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Article

Comparison Between Waste Management Indicators From the Perspective of Smart Cities and Circular Economy

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ABSTRACT

Faced with urban challenges, governments are urged to adopt smarter and more sustainable models, promoting strategies that reconcile urban growth, environmental preservation, and quality of life. In this regard, developing guidelines that not only mitigate environmental impacts but also strengthen the resilience and efficiency of contemporary cities is essential. This study investigates the concepts of Smart City (SC) and Circular Economy (CE), analyzing their different approaches to urban waste management. The comparison of indicators is based on the 2023 edition of the Connected Smart Cities (CSC) ranking by Urban Systems and Necta, as well as the study by Girard and Nocca (2019). The results indicate a stronger alignment of CE with this theme but highlight the need to integrate circularity and urban intelligence for more effective and sustainable waste management. The combination of these concepts can guide public policies and strategic decisions, fostering more resilient and environmentally responsible cities.
Keywords: waste management; urban intelligence; circularity; urban sustainability; indicators.

RESUMO

Diante dos desafios urbanos, governos são instados a adotar modelos mais inteligentes e sustentáveis, promovendo estratégias que conciliem crescimento urbano, preservação ambiental e qualidade de vida. Nesse sentido, torna-se essencial o desenvolvimento de diretrizes que não apenas mitiguem os impactos ambientais, mas também fortaleçam a resiliência e a eficiência das cidades contemporâneas. Este estudo investiga os conceitos de Cidade Inteligente (CI) e Economia Circular (EC), analisando suas diferentes abordagens para a gestão de resíduos urbanos. A comparação entre os indicadores fundamenta-se no ranking Connected Smart Cities (CSC) 2023, da Urban Systems e Necta - última edição, e no estudo de Girard e Nocca de 2019. Os resultados apontam maior afinidade da EC com a temática, mas ressaltam a necessidade de integrar circularidade e inteligência urbana para uma gestão mais eficaz e sustentável. A combinação desses conceitos pode orientar políticas públicas e decisões estratégicas, promovendo cidades mais resilientes e ambientalmente responsáveis.
Palavras-Chaves: gestão de resíduos; inteligência urbana; circularidade; sustentabilidade urbana; indicadores.

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Introduction

The accelerated growth of cities in recent decades has raised concerns among municipal managers. According to the United Nations World Cities Report, urban areas already house approximately 55% of the global population, a figure expected to reach 68% by 2050, when the world population is projected to total 10.2 billion inhabitants (UN, 2022). With the future becoming increasingly urban, it is evident that many cities are unprepared for this demographic expansion, which could result in even greater social and environmental problems if the current unsustainable development model persists.

When reflecting on the issue of solid waste in cities, it becomes clear that it has caused a range of environmental and public health complications. The negative impacts include soil and groundwater contamination, the spread of diseases, river siltation, greenhouse gas emissions, and visual degradation of the landscape.

Brazil stands out as one of the largest producers of solid waste, much of which is inappropriately disposed of in open dumps, controlled landfills, sewage systems, or through incineration (IPEA, 2020). The illegal and improper disposal of construction and demolition waste, in particular, has significant environmental impacts and represents one of the main challenges in urban waste management. These materials, often voluminous, can obstruct rivers and increase flood risks. Furthermore, improper disposal contributes to the depletion of natural resources (Kuyven & Oliveira, 2023).

Given the urgent need for intervention in cities, Smart Cities (SCs) have emerged as a new model of urban development, characterized by innovation, creativity, and sustainability. This model emphasizes urban development, administrative and economic efficiency, social inclusion, technology, innovation, and sustainability (Caragliu et al., 2011). According to Giffinger et al. (2007), SCs are defined across six dimensions: economy, people, governance, mobility, environment, and living.

Within this perspective of smarter cities, the concept of the Circular Economy (CE) arises as an approach to reduce environmental impacts through modern management practices and technologies. According to Girard and Nocca (2019) and Silva and Franz (2022), CE not only deals with resource management and waste flow but also seeks to promote economic prosperity, social cohesion, fulfillment of needs, human rights, and well-being.

