



Circular economy in solid waste management: framework proposal based on the case of the Federal District – Brazil

Economia circular na gestão de resíduos sólidos: proposta de estrutura baseada no caso do Distrito Federal – Brasil

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ABSTRACT

The implementation of the Circular Economy (CE) requires collaboration between members of society and is influenced by the institutional context. In the Federal District, solid waste management has evolved with the implementation of the Brasília Landfill and the expansion of selective collection, which covers more than 90% of the urban area. However, the quantity and quality of landfilled materials show that current actions are insufficient. This study seeks to answer two questions: (1) what are the challenges, opportunities and strategies for implementing CE in solid waste management according to the perception of social actors? (2) which solid waste management model can best align the Federal District with the principles of CE? Based on the concept of CE, which aims to extend the value of products and minimize waste, a qualitative study was carried out using document analysis, semi-structured interviews and content analysis. Twelve actors were interviewed, representing key categories. The results indicate the importance of waste picker cooperatives and associations, as well as the articulating role of public authorities. The research suggests a management model inspired by Elinor Ostrom's IAD-Framework, made up of external variables, an arena for action, evaluation criteria and expected results.



Keywords: circular economy; solid waste management; sustainability; intersectoral collaboration; IAD-framework

RESUMO

A implementação da Economia Circular (EC) exige a colaboração entre os membros da sociedade e é influenciada pelo contexto institucional. No Distrito Federal, a gestão de resíduos sólidos evoluiu com a implementação do Aterro Sanitário de Brasília e a expansão da coleta seletiva, que abrange mais de 90% da área urbana. No entanto, a quantidade e a qualidade dos materiais aterrados demonstram que as ações atuais são insuficientes. Este estudo busca responder a duas perguntas: (1) quais são os desafios, oportunidades e estratégias para a implementação da EC na gestão de resíduos sólidos, segundo a percepção dos atores sociais? (2) qual modelo de gestão de resíduos sólidos pode melhor alinhar o Distrito Federal aos princípios da EC? Com base no conceito de EC, que visa prolongar o valor dos produtos e minimizar o desperdício, foi realizado um estudo qualitativo utilizando análise documental, entrevistas semiestruturadas e análise de conteúdo. Doze atores foram entrevistados, representando categorias-chave. Os resultados indicam a importância das cooperativas e associações de catadores de materiais recicláveis, bem como o papel articulador do poder público. A pesquisa sugere um modelo de gestão inspirado na estrutura IAD de Elinor Ostrom, composto por variáveis externas, uma arena de ação, critérios de avaliação e resultados esperados.

Palavras-chave: economia circular, gestão de resíduos sólidos, sustentabilidade, colaboração intersectorial, estrutura IAD

1 INTRODUCTION

As the populations and economies of nations and cities grow, they expand the supply of goods and services to their inhabitants and engage in international trade and exchange. Consequently, the emission of atmospheric pollutants, water contamination, and the production of solid waste emerge as increasingly urgent challenges (Kaza et al., 2018). The recent report by the United Nations Environment Programme confirms the trend of growth and inequality since the countries that pollute

the most are usually the richest, and the countries that feel the most socio-environmental negative consequences are usually the developing countries (UNEP, 2024).

Over time, garbage dumps reach their maximum capacity due to the high production of Municipal Solid Waste (MSW) per person, leading to their exhaustion in a short time. This is due to the fact that the current economy follows a linear model centred on the production and consumption of goods, without considering the environmental impacts associated with the extraction of natural resources and the production of waste and pollutants (Sauvé et al., 2016).

Implementing the Circular Economy (CE) requires collaboration between members of society to find solutions to shared challenges, and this ability is influenced by the institutional context in which they operate. According to Healey (1998), institutional capacity refers to the ability of a group of social actors to participate in joint activities to address issues of common interest. Its construction is necessary to achieve common objectives (Blomquist & Ostrom, 1985).

In the context of the Federal District and according to the Urban Cleaning Service (UCS), around 696.9 thousand tons of household and commercial waste were collected in 2022. Of this total, 36.7 thousand tons of dry recycled materials were recovered (which corresponds to 5.27%) and 96.07 thousand tons of organics (which corresponds to 13.78%) (Federal District, 2022).

The construction and operation of the Brasília Landfill (BL) removed the stigma of the city as the holder of the largest landfill in Latin America (Capelari et al., 2020), and the Selective Collection coverage exceeds 90% of the urban area of the federal capital. Even so, given the quantity and quality of currently landfilled materials, it is clear that recycling and selective collection actions have proven to be insufficient, and the valuable life of BL, initially estimated until 2030, is increasingly reduced.

