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Gestão Ambiental

Solid waste management in small municipalities: when and how to discuss a new fee?

Gerenciamento de resíduos sólidos em municípios pequenos: quando e como discutir uma nova tarifa?

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RESUMO

O gerenciamento de resíduos sólidos urbanos em municípios é uma questão desafiadora para países em desenvolvimento. Geralmente, os serviços relacionados ocorrem com déficit financeiro, são de baixa qualidade e possuem altos impactos ambientais. A pesquisa visou avaliar como as políticas públicas e orçamentárias podem afetar a qualidade do gerenciamento de resíduos sólidos em pequenos municípios de países em desenvolvimento. Este estudo apresenta o impacto econômico da rotina operacional, legislação, impostos e o total de custos deste gerenciamento em uma pequena cidade brasileira (36.000 habitantes). Onze tipos de resíduos e serviços relacionados foram avaliados de 2017 a 2020. Os resultados mostram que o orçamento para o gerenciamento de resíduos sólidos deve aumentar do atual 3.64% para 7,48% do orçamento total da cidade para que houvesse recursos para o cumprimento total da legislação pertinente. Os custos requeridos para esse cumprimento elevariam os gastos de US$ 29.09 para US$ 46.05 por habitante por ano. Alternativas para solucionar ou aliviar o problema são a melhoria contínua da eficiência, novas formas de financiamento, consórcios intermunicipais e aumento na fiscalização, especialmente relacionada para o real estabelecimento das responsabilidades legais de geradores de resíduos. Uma nova tarifa também pode ser discutida uma vez que essa cidade (assim como mais da metade das cidades brasileiras) não tem uma cobrança específica para resíduos sólidos. Um valor de US$ 9.40 por habitante por ano cobriria os custos operacionais relacionados aos resíduos sólidos domésticos.

Palavras-chave: Países em desenvolvimento; Políticas públicas; Desenvolvimento sustentável; Custos

ABSTRACT

Solid waste management (SWM) at the municipal level is challenging for developing countries. Typically, the service runs at an economic loss and is of low quality, with high environmental impacts. The research aimed to evaluate how budgetary and public policies may affect the quality of solid waste management in small municipalities in underdeveloped countries. This study reports the economic impact of the operational routine, legislation, taxes, and total SWM costs in a small municipality in Brazil (36,000 inhabitants). Eleven types of waste and related services were evaluated from 2017 to 2020. Results show that the SWM budget would have to increase from the current 3.64% of the annual city budget to 7.48% to supply this management's financial needs under a future scenario of full legislative compliance. The costs required for this compliance would increase expenses from US$ 29.09 to US$ 46.05 per inhabitant per year. Alternatives to solve or alleviate the problem are efficiency's continuous improvement, new types of fundraising, inter-municipal cooperation, and increased inspection, especially related to establishing the legal responsibilities for waste generators. A new fee could also be discussed since this municipality (as well as more than half of Brazilian cities) has no specific charge for SWM. A US$ 9.40 per inhabitant/year charge would cover the operational costs related to domestic solid waste.

Keywords: Developing countries; Public administration; Sustainable development; Legislation; Costs

1 INTRODUCTION

In most countries, municipal solid waste management is generally the responsibility of municipal governments, which should constantly seek to improve the collection, transport, and disposal services (Ferraz *et al.*, 2021; Kaza *et al.*, 2018). As a result, a significant challenge for municipal public administrations is to guarantee financial resources for daily activities and increasingly bold goals (Alzamora; Barros, 2020; 2023). These goals can be established by the municipal administration, state or national legislation, or even by a group of countries (Giannakitsidou; Ginnikos; Chondrou, 2020).

Since the first recorded charges for solid waste management were applied in 17th-century Europe, the gradual evolution of collection services has expanded worldwide, based on three principle models: fixed charge, usage charge, and combined charge (Chung; Yeung, 2019; Dutra *et al*., 2020; Welivita; Wattage; Gunawardena, 2015). Other models involve tax incentives, tax reductions and/or other incentives like food donations to those who deliver their waste or reduce the volume generated (Franco; Cicatiello, 2021; Kaza *et al*., 2018).