In this context, this study aims to identify how the concepts of SC and CE relate to the management of solid waste in urban areas. In addition to the present introduction and final considerations, the structure of this article comprises the following sections: Methodology, which presents the methodological procedures adopted; Conceptual Framework Perspectives, discussing the concepts of SC and CE; Indicators for Waste Management, addressing specific aspects related to waste management from the perspective of Urban Intelligence and Circularity; and Comparative Analysis, presenting the evaluation of the analyzed indicators.

Perspectives on the Conceptual Foundations

In response to the socio-economic and environmental challenges faced by urban spaces as a consequence of globalization, governments have been increasingly required to invest in more sustainable and efficient development strategies. In this context, various innovative typologies for (re)thinking urban spaces have emerged, aiming to establish guidelines that support the management of urban problems.

The concepts of Smart Cities (SC) and Circular Economy (CE) represent frameworks that can be applied simultaneously in urban governance, given their conceptual interconnections. While SCs have become central actors in the effort to resolve or mitigate urban bottlenecks—supporting city operations through intelligent planning aided by Information and Communication Technologies (ICTs)—CE proposes an organization of systems that mirrors natural systems, eliminating waste and incorporating principles of circularity to establish a regenerative and accessible system (Girard & Nocca, 2019; EMF, 2020; Lacerda & Leitão, 2021; WEF, 2018).

Smart Cities

When it comes to Smart Cities (SC), a concept closely linked to how urban development evolves—especially from an economic and technological perspective—this model gains prominence as smart systems and technologies become essential tools to solve urban challenges and ensure a more sustainable future for cities (Choi & Song, 2023).

Discussing Smart Cities requires a comprehensive approach, as various studies present distinct definitions of the concept, reflecting specific visions and aspects of the cases analyzed. Although the topic is widely debated, it is evident that a city must be both smart and sustainable in order to meet the needs not only of its residents but of all those who inhabit urban spaces (Silva & Seabra, 2022).

According to Caragliu et al. (2011), a Smart City invests in human and social capital, urban mobility and technological infrastructure, combined with intelligent resource management and participatory governance. This integration fosters sustainable economic growth and enhances the quality of life within urban areas.

Other perspectives focus more specifically on technology, defining the model based on maximizing efficiency through the extensive use of Information and Communication Technologies (ICTs). Schaffers et al. (2011) highlight technologies such as the Internet of Things (IoT), big data, cloud computing, and artificial intelligence as key drivers in the delivery of electronic services within urban environments, repositioning cities as engines of innovation.

In this primarily academic context, the Brazilian standard (ABNT NBR ISO 37122:2020 – Sustainable cities and communities — Indicators for smart cities) seeks to offer applicability and intervention mechanisms by providing its own definition of Smart Cities in Section 3 – Terms and definitions, where we find:

> [A Smart City is] a city that increases the pace at which it delivers social, economic, and environmental sustainability outcomes, and that responds to challenges such as climate change, rapid population growth, and political and economic instabilities. It fundamentally improves the way it engages society, applies collaborative leadership methods, operates across disciplines and municipal systems, and uses data information and modern technologies to provide better services and quality of life for those who live in it (residents, businesses, visitors), now and in the foreseeable future, without unfair disadvantages or degradation of the natural environment" (ABNT, 2020, p. 2).

According to Höjer and Wangel (2014), a city that is considered sustainable and smart must meet the needs of its citizens through the support of Information and Communication Technologies (ICTs), without compromising the needs of other citizens, future generations, or exceeding environmental limits.

Thus, Ahvenniemi et al. (2017) highlight that in this development model, the implementation of modern technologies stands out as a facilitator for improving the quality of life of the population and reducing environmental impacts. Dameri (2013) reinforces that technology is identified as the primary factor for the emergence and advancement of cities. However, he notes that this is not the only element for the success of this concept; entities such as universities, research institutions, and high-tech companies play a key role in generating ideas and solutions.

