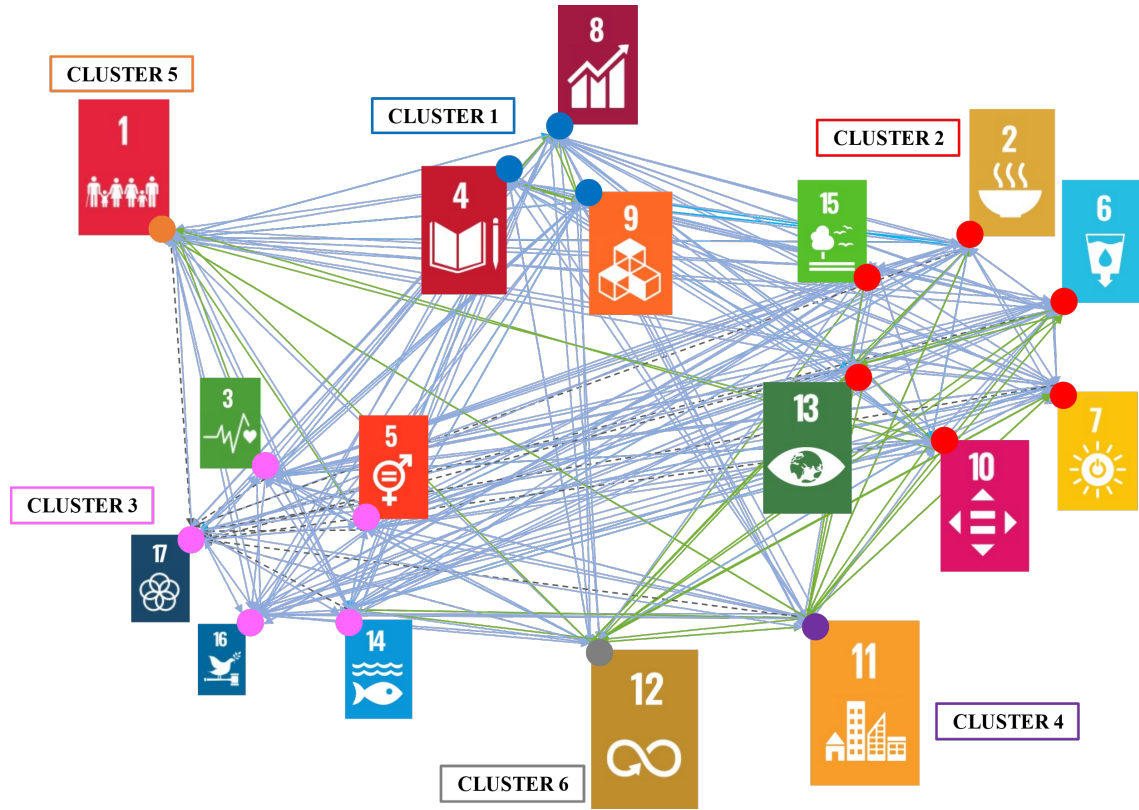


Figure 6 Network multigraph of SDGs interactions under UWM context divided into clusters

7 Discussions and Propositions

This section presents discussions of the interactions between UWM elements and the SDGs to foster new propositions for creating systemic and priority-setting approaches that support the 2030 Agenda.

Urban Waste Management conceptualization

The Integrative Review (IR) revealed nine Urban Waste Management (UWM) concepts, with the most popular being "The processes to reduce threats". In accordance with the Sustainable Spectrum Theory, the concept was evaluated based on seven characteristics (resource change, identity, power, type of economy, green labels, management strategies, and ethics) to ascertain the level of sustainability fomented by UWM: technocentric (weak sustainability) or ecocentric (strong sustainability) (Landrum, 2017).

Source of change: UWM has adapted to environmental changes (weak sustainability) by shifting the waste concept to the reuse of materials (Filho et al. 2016), thereby demonstrating its commitment to resource conservation.