Gaps were identified in the Circular Economy literature (generally linked to the Production and Operations area) and in the Public Administration area. According to Bockel et al. (2021), there needs to be more research that debates the role of governments in implementing CE. Sehnem et al. (2019) warn of the lack of studies that analyse the understanding of public and private managers who understand, in practice, the difficulties of executing more circular business models. Finally, Oh and Hettiarachchi (2020) stand out, reiterating the need for academia to contribute to constructing circular Urban Solid Waste (MSW) management systems.

Therefore, this research aims to answer two Research Questions, namely:

RQ 1: Based on the perception of social actors, what are the challenges, opportunities and strategies for implementing the Circular Economy in the Solid Waste management and handling system in the Federal District?



RQ 2: Which Solid Waste Management framework would help the Federal District to improve alignment with the principles of the Circular Economy?

So, this paper aims to analyse waste management in the Federal District from the perspective of social actors and the principles of Circular Economy. The article is divided into four more sections. The Theoretical Framework presents theoretical and empirical studies on the topic, highlighting circular principles and demonstrating the use of a framework aligned with institutional theory. The methods section shares the research classification and the way of obtaining data. Then, the results of the reality in the Federal District (FD) are presented and debated with the public management and CE literature to propose practical improvements based on a theoretical structure. As this is a constantly evolving topic, in the end, the limitations of the research are highlighted, and future investigations are suggested.

2 THEORETICAL BACKGROUND

2.1 Municipal Solid Waste Management and the principles of the Circular Economy

The generation of Municipal Solid Waste (MSW) in the country increased, under the direct influence of the COVID-19 pandemic, during 2020, generating approximately 82.5 million tons or 225,965 tons/day. As a result, on average, each Brazilian generated around 1.07 kg of waste/day. As a comparison parameter, per capita generation in 2018 was 1.039 kg/day (Abrelpe, 2021). The need for people to stay at home explains the increase since this new social dynamic has transferred greater food consumption, and waste generation to homes. The delivery system, and disposal replaced consumption in restaurants began to take place in homes (Abrelpe, 2021).

The current global economic system, a legacy of the 19th century Industrial Revolution, is based on the assumption that the planet's resources are unlimited, and that the Earth's capacity for regeneration is considerable (Ouro-Salim; Guarnieri, 2022). This model is summarized in the pillars “take, make, dispose”, capturing the resources necessary to meet human needs, producing goods and products that can be sold to increase profits, and dispose of what is no longer needed (Sariatli, 2017).

The need to transition to another model was perceived to reduce the challenges posed by the classical and linear economy, thus emerging the Circular Economy (Hartley et al., 2020). In the CE, the aim is to maintain the value of products and goods for an extended period, minimizing waste and the use of resources. When a product reaches the end of its useful life, it is reintroduced into the

system to create new value. This approach can generate various economic benefits, promoting innovation, growth, and job creation (Kirchherr et al., 2018).

The dematerialization of the economy is a significant aspect that enables a substantial reduction in the use of natural resources. Hence, there is a need for a model, defended by the CE, based on functional services in which retailers increasingly retain ownership of their products and sell the use of these products. This practice encourages manufacturing durable products that can last longer in the economic cycle (Ellen MacArthur Foundation, 2013).

Therefore, the Circular Economy has established itself as a new paradigm of the 21st century with significant practical possibilities. The benefits can promote contemporary society's development in several areas, such as business, economics, and the consumer/user.

2.2 Decision-making supported by Elinor Ostrom's Framework

Society's participation strengthens material recovery and recycling activities because of engagement and desire to make things happen. However, it is often necessary to develop and implement educational campaigns that allow the public's hesitation to be convinced (Oh & Hettiarachchi, 2020).

In this sense, there are two plausible possibilities for understanding how decisions and choices are made in a socio-ecological system: the economic theory that deals with collective action and the so-called IAD Framework (Ostrom et al., 1994). According to Oh and Hettiarachchi (2020), collective action is carried out by a group of people who aim to improve their current state and achieve a common objective. The IAD Framework helps different disciplines observe how people collaborate and organize themselves to manage a shared resource (Ostrom et al., 1994).