In this way, cities become part of — or even the entirety of — an eager system of innovation, an enabling factor for regional development, particularly economic development (Johnson, 2008). By integrating the use of ICTs, the cities of the future are envisioned as a new approach to urbanism, as a data-sensitive science, offering an alternative to past misguided planning models and promoting environmental sustainability, social progress, and the guarantee of the right to the city.

Circular Economy

When it comes to the Circular Economy (CE), Silva and Franz (2022), drawing on the contributions of Prieto-Sandoval et al. (2018), explore the concept by highlighting its fundamental pillars: *reduce, reuse, and recycle*. Urban circularity, therefore, aims to achieve sustainable development. However, just like the concept of Smart Cities, CE is also not rigidly defined. Various interpretations coexist, and its implementation varies considerably, as observed by Girard and Nocca (2018; 2019).

One of the main goals of CE is to close the loop of products created in the system, reusing materials from the production chain so they circulate continuously throughout the production process (Sauka & Silva, 2023). Furthermore, the approach proposes a transition from a linear model of natural resource use to a regenerative circular model, in which materials are continually reused, repaired, remanufactured, and recycled — eliminating waste and the need for the extraction of new raw materials. This shift seeks to reduce environmental impact, protect natural resources, and promote resilience for sustainable development (Petit-Boix & Leipold, 2018; Lacerda & Leitão, 2021; Silva & Franz, 2022; Munaro & Tavares, 2022).

A comparative analysis between the principles and characteristics of the linear economy and the circular economy, presented in Table 01, highlights fundamental differences in terms of production approach, resource management, and environmental, social, and economic impacts — underlining the importance of transitioning to a circular economy.

Table 01 – Economic models: linear and circular

Aspect	Linear Economy	Circular Economy
Resource extraction	Intensive and continuous	Recovery and reuse
Goods production	Large-scale	Product reuse
Goods consumption	Disposable and without reuse	Encouragement of reuse
Waste disposal	Greater waste generation	Transformation into new products

Source: Prepared by the authors based on Aquino et al. (2023); EMF (2019); Munaro (2023); Palafox-Alcantar et al. (2020); Petit-Boix and Leipold (2018); Lacerda and Leitão (2021); Sauka and Silva (2023); Silva and Franz (2022).

Thus, by implementing production models centered on these principles, the circular economy (CE) approach (Figure 01) emerges as a viable alternative to the linear production model, which is characterized by intensive exploitation of natural resources and excessive waste generation.

This paradigm shift aims to optimize the use of material resources and manage waste efficiently by reintegrating it into the product life cycle and the production chain (Palafox-Alcantar et al., 2020). The CE model (Figure 02) proposes closing the product life cycle, allowing items, at the end of their use, to be repurposed, reused, or recycled—resulting in a range of economic, social, and environmental benefits (Vier et al., 2021). In this regard, the CE concept is oriented toward a "[…] truly sustainable economy, which operates without waste, conserves resources, and functions in synergy with the biosphere" (Weetman, 2019, p. 66).

As shown in the figure, the CE butterfly diagram illustrates the continuous flow of materials within circularity, divided into two paths: the technical cycle (right side of the figure) and the biological cycle (left side). The biological cycle establishes the organic regeneration of renewable materials with low environmental impact, in which, throughout the supply chain, their utilization or transformation returns to the ecosystem.

The technical cycle, on the other hand, focuses on maintaining the full usability of the product until it is no longer of interest to the consumer, while preserving its functionality. In this flow, the systemic circulation of waste and products occurs through processes such as transformation, repair, and recycling (EMF, 2019). These cycles, represented as closed loops, preserve environmental capital while minimizing negative externalities.