Identity: As noted by Magrini, Pozzo, and Bonili (2022), UWM has an interdependent number of actors to facilitate its processes implementation (weak

sustainability) through the formation of partnerships, the increased specialization of employees, and the combining of transversal knowledge (Bajçinovci, 2018; Song et al., 2022).

Power: Urban waste managers have created policies, regulations, and educational materials regarding waste management (weak sustainability) to ensure UWM efficiency through its coordination and enforcement of sanctions (Lech, 2021).

Type of economy: UWM fosters sustainable markets (weak sustainability) by enhancing economic competitiveness through a circular economy (Magrini et al., 2021; Lech, 2021).

Green labels: UWM has a priority to promote sustainability through the application of a waste process hierarchy that emphasizes the prevention of waste generation (strong sustainability) rather than reuse and recycling (weak sustainability) (Lech, 2021; Agarwal, Bardhan & Das; 2021; Cialani & Mortazavi, 2020).

Management strategies: UWM maintains a commitment to weak sustainability by pursuing strategies that reduce environmental degradation and enhance the quality of life of its population (Lee-Gailler & Kutting, 2021; Romano & Molinos-Senante, 2020).

Ethics: UWM aims to preserve the ecosystem (weak sustainability) through strategies that focus on the health of the community and making resources available to all citizens (Rutkowski & Rutkowski, 2015; Bajçinovci, 2018; Cialani & Mortazavi, 2020).

Due to the fact that most characteristics of UWM are assessed as being weak, we propose:

Proposition 1. If UWM strategies align their level of identity, power, type of economy, management strategies, source of change, and ethics to a strong and sustainable development, it will be able to achieve an ecocentric approach.

This subsection corroborated the integrative review results related to UWM definitions and revealed that waste management strategies can foster sustainable development at a weak-oriented level.

7.1 UWM and SDGs interactions

Level 1 Analysis results enabled the formulation of propositions regarding interactions among Urban Waste Management (UWM) elements and environmental, social, economic, law, and health-oriented Sustainable Development Goals (SDGs).

7.1.1 Impact of UWM on environmental-oriented SDGs

The analysis of environmental UWM elements and their impacts on the SDGs has corroborated the understanding of principles that can promote synergies that compensate for trade-offs to improve the preservation of the environment and even its reconstruction.

Generating clean energy and adopting modern infrastructures to manage and treat waste are the most synergic UWM elements to support environmental-oriented SDGs, as they reduce the emission of greenhouse gases, prevent the disposal of materials in landfills, and avoid environmental degradation (Lech, 2021; Magrini et al., 2021; Song et al., 2022). However, landfill usage and secondary pollution from waste treatment techniques present trade-offs, as they can pollute the air, soil, and water (Bruni et al., 2020; Cialani & Mortazavi, 2020; Oduro-Appiah et al., 2020).

Given that UWM can foster environmental-oriented SDGs by promoting the longevity of the ecosystem but also present threats to society's prosperity, we suggest:

Proposition 2. As UWM provides solutions for generating clean energy and modern infrastructure for managing and treating waste, it can facilitate the reduction of hunger and the increase of sustainable agricultural practices (SDG 2), promote lasting quality of water and land life (SDG 13, 14 & 15), provide sanitation and clean water for communities (SDG 6), and facilitate the development of a responsible chain of materials (SDG 7 & 12).

Proposition 3. If UWM refrains from using landfills and reduces secondary pollution from its processes, it can reduce threats to the ecosystem.

7.1.2 Impact of UWM on social-oriented SDGs

The analysis of social UWM elements and their impacts on the SDGs has led to the comprehension of directions to promote synergies that compensate for trade-offs and elevate society's dignity and quality of life.

Employment and partnerships generation are the most synergistic UWM elements to foster social-oriented SDGs for promoting safety, social resilience, and integration of the poor, immigrants, and women (Chifari et al., 2018; Filho et al., 2016; Lee-Gailler & Kutting, 2021), as well as boosting UWM strategies (Bruni et al., 2020; Lissah et al., 2021; Oduro-Appath et al., 2020). However, social prejudice diminishes human dignity and nourishes social exclusion (Filho et al., 2016; Randhawa et al., 2020; Tvedten & Candiracci, 2018).