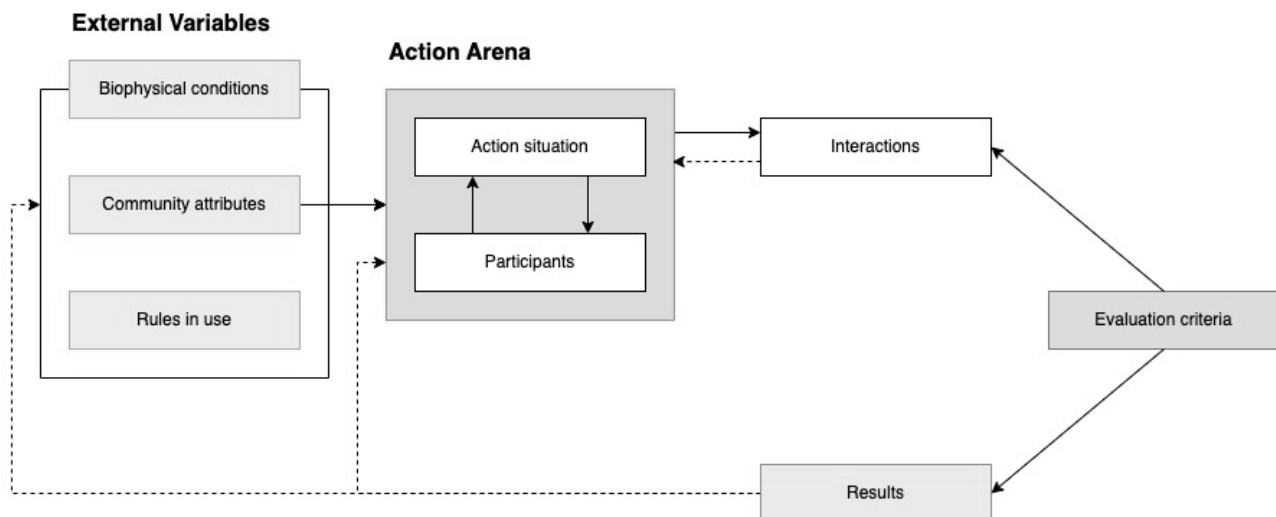
Solid Waste can be considered a resource and applied in collective action and the IAD Framework. Although they were not initially considered resources, how this is interpreted is changing. The depletion of virgin raw materials extracted from nature generates their scarcity, increasing the need to reuse recyclable materials found in the dynamics of logistics chains (Hettiarachchi et al., 2018). The Circular Economy, therefore, emerges as a robust balancing mechanism in this environment.

The IAD Framework is a useful tool for simplifying data and reaching practical conclusions for policies aimed at the Circular Economy (3Rs). Furthermore, its framework considers the formal game of actors in the decision-making process. It was designed to analyse the governance of common pool resources and investigate robust self-governance models. Additionally, it is based on cooperation

and efficient communication between individuals, as they utilize the same rules to adapt to new situations over time (Ostrom, 2002).

The polycentric model has multiple decision-making units organized in different jurisdictions (local, regional, national) and may include particular transversal elements that integrate these dimensions (McGinnis, 2011). The IAD Framework deals with external factors (such as environmental conditions, community characteristics and norms in force) and the sphere of action. They are used to analyse the formal game as characteristics of the actors (participants) and the action situation. Based on evaluative criteria and interactions between actors, results have reached that feedback into both the exogenous context and the action arena (Ostrom, 2010). The model defines the action arena as a relevant unit of analysis to understand a system (Hijdra et al., 2015). Figure 1 shows its structure.

Figure 1
Structure of Elinor Ostrom's IAD-Framework



Source: Ostrom (2005)

The IAD Framework is based on the general approach of policy-oriented systems, in which inputs are processed by policymakers, whose results are evaluated and subject to feedback at a later stage (McGinnis, 2011). According to McGinnis (2011), the inputs to this system are made up of exogenous variables. These contextual factors encompass aspects of the social, cultural, institutional and physical environment that define the context.

An example of applying the IAD Framework can be seen in the work of Martins and Futemma (2022). The study examines community-based tourism from the perspective of young people from a quilombola community in the Vale do Ribeira region, State of São Paulo. The study's objective was



to analyze how the self-organization of tourism occurs as a common good, focusing on the participation of young people (Martins & Fudemma, 2022).

According to the authors, tourism proved to be a common good when considering the nature of community management (Martins & Fudemma, 2022). In this way, it is possible to infer that the IAD-Framework model can be adapted for different occasions, whether to analyze elements related to collective decisions or for political analysis, with Solid Waste and the Circular Economy being part of this context.

3 METHODOLOGY

To achieve the objectives of the paper, applied research with a qualitative approach was chosen. As a technical procedure, a documentary search in secondary sources and a semi-structured interview as a primary source were adopted, in addition to using content analysis instruments.

From the documentary survey of the bodies involved in waste management in the Federal District, the social actors to be interviewed were identified: 1) public authorities, 2) the business sector and 3) civil society entities. The object of study was chosen because it should be a city that follows the logic of MSW in the context of a linear economy that starts at the point of generation (households and companies) and ends at the final disposal in a landfill. This illustrates how Brazilian municipalities typically manage their waste.

The second criterion was the high generation rates and low recovery rates of the sorted material. The choice of the federal capital also proved correct due to the available data and information from the public authorities on Municipal Solid Waste Management (available on the UCS website).