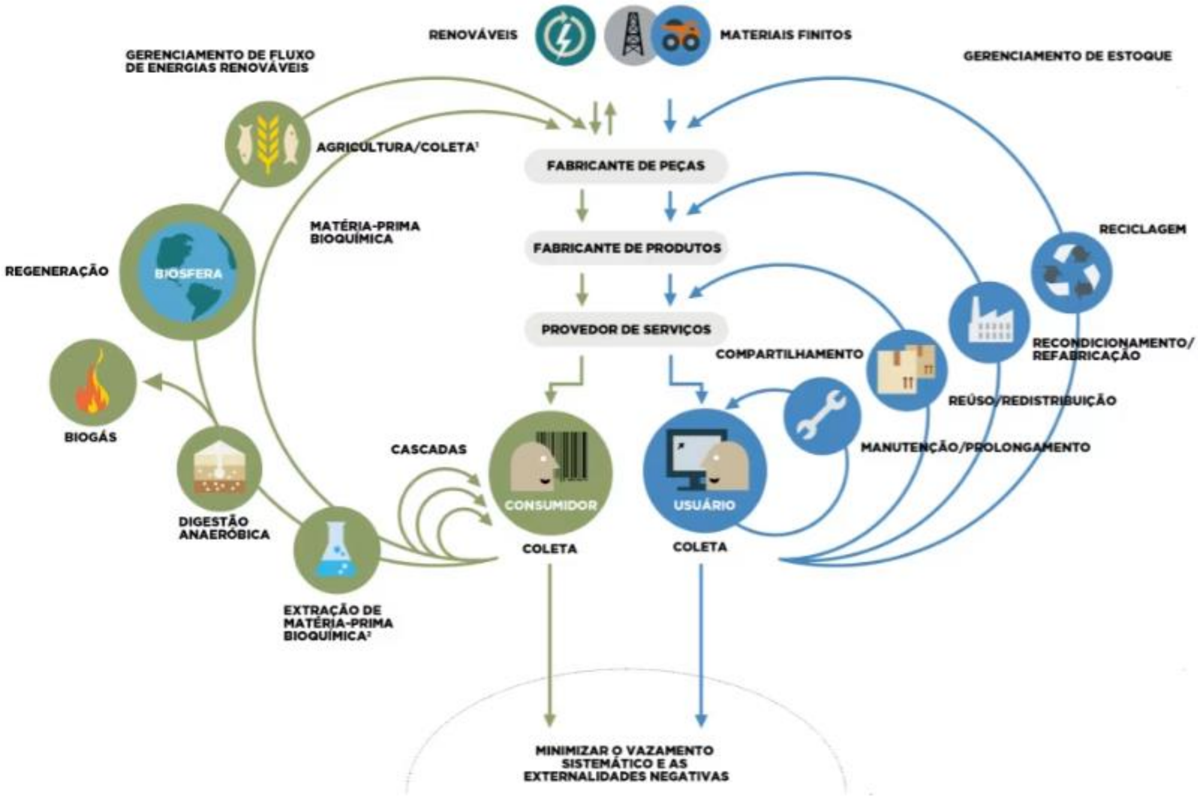

Figure 01. Circular Economy Butterfly Diagram. Source: EMF (2019).

It can thus be observed that there is a redefinition of the concept of "waste" to "residues" of goods, resources, and raw materials that are to be transformed through a new production cycle (Weetman, 2019). With technological advancements, product and component engineering now enables the remanufacturing of items so that they return to the condition they had when first transformed from raw materials into new products (EMF, 2024).

At the same time, the circular economy (CE) is seen as a system that promotes and develops new markets that are viable both environmentally and economically. Its implementation, however, depends on collective efforts. Furthermore, the state plays a vital role in designing and implementing circular systems through public policies that encourage companies and individuals to adopt circular economy practices (Aquino et al., 2023).

Despite its challenges and potentials, the CE has gained popularity at various levels and in different areas of city structures. According to Petit-Boix and Leipold (2018), most research has focused on recycling schemes for various types of materials and products, such as plastics, aluminum scrap, end-of-life vehicles, construction and demolition waste, electronic devices, and industrial waste. However, sharing activities—such as car sharing—and the reduction of disposable products are rarely addressed.

In the realm of urban planning, especially regarding land use and occupancy, CE is still not a central theme (Petit-Boix & Leipold, 2018). Considering this gap, urban intelligence may be a valuable tool to help bridge it by using technology to track consumption patterns and identify opportunities for applying CE principles (Caragliu et al., 2011).

Supporting this perspective, Sukndev et al. (2018) emphasize the relevance of CE in the urban context, offering a framework for rethinking and operating urban systems in a way that preserves natural, social, and financial resources. The application of urban intelligence can strengthen this framework, enabling cities to implement CE solutions in a more integrated and informed manner.