Therefore, given that UWM can promote employment, social integration, and partnerships among actors in the waste chain, but also implies negative effects on social well-being and development, we suggest:

Proposition 4. UWM will facilitate the development and access to quality education (SDG 4), employment (SDG 8), and innovation to promote sustainable industrial development (SDG 9) through the creation of secure employment and partnerships among UWM actors.

Proposition 5. If UWM strategies are inclusive and accessible to all, it can lead to an improved quality of life and well-being for citizens.

7.1.3 Impact of UWM on economic-oriented SDGs

The analysis of economic UWM elements and their impacts on the SDGs has corroborated the detection of principles to elevate economic development and improve the standard of living of society.

Controlling UWM processes and establishing partnerships among UWM actors are the most synergistic elements for favoring economic-oriented SDGs, reducing corruption in the waste sector, and mitigating inflation in waste markets (Gastaldi et al., 2020; Reis, Mattos & Silva, 2018; Romano, Masserini & Lombardi, 2021; Rutkowski & Rutkowski, 2015). However, the usage of landfills increases transportation and pollution management costs (Agarwal, Bardhan & Das, 2021; Magrini et al., 2021; Romano et al., 2022).

Because UWM reduces corruption through coordination of the waste sector and creates conditions for partnerships but also implicates trade-offs for local economic improvement, we suggest:

Proposition 6. Due to the coordination of UWM and the formation of partnerships among actors in the waste chain, it will assist in reducing poverty (SDG 1), thus

diminishing local and global inequalities (SDG 10) while also promoting gender equality (SDG 5).

Proposition 7. If UWM implements strategies that forego the use of landfills, it will be possible to reduce the economic deficit, inflation, and excessive costs associated with waste management processes.

7.1.4 Impact of UWM on law-oriented SDGs

The analysis of law UWM elements and its impacts on the SDGs substantiated the comprehension of precepts to foment partnerships among nations and the development of efficient waste sector regiments and coordination.

Partnership creation and transparency have been identified as the most synergic elements for fostering law-oriented SDGs progress, as they involve the whole society in the waste chain (Lech, 2021; Lissah et al., 2021; Tvedten & Candiracci, 2018) and boost strategies efficiency while decreasing corruption (Lissah et al., 2021; Magrini et al., 2021; Reis, Mattos & Silva, 2018; Tvedten & Candiracci, 2018). However, corruption in the waste sector presents trade-offs, as it reduces UWM efficiency due to poor regulations and coordination (Lee-Gailler & Kutting, 2021; Romano et al., 2022; Romano, Masserini & Lombardi, 2021).

Due to the fact that UWM creates partnerships between stakeholders in the waste sector, and applies transparent processes that involve the entire community while also implying trade-offs for the local development of the waste sector, we suggest:

Proposition 8. By fostering partnerships among waste chain actors and implementing clear UWM strategies, it will create conditions for maintaining and establishing peace, justice, and partnerships in the sector worldwide (as per SDG 16 & 17).

Proposition 9. If UWM strategies reduce corruption in the waste sector, it will be possible to avoid barriers to partnerships and efficient coordination of local processes.

7.1.5 Impacts of UWM on health-oriented SDG

The analysis of UWM elements and their impacts on the SDG 3 has corroborated the understanding that certain precepts are essential to human health and well-being.

Labor safety and selective collection of waste are the most synergic elements for promoting progress towards the health SDG, in order to avoid the aggravation of health problems, the spread of diseases, and the improvement of people's well-being (Shan, 2021; Tvedten & Candiracci, 2018; Zand & Heir, 2021). However, secondary pollution from waste treatment processes may lead to trade-offs, such as the emission of pollutants into water, air, and soil (Lissah et al., 2021; Tong & Tao, 2016; Zand & Heir, 2021).

Because UWM strategies improve the quality of life, health, and safety for the local population, as well as having implications for citizens' life, we suggest:

Proposition 10. UWM strategies promote labor safety and the selective collection of waste, which will facilitate the development and improvement of the population's good health and well-being (SDG 3).