The Federal District comprises 35 administrative regions spread over 5,770 km². The total area of the landfill is approximately 760,000 m² or 76 hectares. Currently, the space for waste disposal, leachate treatment, waste from health services, and administrative and operational support area covers 490,000 m² or 49 hectares (Federal District, 2022). Figure 2 shows an aerial view of the Brasília Landfill (BL).

Figure 2

Brasília Landfill (BL)



Source: Federal District (2022)

However, with increasing generation rates each year due to the increase in population and consumption, the ASB may have its capacity compromised before the expected period, and its depletion may occur prematurely, creating the need to seek a new area for creation from another landfill.

Therefore, it is urgent to think about a strategy to optimize generation, reduction, reuse, remanufacturing, recycling, and composting in the Federal District. A plausible alternative is the insertion of the CE in this context.

For the present qualitative research, the saturation point was reached at four representatives for each category (twelve actors interviewed). Category 1 comprises four actors linked to the Public Power (PP). The PP representatives were chosen because they are directly or indirectly connected to the process of management, execution, regulation and inspection of Urban Solid Waste in the Federal District. Category 2, in turn, presents the perspective of the Business Sector (BS), distributed in the areas of consultancy, industry, and trade of recyclable materials, sale of used products, and the food sector. Finally, Category 3 comprises Civil Society (CS) entities. Among them are representatives of residents' associations and waste picker cooperatives.



The semi-structured interview script had between 17 and 22 questions, depending on the category of the interviewee. The names of the interviewees were kept confidential, and this research was approved by the Plataforma Brasil Ethics Committee (Opinion nº 6,094,095 of the CEP - Research Ethics Committee). Plataforma Brasil is a national and integrated base for research involving human beings.

The interviews took place in person and online, depending on the interviewee's availability and lasted approximately one hour. All interviewees signed two copies of the Free and Informed Conduct Term, demonstrating their interest in voluntarily participating in the research and granting data for scientific purposes. The interviews were recorded with the permission of the interviewees.

Therefore, the techniques used for data collection were Documentary research, Semi-structured interviews and on-site visits (with photographic records and direct non-participant observation). After the interviews, transcription and subsequent content analysis were carried out, which, according to Bardin (2016), systematically describes interpreting a given message.

The interpretation of the message allowed researchers to understand the convergent perception of social actors, including the challenges, opportunities, and strategies each has regarding the municipal solid waste management system in the Federal District and insights about implementing the Circular Economy. Finally, a circular theoretical model was proposed based on Elinor Ostrom's IAD-Framework.

4 DISCUSSION AND RESULTS

4.1 Solid Waste Management in the Federal capital of Brazil

The management and handling of municipal solid waste in the Federal District are the responsibilities of the UCS-FD (Urban Cleaning System of the Federal District). However, outsourced companies effectively carry out the collection, sweeping, treatment, and disposal services for household Solid Waste in the 35 Administrative Regions (cities in the Federal District) (UCS, 2023b). Typically, they are specialized in the context of the activities for which they are hired.

In 2020, within the Federal District, 787,733 tons of waste were collected through conventional collection and a further 17,273 tons through Selective Collection, totalling 805,006 tons. From this amount, 20,621.83 tons of recyclable material were sorted and sold by waste picker cooperatives contracted by UCS. In percentage terms, Selective Collection represented only 2.14% of the total. (UCS, 2023b).



The materials are weighed after collection and separation into groups, and the data is entered into specific spreadsheets. The number of trips, date of collection, type of sample (selective, conventional, waste from Waste Recovery Facilities - WRF, waste collector, and VDS - Voluntary Delivery Sites), type of vehicle, and collection weight are taken into account, specific weight (kg/m³), and moisture content.

The legal instrument for planning the management of Urban Solid Waste in the Federal District is the PDGIRS (District Plan for Integrated Solid Waste Management). Its primary purpose is to establish and promote the necessary actions for managing urban solid waste generated in the federal district. Its bases prioritize non-generation, reduction, reuse, recycling, and treatment of Solid Waste, and final disposal in sanitary landfills, following what is established by national Law nº 12.305/10.

This federal legislation was studied by Jabbour et al. (2014), highlighting the need for Brazilian cities to monitor the flow of waste to prepare integrated management plans. Furthermore, they highlight the possible business opportunities such regulation could bring, including developing cleaner technologies and environmental consultancies. Also, they alert the need to redesign the curriculum of educational institutions in areas such as Engineering and Administration to teach about reverse logistics and waste management. (Jabbour et al., 2014).

Outsourcing operations plays a significant role. Four companies work on conventional collection and urban cleaning, namely: Valor Ambiental (urban waste, area I), Sustentare (urban waste, area II), Suma (urban waste, area III) and Belfort (Waste of the Health Service – RSS) (Federal District, 2022).