Ultimately, these concepts must be incorporated into the rethinking of urban dynamics. It is necessary to raise awareness among companies, citizens, and governments so that urban intelligence and circularity foster reshaping and stimulate new management practices.

Methodology

This research adopted a qualitative approach, anchored in bibliographic and documentary research, characterized as a literature review. Initially, the research was carried out through bibliographic constructs and was complemented by documentary analysis to ensure its integrity. The works presented serve as references for academics, professionals, and policymakers interested in understanding the theoretical framework regarding Smart Cities (SC) and the Circular Economy (CE).

To address the research objective, an exploratory and descriptive methodology was adopted. Considering the concept of SC, the research data source used the Connected Smart Cities (CSC) ranking by Urban Systems and Necta, which classifies Brazilian cities based on their level of connectivity and intelligence, grounded on premises (Figure 02) for sustainable urban development (Urban Systems, 2023).

To create the ranking, several international and national publications on the topics of SCs, connected cities, sustainable cities, and human cities were used as references, along with the standards ABNT NBR ISO 37120 and ISO 37122, which relate to indicators aimed at urban development (Urban Systems, 2023).

Regarding CE, the study adopted the indicators proposed by Girard and Nocca (2019). In their study "Moving Towards the Circular Economy/City Model: Which Tools for Operationalizing This Model?", the authors present two sets of indicators. The first set was developed from theoretical studies, which can make practical application difficult, especially due to a lack of concrete data in some cases. The second set gathers indicators drawn from case studies conducted by the authors, which are mostly practical and applicable.

The cities analyzed by Girard and Nocca (2019), which self-identify as "Circular Cities," produce systematized reports with global urban-level strategies. Among the cities analyzed are: London and Glasgow (United Kingdom); Rotterdam and Amsterdam (Netherlands); Paris and Marseille (France); Antwerp and Brussels (Belgium); Maribor and Ljubljana (Slovenia); Prague (Czech Republic); Kawasaki (Japan); Kalundborg (Denmark); and Gothenburg and Malmö (Sweden)..

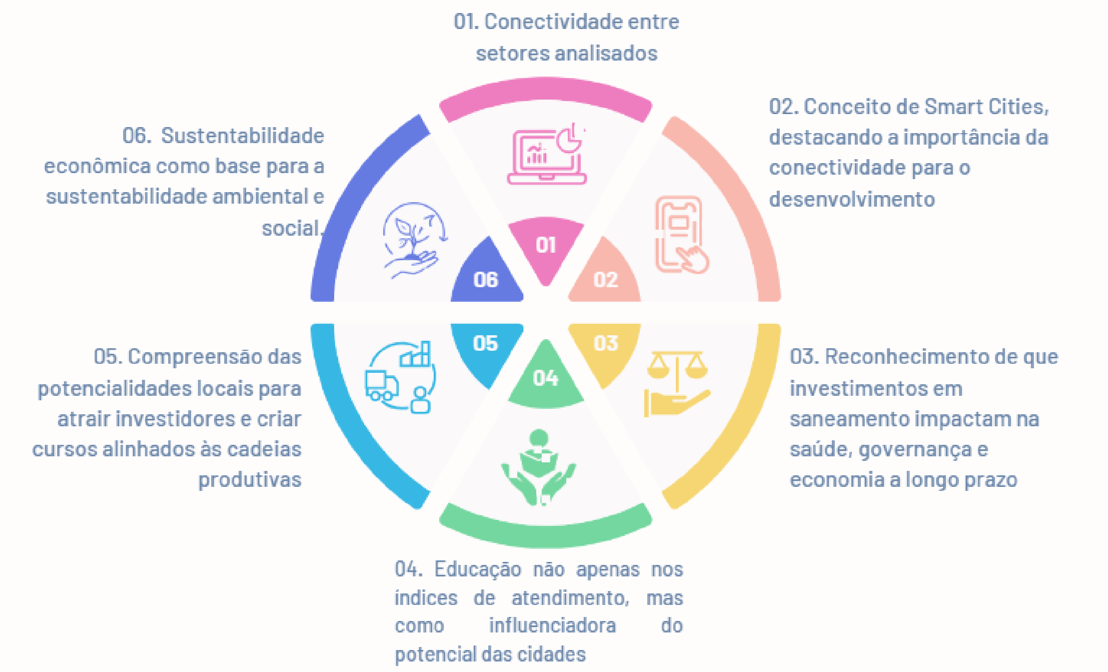

Figure 02. CSC Ranking Premises. Source: Prepared by the authors based on Urban Systems (2023).