Proposition 11. If UWM strategies reduce secondary pollution from waste treatment processes, it will be possible to enhance people's health, well-being, and quality of life.

7.1.6 Impacts of UWM on SDG categories

The analysis of UWM elements and their interactions with the 17 SDGs according to their categorization facilitates the comprehension of the primary impacts the sector implies to promote SD.

The average synergic impact of UWM is most significant for the economic, social, health, environmental, and legal SDGs categories, respectively. This favors *Proposition 1*, which emphasizes that UWM strategies foster waste markets and economic competitiveness through a circular economy (Lech, 2021; Shan, 2021), but neglects some social and environmental needs in terms of strategies to reduce ecosystem degradation instead of restructuring (Ezekwe & Arokoyu, 2017; Bruni et al., 2020; Lech, 2021). Therefore, it is suggested that:

Proposition 12: As long as UWM maintains a weak sustainability strategy, the social and environmental SDGs categories are unlikely to be the primary beneficiaries of the waste sector for the progress of the 2030 Agenda.

7.2 Interactions among SDGs under UWM context

The results of Level 2 Analysis, combined with Network theory concepts, enabled the development of propositions regarding the interactions and interdependencies of the Sustainable Development Goals (SDGs) within the Urban Waste Management (UWM) context, as discussed below.

7.2.1 Overview of interactions among SDGs under UWM context

The understanding of systemic interactions between SDGs and the circumstances under which synergies or trade-offs are stimulated provides a robust basis for prioritizing SDGs efforts (Weitz et al., 2017; Nilsson et al., 2018). The cross-impact matrix, as a tool designed to facilitate the analysis of relationships between variables, can propel an in-depth understanding of Agenda 2030 to guide the development of strategies to maximize the potential of UWM in boosting sustainable development (Nilsson et al., 2018).

Analysis of the matrix designed with SDGs-L1 impacts over SDGs-L2 indicates that 90% of the interactions are synergistic, thus mitigating the trade-offs implied by the UWM context. This suggests that UWM generally has a positive influence on SDGs inter-relations and progress in one area can make it easier for other goals to be achieved as well (Weitz et al., 2017). Due to its importance for human health, environmental quality, economic competitiveness, and the ecosystem's longevity, UWM is a sector of economic and public interest (Magrini et al., 2021), making it a key factor in ensuring the success of the SDGs.

The higher row-sum value indicates that SDG 13 (Climate Action) receives a positive influence from other SDGs and has low control or independency over its own progress or retraction (Weitz et al., 2017). Magrini et al. (2021) state that a combination of distinct UWM strategies, such as prevention, reuse, recycling, and decomposition of organic matter to generate fertilizers and clean energy, can help to achieve greater progress on SDG 13 (Climate Action).

On the other hand, the highest column-sum suggests that SDG 11 (Sustainable Cities and Communities) is the most influential way to promote progress on Agenda 2030 under the UWM context (Weitz et al., 2017). It is likely that this result is due to effective UWM strategies that can reduce air (SDG 13), soil (SDG 15), and water (SDG 14) pollution while mitigating human health threats (SDG 3) and fostering financial stability

through sustainable practices (SDG 1, 2, 8, 9 and 12) (Bardhan & Das, 2021; Bruni et al., 2020; Magrini et al., 2021; Song et al., 2022; Viva et al., 2020). Therefore, we suggest:

Proposition 13: As UWM elements are consistent with SDG categories such as environmental, social, economic, legal, and health, it will be possible to balance and compensate for any conflicts in progress toward Agenda 2030, resulting in a greater impact on SDG 13 (Climate Action).

Proposition 14: If UWM involves processes to foster communities' sustainable development (SDG 11), it will maximize its potential to further progress within the scope of Agenda 2030.