Wasserbaur et al. (2022) point out that government policies and business models are critical for transitioning to the Circular Economy. According to the authors, the most studied interaction is between command and control regulations and the value proposition element of business models. The idea that technologies can lead to circular business model innovation is reinforced, which forces policymakers to adapt.

In this sense, Sehnem et al. (2021) state that innovations in how business is planned (design) can positively influence the implementation of circular practices. Still, the organization's capabilities relate to other actors in the chain (Relational skills) and the development of flexible behaviour (Dynamic capabilities).

Politicians must pay attention to the need for new circular business models to create support mechanisms for their competitiveness. On the other hand, one of the interviewed businessmen (BS)

highlights that the government needs to make the incentives aimed at the Circular Economy clearer through public policies:

BS4: The Circular Economy is a vital and recent topic for businesspeople, especially in the context of the Federal District. A lot is yet to happen, but some people are already taking some action. However, I think the government could create and encourage the Circular Economy through public policies. I think this would be easier for everyone.

According to UCS (2023b), public cleaning in the Federal District is related to the following activities: 1) Collection, transportation, sorting, transshipment, treatment and final disposal of household solid waste and those arising from Selective Collection; 2) Sweeping and cleaning of public places and roads, including waste removal and transportation activities; 3) Collection of bulky waste, from civil construction and related waste, both those delivered correctly and those of clandestine origin and 4) Operation and maintenance of plants and facilities for sorting and composting, which includes the transportation, treatment and final disposal of waste.

Conventional collection works to collect common waste from houses, buildings (households), and institutions, generating a volume below 120 litres/day. Companies contracted by UCS carry out the activity, taking place in urban and rural areas, and businesses. In places where Selective Collection exists, the population must make available only organic materials and waste (such as food waste, fruit and vegetable peels, toilet paper, disposable diapers, and animal faeces) (UCS, 2023a). In addition to the collection service, the UCS provides public equipment for delivering waste, such as recyclable and rubbish bins.

Recyclable containers, also known as VDL (Voluntary Delivery Locations) or VDP (Voluntary Delivery Points), are surface containers with a capacity of 2.50 m³ and a raised opening to prevent access by animals and unauthorized individuals. Its objective is to expand selective collection in places where it still needs to prevail or exist. They are designed to receive paper, plastic, cardboard, metal or Styrofoam (UCS, 2023a). Furthermore, they function as an instrument to raise awareness among the population about the importance of separating recyclables since the procedure for their use is printed on their upper part.

Finally, some rubbish collectors aim to receive materials whose volume is at most 1m³. In addition to construction waste, it is also possible to deliver cooking oil used in frying to the Waste Container, which is sent to the Federal District Environmental Sanitation Company. It is



recommended that the material be taken in plastic fabric softener or shampoo bottles and no more than 50 litres per person/day (UCS, 2023a).

Among the critical success factors for the Circular Economy listed by Sehnem et al. (2019) are adopting the correct technology for the production chain, ensuring the engagement of the various participants in the supply chain and developing an organizational culture for sustainability. In this research with companies in Brazil and Scotland, the importance of environmental education for executives working at the top of the hierarchy was also noted to encourage circular practices (top Management commitment).

UCS has the so-called Conscious Selective Collection (CSC) program, which highlights that the consolidation of selective collection effectively only occurs when there is engagement between Regional Administrations and community leaders. The idea is to expand the discussion on the topic through forums and mobilization actions. The intention is to integrate communities and bring representation to representatives from different areas, such as residents, waste pickers, teachers, students, industry, traders, and others (UCS, 2023a).

To expand and inform the population about the Solid Waste collection process in the Federal District, UCS provides an application for cell phones called "SLU Coleta DF". Through it, residents can access the days and times of conventional and selective collection according to their address. A warning signal of the collection vehicle's approach is sent to registered people.

Even though the infrastructure of some cooperatives in the DF has improved in recent years, selective collection still needs to be improved, and recyclable materials are contaminated with organics. The speech of a waste picker (identified as Civil Society CS3) illustrates the need to modernize cooperative equipment, given that operational costs are high.

CS3: We need equipment compatible with the quality of the waste that companies deliver to us because the conveyors are designed for recyclable waste. As we collect waste with 60% organic waste, they cannot bear it.

The case study conducted by Guarnieri and Cerqueira-Streit (2015) carried out telephone interviews and on-site visits to the 23 cooperatives in the Federal District of Brazil. The growing influence of these actors on waste management was highlighted, and their degree of representation has grown as people realize this category's environmental and social importance. They allow the valuable life of the material to be extended through recycling and the generation of jobs for young people and women who are outside the formal job market (Guarnieri & Cerqueira-Streit, 2015)

The history of collector cooperatives in the Federal District dates back to the former "Lixão da Estrutural", considered the largest open-air dump in Latin America (Campos, 2018). The eight cooperatives from this location were installed in five warehouses rented by UCS to handle recyclable materials. Notably, the quantities of Solid Waste received by the cooperatives are those delivered by the UCS. However, the volume of waste also contains materials from their collections or donations (Federal District, 2022). Below are photographic records of the on-site visit to the main CENTCOOP-DF warehouse (Figure 3), where collectors work in sorting, weighing, pressing, and shipping part of the recyclable materials collected in the federal capital.