Indicators for Waste Management

It is evident that cities play a significant role in the contemporary context. Therefore, it is essential to consider effective approaches for the development of these spaces. The use of analytical tools enables the comparison of data and actions among cities based on specific indicators. This not only allows for the assessment of current policies and the verification of their effectiveness but also presents an opportunity to use the results as a marketing strategy to attract new investments.

Thus, to better understand the scope of the smart city (SC) concept and its approach to waste, the CSC ranking was utilized. This ranking, widely used in Brazil, aims to map cities with the greatest potential for smart development. It is composed of 74 interconnected indicators, distributed across thematic axes, as illustrated in Figure 03.

The themes Mobility (MOB), Environment (ENV), Urbanism (URB), Technology and Innovation (ICT), Health (HEA), Safety (SAF), Education (EDU), Entrepreneurship (ENT), Energy (ENE), Governance (GOV), and Economy (ECO) comprise the assessment criteria.

Figure 03. CSC Ranking – Thematic Axes. Source: Urban Systems (2023).

In its 2023 edition (8th edition), all Brazilian cities with over 50,000 inhabitants were evaluated, totaling 656 municipalities. Among these, 41 cities had over 500,000 inhabitants, 278 had between 100,000 and 500,000 inhabitants, and 337 were in the range of 50,000 to 100,000 inhabitants (Urban Systems, 2023).

The selection of indicators and axes in the ranking does not aim to replace other perspectives on SC but rather adapts to the reality of Brazilian cities in comparison with international contexts. In the most recent edition, Florianópolis (SC) leads the ranking, followed by Curitiba (PR), São Paulo (SP), Belo Horizonte (MG), and Niterói (RJ), with three of the five smartest cities located in Brazil's Southeast Region (Urban Systems, 2023).

Among the 74 indicators related to waste management, only three indicators (see Table 02) were selected from the thematic axis "environment." One of these indicators also appears under the "health" axis due to its relevance to human health.

Table 02 – CSC Ranking Indicators

	'Environmental' thematic axis	'Health' thematic axis
Indicators	Recovery of recyclable materials	--
	% of recovered plastic waste	--
	% coverage of solid waste collection	

Source: Adapted from Urban Systems (2023).

In relation to the understanding of the Circular Economy (CE) within the scope of waste management, Girard and Nocca (2019) emphasize the importance of implementing indicators to assess the efficiency of the concept, especially in the context of transition. Currently, there is no established set of indicators available to evaluate how effectively a city is progressing toward circularity, nor are there specific support tools. However, it is crucial to present evidence of the multidimensional benefits of the CE in order to persuade policymakers, communities, and businesses about the feasibility and desirability of investing in this model.

Although the cities evaluated by Girard and Nocca's indicators self-identify as Circular Cities, the authors highlight that the adjective "smart" appears several times in the reports of cities implementing the concept—particularly in Amsterdam and Rotterdam. They also point out that the greatest challenge in identifying the indicators in the case studies was data collection, as many documents lack transparency and clarity. Often, the indicators were only defined at a theoretical level, or the data needed to support them were unavailable. In the cities' reports, the data were not always systematized, making comprehension difficult. Additionally, some cities used different indicators and units of measurement, which made it difficult to compare impacts (Girard & Nocca, 2019).

Regarding the dimensions and number of indicators, these were derived from academic literature as well as official documents and reports, and were classified into the following dimensions: environmental, economic and financial, and social and cultural (Figure 04) (Girard & Nocca, 2019).