7.2.4 Interactions among SDGs-L1 (fosters of progress) and SDGs-L2 (receivers of progress)

Even though the cross-impact matrix provides an overview of the SDGs' net influence on each other and the magnitude of such interactions, it does not ease the decision-making on setting prioritizations nor where to focus action to foster the most progress on Agenda 2030 under the UWM context (Weitz et al., 2017). Moreover, since interactions among the SDGs are not symmetric, Weitz et al. (2017) suggest the use of Network Theory to develop multigraphs that not only emphasize the magnitude and the direction of interactions, but also the representation of multiple uneven links among the SDGs, which can be grouped in clusters according to their behavior similarity. Thus, this facilitates the comprehension of the SDGs' interdependencies.

Through the results of the clustering analysis, it is possible to conclude that the social category has minor interdependency with other categories from Agenda 2030, since its SDGs were grouped singularly in the same cluster. Moreover, it can be assumed that SDGs from the economic and environmental categories have the most interdependencies, since they were allocated together in two distinct clusters. Additionally, there appear to be stronger interdependencies between these two categories and the law and health ones, due to the fact that they were grouped together. Finally, SDG 1 (No Poverty), 11 (Sustainable Cities and Communities), and 12 (Responsible Production and Consumption) stand out as outliers, having the most synergic interactions with other SDGs, both as receivers and fosterers of progress.

This subsection corroborated the understanding of SDGs interactions, enlightening decision-makers to develop comprehensive strategies for the achievement of the United Nations' 2030 Agenda. Thus, it is suggested:

Proposition 15 If strategies employed by the UWM are aligned with the SDGs categories, then SDG 1 (No Poverty), 11 (Sustainable Cities and Communities), and 12 (Responsible Production and Consumption) will be the key SDGs to propel the progress of the entire Agenda 2030.

Proposition 16. If there is any impact on SDGs from economic, environmental, law, or health categories, it will affect such categories-oriented SDGs more strongly than the social-oriented ones.

7.3 Synthesis of interactions between UWM and SDG

Figure 7 depicts a synthesis of the propositions ranging from 1 to 16. The first frame illustrates the Sustainable Development Goals (SDGs) categories (economic, social, health, environmental, and law, respectively), their respective goals (in black), and

the main elements of Urban Waste Management (UWM) synergy (in green) and trade-off (in red).

The next frame describes the interactions between UWM and the SDGs according to their respective categories. From left to right, the categories are ordered based on their magnitude of synergy with UWM. The representation below highlights the SDGs synergically impacted, with SDG 11 (Sustainable Cities and Communities) emphasized due to its greater magnitude. Furthermore, the red rectangles indicate the more interdependent categories, where progress or regression in one SDG will affect others to varying degrees.

Finally, the last frame describes the four main actors SDGs for the Agenda 2030 progress under the UWM context, further reinforcing the conclusion that UWM strategies are inadequate to promote sustainable development as it is primarily focused on economic development and the reduction of threats, rather than the restoration of the ecosystem.