Figure 3: FD Recyclable Materials Cooperatives Centre (CENTCOOP-DF)
Source: Authors

Waste picker cooperatives and associations play a crucial role in the management and handling of Municipal Solid Waste in the Federal District. However, the low rates of recyclable materials that are sent to cooperatives bring inevitable negative consequences, such as, for example, reduced

longevity of the landfill and lower remuneration to collectors for processing a volume below their capacity.

Human supply chain management is also critical for implementing the CE. Given the cases studied by Jabbour et al. (2017), there is a direct relationship: the more significant the organizational proactivity towards building a Green Supply Chain (GSC), the greater the tendency for this company to involve employees and third parties, carry out training, and develop suppliers. This relation positively creates long-term competitive advantages (Jabbour et al., 2017).

The Circular Economy offers viable benefits for facing current economic and social challenges. One of the Public Power representatives who was interviewed for this research (PP1) highlights the potential of the inclusive circular economy in the context of waste management in the case study:

PP1: We understand that it is positive because it has dramatically improved their (pickers') quality of life, probably in the micro-region where they live. We have reports here from waste pickers. When the selective collection contract began in 2016, many of them lived in wooden shacks, and currently (2023), he built his house due to the consistency in renewing the Selective Collection contracts. So, I believe that, indirectly, we contributed to the Circular Economy.

From a logistical perspective, the Brasília Landfill (BL) is not far from the collection areas and has access roads in good condition. Another advantage is its proximity to the sewage treatment station, which treats the generated leachate. Regarding operation, BL strictly controls technical and environmental conditions.

Furthermore, in its operations, there is daily coverage of waste and waterproofing of the foundation, and there are drains for gas capture and treatment (UCS, 2023a). The useful life of the BL was estimated at 13.3 years, but it is expected to be shorter due to the high volume of materials deposited.

4.2 Framework proposal including the principles of the Circular Economy in Solid Waste Management

The idea of proposing this theoretical structure was to answer the second research question: Which framework would help the Federal District to align Solid Waste Management with the principles of the Circular Economy?



For its elaboration, the following parts were considered: a) External Variables (biophysical attributes, community attributes, and rules in use); b) Action Arena (social actors, interactions between the elements that are part of the action arena and convergent perception of the social actors identified in the documental analysis; c) the Evaluation Criteria; d) Expected Results. Furthermore, at the top of the model, its division into two large parts is evident: AS-IS (left side) and TO-BE (right side), with the principles of the Circular Economy as dividing elements.