Based on these dimensions, CE still focuses heavily on waste management. A significant number of indicators related to this aspect is emphasized. These indicators are classified by dimension, as presented below, to facilitate the evaluation process.

Figure 04. Circular Cities Indicators.Source: Prepared by the authors, adapted from Girard and Nocca (2019).

The dimensions considered—environmental, financial and economic, and social and cultural—are derived from two sources: academic literature and official documents and reports, as previously mentioned. The structure of this model, as proposed by Girard and Nocca (2019), presents the indicators within the environmental dimension (Table 03) according to each data source.

Table 03 – Environmental Dimension

	Derived from official documents and reports	Derived from the literature
Environmental Dimension	Quantity or percentage of waste separation	Municipal recycling rate
	Increase in clean plastic flows and beverage packaging from residential waste	Packaging waste recycling rate
	Percentage of recycling of solid waste generated in the city	Quantity of landfilled waste
	Percentage of packaging waste recycled	Percentage of solid waste materials deposited in landfills
	Percentage of municipal waste recycled	Percentage of household waste ending up in sanitary landfil
	Quantity of construction waste and implementation of circular economy-related interventions	Percentage of solid waste incinerated
	Difference between tons of waste and tons of consumed products	Quantity of food waste treated
	Tons of waste diverted through repair, reuse, recovery, and recycling (recycling centers, artisans, thrift shops, repair labs, etc.)	Food waste treated in small and medium-sized enterprises
	Hazardous waste traceability; quantity of waste generated in the city; per capita waste generation	Separated waste (valorization and treatment of waste generated in the city).
	Quantity of waste produced and treated within the city itself	
	Quantity of solid waste reused	
	Quantity or percentage of waste avoided	
	Quantity of household waste reduced by avoiding waste and encouraging reuse	
	Percentage reduction in waste collection fleet	
	Quantity of biowaste from households and corporate canteens used for compost and biogas production	

Source: Prepared by the authors, adapted from Girard and Nocca (2019).

Environmental indicators are established based on evidence from official documents and reports, demonstrating the interest of public and social actors in assessing environmental impacts and data. As for the financial and economic dimension indicators, Table 04 presents the findings compiled by Girard and Nocca (2019).

The financial and economic dimension highlights financial constraints as the main barrier to implementing the Circular Economy (CE), primarily due to public sector limitations. At the same time, the private sector is reluctant to invest in environmental, sanitary, and other related issues due to high costs, which could affect profitability.

Regarding the social and cultural dynamics, the indicators derived from data sources can be observed in Table 05.

Table 04 – Financial and Economic Dimension

	Derived from official documents and reports	Derived from the literature
Financial and Economic Dimension	Financial savings for public sector bodies through improved waste management; cost of waste management.	Expenditure on waste management.
	Economic opportunity generated from waste originating in incinerators and landfills, and from material exchanges.	

Source: Prepared by the authors, adapted from Girard and Nocca (2019).

Table 05 – Social and Cultural Dimension

	Derived from official documents and reports	Derived from the literature
Social and Cultural Dimension	Number of people using applications that display real-time data flows from smart energy, water, and waste meters, helping to raise awareness about consumption.	Habitability (better treatment of waste and wastewater, and time lost in traffic congestion in relation to the increase/reduction of air pollution).

Source: Prepared by the authors, adapted from Girard and Nocca (2019).

In general, within the tool developed by Girard and Nocca (2019), a total of 48 indicators were identified from the literature and 90 from official documents and reports within the environmental dimension. In the economic and financial dimension, 6 indicators were derived from the literature and 35 from official documents and reports. In the social and cultural dimension, 6 indicators were identified in the literature and 39 in official documents and reports, totaling 224 indicators.

Among the waste-related indicators presented in Tables 3, 4, and 5, there are 24 indicators in the environmental dimension, three in the financial and economic dimension, and two in the social and cultural dimension, accounting for 12.95% of the total set of indicators.

Waste management is a critical issue in any environmental, economic, and social analysis. The inclusion of waste-related indicators reflects the need to monitor and improve waste management practices in order to mitigate impacts and promote sustainability..