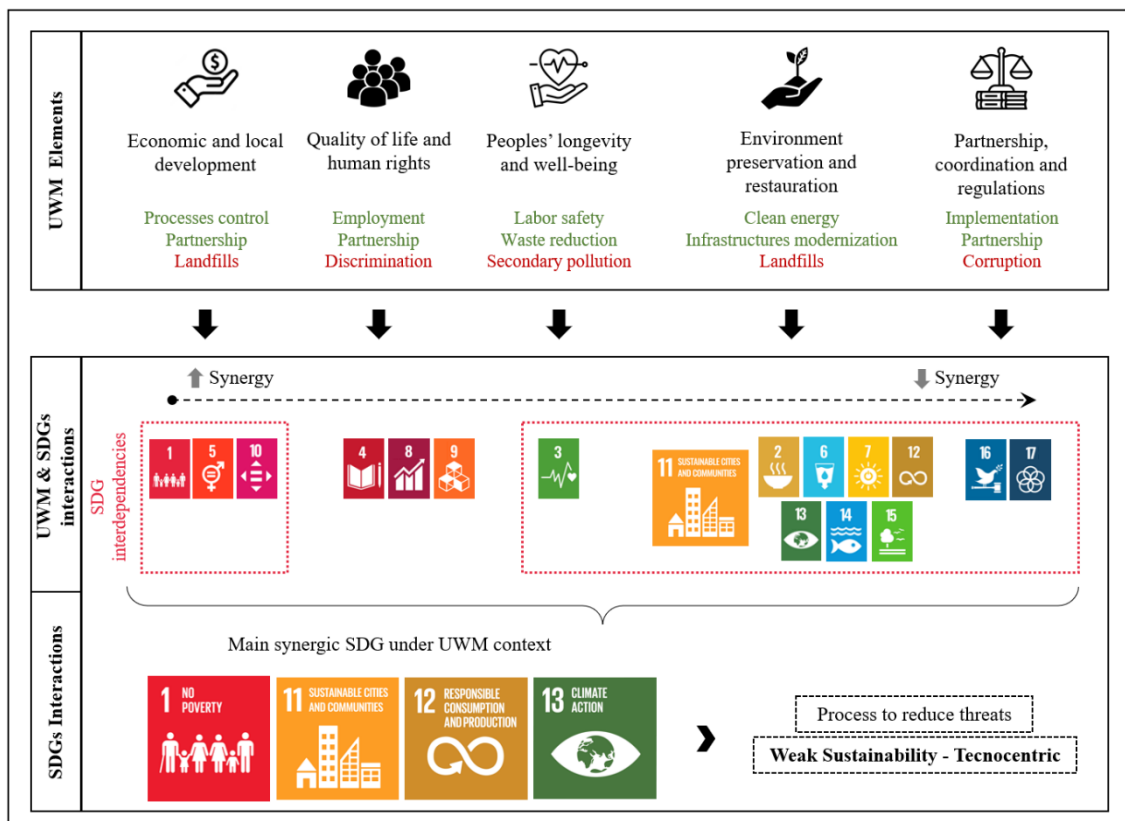


Figure 7 Synthesis of the **propositions** (from 1 to 16) – systemic view of SDGs progress under UWM context

8 Conclusion

This article demonstrates a practical approach to systematically understanding the interactions and interdependencies between the Urban Waste Management (UWM) context and the Sustainable Development Goals (SDGs). It provides organizational managers and public policy formulators with the necessary guidance to make decisions about UWM strategies that promote progress toward the SDGs through synergies and trade-offs. Additionally, drawing upon responsible managerial concepts, Network and Sustainability Spectrum theories, it is possible to foster a discussion about the grand social challenge of waste management and create new research opportunities that could benefit the SDGs.

UWM can facilitate and enhance progress towards the SDGs through synergic compensations between its elements. SDG 11 (Sustainable Cities and Communities) stands to benefit the most from UWM elements, having a significant positive impact on other SDGs, particularly SDGs 1 (No Poverty), 12 (Responsible Consumption and Production), and 13 (Climate Action).

However, upon analyzing the interactions between each category, it was found that the most significant positive impact was in the economic one, which presented stronger interdependencies with the SDGs from the law, health, and environmental categories. Therefore, these results confirm the UWM's technocentric, or weak sustainability, definition, which focuses on promoting local economic growth and mitigating ecosystem degradation while potentially leading to neglecting social and environmental necessities.

The key strengths of this approach are that it facilitates the development of novel perspectives to create structured methodologies and even tools to facilitate and guide policymakers' decisions while optimizing UWM resources and promoting sustainable development worldwide. However, the potential weakness of this approach is that the quality of the results is dependent on a content analysis of UWM elements and their interdependencies and trade-off implications for driving SDGs progress, which can vary depending on the perspective taken, even if the arguments are based on international literature papers stemming from the Integrative Review results. To make this approach more robust, it is important to review the data inputs with various waste chain actors, such as policymakers, specialists, and even the population, using specific methodologies to reach a consensus among the participants. Moreover, this paper focuses on the general characteristics of the world's UWM systems. It is possible to extend this analysis to specific countries or communities to understand the impact of culture, economy, UWM strategy, and society on UWM.

The analysis has highlighted the benefits, threats, and possible compensation strategies of the grand social challenge of UWM, with the aim of improving its interaction with SDGs and promoting sustainable development worldwide.

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