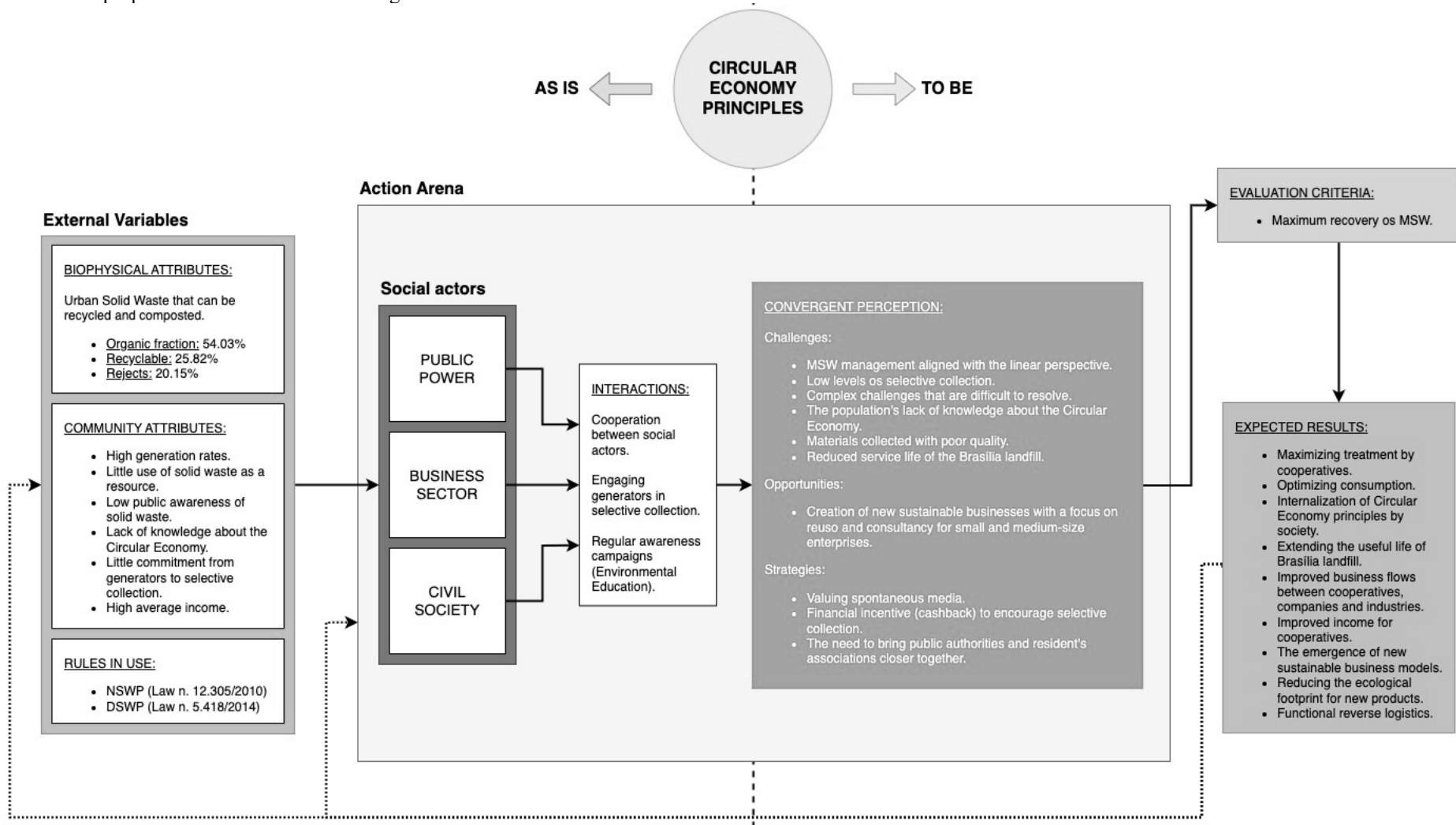
As a starting point, it is fundamental to explain the meaning of the terms AS-IS and TO-BE in the context of the model. AS-IS is an expression that means “current state”. Thus, in the left part of the proposal, the external variables contain the biophysical attributes, the community attributes, and the rules in use. The social actors are divided into three categories (public authorities, business sector and civil society). The description of these elements presents the current situation in the Federal District regarding the management of MSW.

On the other hand, the term TO-BE, in this context, means “future situation”. The idea here is to show a process of transformation of the current state, which is based on the Linear Economy, and result in the benefits brought by the implementation of the Circular Economy (Ellen MacArthur Foundation, 2013). Circular principles function as dividing elements because it is from them that change can occur throughout the management system.

Despite the complexity of the themes linked to Municipal Solid Waste, the model can have a simple and objective application. Thus, considering the aspects analysed in the present paper and Ostrom's IAD-Framework (2005), Figure 4 presents the proposal for a circular theoretical model adapted to the reality of the Federal District.



Figure 4:
Framework proposal based on the waste management of the Federal District – Brazil



Source: Authors.

The starting point was the identification of biophysical attributes, which are at the top of the external variables and constituted by the gravimetric composition of MSW from the Federal District. The distribution is 54.03% for organics, 25.82% for recyclables and 20.15% for waste (UCS, 2021).

To improve selective collection (increase the percentage of recyclables), it is possible to invest in awareness campaigns regularly, reminding the population of the steps necessary for sorting at the source to happen correctly. It is also vital to encourage cooperative actions with generators (Maass et al., 2014).

The arena of action, in turn, is primarily constituted by social actors. In this case, it is represented by public authorities, the business sector and civil society. The IAD-Framework and the economic model of collective action highlight the importance of cooperation as an element that induces success for actions of collective interest (Silva et al., 2020).

In the case of the framework presented, for cooperation to have the desired effect, it is necessary to involve and encourage debate among social actors within the action arena to find the best implementation practices. At this point, public authorities in particular can act as an articulating agent and inducer of the process.

By observing the model proposal and based on interviews with representatives of each category, a consensus was reached on their perceptions based on three aspects: challenges, opportunities and strategies. This was called "convergent perception", common to all interviewees in these three aspects.

Regarding the challenges, the linearity of the current SWM model, the low levels of selective collection and the reduction in the useful life of the Brasília Landfill stand out. The opportunity that social actors repeatedly remembered was the creation of new sustainable enterprises. These organizations seek reuse as a central aspect and property restoration companies consultancies on solid waste management and circular economy. The growth of stores that sell used products, such as thrift stores and sustainable fashion, is expected.

At least three common strategies were identified by the actors, namely: 1) valuing spontaneous media; 2) financial incentive to encourage Selective Collection; 3) the need for closer ties between public authorities and residents' associations. For strategies to be implemented, active participation of social actors is recommended.