Comparative Analysis

Urban waste management is one of the main challenges faced by contemporary cities, especially as the urban population continues to grow. When considering the indicators presented by the SC (Smart Cities) and CE (Circular Economy) frameworks, the breadth and significance of these metrics become clear in assessing various aspects of urban sustainability. A comparative analysis of the waste management indicators in both approaches reveals significant differences in methodology, scope, and implementation.

The efficiency of selective collection and recycling systems is an essential factor for the sustainable management of solid waste in cities. Indicators that measure source separation and municipal recycling rates directly reflect the effectiveness of these practices. Proper waste separation contributes significantly to increased recycling rates and a reduction in the volume of waste sent to landfills, thus mitigating environmental impacts and optimizing the use of available resources.

In this context, the specific treatment of packaging waste plays a strategic role. The recycling rate of these materials is a relevant indicator to assess management systems and encourage the reintegration of inputs into the production cycle, reinforcing CE principles. Likewise, the management of food waste emerges as a priority issue. The adoption of practices for the proper reuse and disposal of such waste, both in households and the commercial sector, helps reduce food loss and promotes more efficient use of urban resources.

The adequate treatment of food waste—whether from homes or commercial establishments—reduces the amount of organic waste sent to landfills. Therefore, reducing food waste becomes a key goal of any waste management system, aligning with sustainability practices and increased resource efficiency.

Beyond operational aspects, the incorporation of technological innovations and public awareness are important elements in this process. The use of sensors to monitor collection, digital platforms to engage citizens, and educational apps are examples of tools that support more sustainable practices. The adoption of such technologies not only enhances waste collection and disposal but also strengthens social participation (Bachendorf et al., 2019).

Based on the data presented, it is observed that the Circular Economy framework covers a broader percentage of indicators within its tool compared to Smart City indicators. This disparity may be due to the fact that CE is often applied in studies focused on various aspects of waste and resource flows, whereas SCs tend to emphasize administrative efficiency, technological adoption, and improvements in urban quality of life (Silva, 2019).

Although the CSC ranking periodically updates its methodology to reflect the evolution of Brazilian cities, the set of urban waste indicators has remained relatively stable. This continuity allows for longitudinal comparative analyses, facilitating the identification of trends and progress. However, the lack of more frequent updates may hinder the incorporation of new approaches and limit adaptability to concepts such as CE. This could result in a fragmented view of urban reality, restricting the development of innovative and effective policies.

In this regard, guidelines set by standards such as ABNT NBR 37122/2020, previously mentioned, and ABNT NBR 37123/2022, focused on urban resilience, offer parameters to improve waste management. These standards reinforce the importance of sustainable and circular practices, encouraging cities to adapt to both environmental and operational challenges. Thus, the convergence between the concepts of Smart Cities and Circular Economy, combined with the normative support of ABNT, may strengthen the development of more technologically advanced and environmentally responsible cities.

Final Considerations

When analyzing the assumptions of urban intelligence and circularity, particularly in the context of waste management, several considerations become evident. The implementation of Smart City and Circular Economy practices faces significant challenges, such as the lack of shared information about their methods and the need for a better understanding of material and service value flows. These limitations underscore the urgency of a systemic reformulation of production and consumption models, which should harmonize the interactions between supply, demand, and public policies.

Furthermore, the integration of emerging technology-based solutions is essential to address these challenges and promote more efficient management of urban resources. By examining the indicators discussed, the relevance of these tools is evident in measuring environmental, social, and economic performance in organizations, communities, and governments. However, it is important to recognize that, in isolation, these indicators may not reflect the full scope of impact. Therefore, a balanced approach, not limited to isolated indicators, is fundamental for a more accurate evaluation.

In conclusion, the rise of the Circular Economy as an innovative paradigm for waste management highlights the need to consider not only environmental but also economic, cultural, and social dimensions. The various indicators and tools available for evaluating circularity and urban intelligence offer insights into best practices and the challenges faced by different cities worldwide.

For future research, it is recommended to expand the CSC ranking database and the studies by Girard and Nocca, as well as to incorporate other analytical tools.

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