The next stage consists of the evaluation criteria. This includes the maximum recovery of MSW. The valorisation of materials (recyclable and compostable) in the proposed circular system for managing MSW follows a constant flow of value addition, which is present in the principles of the

Circular Economy. This can increase the durability of the product's life cycle and reduce the need for new elements extracted from the natural environment. The aim of minimizing waste is to show that consumption can be balanced so as not to generate surpluses or unnecessary solid waste, as, otherwise, it could lead to an overload of the final disposal area of the Federal District, in this case, the Sanitary Landfill from Brasília.

Once implemented, the model would favour society's internalization of circular principles, and people would already understand that reuse, maintenance, and recycling are part of their daily activities. As a consequence, the useful life of the Brasília Landfill would be expanded since most materials (recyclable and organic) would be diverted to cooperatives or composting centres and no longer be deposited in the landfill.

Other opportunities are valuing recyclable materials, saving water and energy, and promoting sustainable purchases by choosing suppliers that respect the environment in their governance practices. The implementation of the proposed model would reduce the ecological footprint of Brazil's federal capital, reducing the need to extract virgin raw materials from the natural environment.

The model closes when the expected results stage is reached. From there, feedback from the system occurs, identifying points to be improved and those that were successful. This feedback is directed to the action arena and external variables. It follows an infinite loop in which the tendency towards self-regulation allows for constant improvement in the face of the most varied situations.

In conclusion, the proposed Municipal Solid Waste Management circular model for the Federal District presents challenges. However, several socio-environmental and economic opportunities are offered that implementing circularity strategies would bring to managers and residents of the capital of Brazil.

5 FINAL REMARKS

This research aimed to analyse waste management from the circular economy's perspective and social actors' perspective. From the empirical case of the Federal District, opportunities, challenges and practices related to CE were raised (Research Question 1).

Additionally, based on Ostrom (2005), a simple and objective application model was created that allows scholars and practitioners to reflect on external variables and the different actors' activity areas. With the appropriate evaluation criteria, the expected results can leverage waste management aligned with the principles of the circular economy (Research Question 2).

The transition from a linear to a circular municipal solid waste management model is possible when facilitated by public policies, technological availability, awareness, and cooperation between people and other social actors. Therefore, encouraging dialogue is essential to develop collaboration between actors. Also, the creation of public policies (national and local) focused on the Circular Economy to guide the procedures to be adopted by society.

Research question 2 was answered by proposing a circular theoretical Circular Solid Waste Management model for the Federal District. Its structure was built on an already consolidated framework: Elinor Ostrom's IAD-Framework. Through it, the MSW management system now has a circular perspective, divided into four parts: 1) external variables, 2) action arena, 3) evaluation criteria and 4) expected results.

One way to finance this transition would be to search for public-private partnerships between the UCS and the private sector to grant economic and tax benefits in return. As it is complex and challenging to resolve, the circular proposal would gradually replace the linear management of solid waste. It is worth noting that challenges such as resistance to change and lack of knowledge about the Circular Economy, for example, must be overcome.

The Circular Economy is an exciting alternative for the Federal District to overcome some of its obstacles, especially Solid Waste-related ones. This is because the valorisation of post-consumption by-products, the creation of new business models and the awakening of awareness through Environmental Education mean that society can be more fair and egalitarian.

The limitations of the present study are related to methodological choices. The framework can be applied in other locations. However, prior empirical research is required for appropriate adaptations. It is also limited by having collected data with few actors. It is understood that more stakeholders (such as the Public Ministry and the federal government) can bring other enriching points of view. Furthermore, data collected from civil society could be collected in greater volume and treated statistically (quantitatively).

For future investigations, some suggestions have been made to advance the topic in the Federal District and different developing countries. Among others, topics such as: a) recycled material market, consumer behaviour, product design and emerging waste streams are suggested; b) waste traceability through new technologies such as Artificial Intelligence and Blockchain; c) studies on socioeconomic models that involve fair working conditions in recycling; d) creation and improvement of indicators for monitoring Municipal Solid Waste.



Additionally, continuous monitoring of legislation is recommended. New regulations for reverse logistics and waste management are constantly coming out. In June 2024, federal decree no. 12,082 established the National Circular Economy Strategy. Among its objectives are the encouragement of reuse and the increase in the useful life of products and encouraging research, development and innovation to promote circularity (Brasil, 2024). In Brazil, there are more innovative law projects to boost the circular economy, mainly in terms of reuse and recycling.

Therefore, this article contributes to academia and professionals working with Waste Management and Circular Economy. After all, we propose an innovative circular model designed based on already consolidated work and stakeholders. It is a viable system with the potential to contribute to constructing more circular and sustainable urban management.

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