Studies have shown more effective cost control, self-sufficiency, and better application of related resources when the charge for service use (generally known as *Pay-As-You-Throw*) system is used, demonstrating greater environmental effectiveness and even population support. This fact implies quality improvements in services provided and the lives of the citizens involved (Agovino; Marchesano; Mussela, 2021; Alzamora; Barros, 2023; Bel; fageda, 2010; Dutra *et al.*, 2020; Welivita; Wattage; Gunawardena, 2015).

Generally, the more developed a country is, the more sophisticated the billing terms involved (Alzamora; Barros, 2020). Some locations try to apply the polluter pays principle more precisely so that charging is as fair as possible and increases cost-efficiency. For example, some Belgian municipalities had the *pay-per-bag* system (one of the most common polluter-pays systems due to its ease of operation). They also operated a system based on an automatic weighing of waste generated in each residence and then left in containers with an identification chip. The *pay-per-bag* system increased cost efficiency by 25% over ten years, while the *weight-based pricing system* achieved a 57% increase (De Jaeger; Rogge, 2013).

However, in developing countries, the reality is quite different, as the infrastructure and education available interfere with waste management effectiveness and operation. This is shown by a study in Yaoundé (Cameroon), where existing regulatory instruments are limited, as are the waste disposal choices and access to such alternatives (Sotamenou; De Jaeger; Rosseau, 2020). In Nepal, an increase in the recovery rate, collection efficiency, and a tax on plastic imports could cover a significant percentage of plastic waste management costs (Bharadwaj; Rai; Nepal, 2020). In China, the flat fee system of charging (where all taxpayers pay the same value no matter how much waste they produce) is usual (Chu *et al*., 2022). In China and India, the revenues from charges normally do not cover the costs of municipal solid waste management (Chu *et al*., 2022; Sarkhel; Banerjee; Banerjee, 2016).

In Brazil, the resources applied by municipalities in the collection and other municipal cleaning services, which include the final destination of municipal solid waste, reached about US$ 2 per inhabitant/month (Abrelpe, 2020), lower than the comparative value of US$ 6.75 per inhabitant/month practised in the United States and US$ 9.44 inhabitant/month in Sweden (Dutra *et al.,* 2020). The Brazilian Solid Waste Policy, enacted in 2010, is considered quite advanced and aligned with the issues of a hierarchy of solid waste management adopted worldwide (Brazil, 2010). However, the current practice in the country as a whole is flawed. For example, Brazil did not reach the initial goal of having environmentally-appropriate final solid waste disposal by 2014 since there were more than 1,500 open-air dump sites in the country in 2020 (SNIS, 2021). A recent law established another timetable for municipalities to achieve that goal from 2021 to 2024. The small municipalities with less than 50,00 inhabitants (which represent 88% of Brazil's cities and 35% of the country's population) have until 2024 to eliminate open-air dumpsites (Brazil, 2020).

The Brazilian National Plan for Solid Waste, approved only in 2022 (12 years after the National Policy), determines lots of goals to be achieved by the country until 2040, not only considering appropriate disposal but also in terms of collection, composting, recycling, waste to energy and charging for solid waste management. According to the Plan, 100% of the Brazilian municipalities must charge for solid waste management in 2024 (Brazil, 2022), but this number was 40.3% in 2020 (SNIS, 2021). Even when present, such charges are generally fixed and included in other existing taxes or, at most, proportional to the household size. Also, for 96% of municipalities, the resources collected to maintain these activities are insufficient even to ensure an appropriate final destination for solid waste. The reasons for that scenario are, among others, a lack of technical capacity, political problems, and the population's rejection of being charged. Of the 1,851 municipalities that said they received waste-treatment-associated revenues, the highest percentage (70%) reported a self-sufficiency value lower

than 50.0%. Only 117 municipalities indicated that they had attained or exceeded 100% self-sufficiency in meeting the costs of provided services (SNIS, 2021). Therefore, Brazil occupies an intermediate position between the absence of charges and fixed charges related to solid waste (Alzamora; Barros, 2020).

There have been individual attempts by some Brazilian municipalities to seek legal solutions for charging for municipal solid waste management. There is, however, a federal law concerning this, which established the first guidelines on sustainable charging regimes, with a preference for a tariff-based costing model. Under such a system, the income from tariffs on waste collection must be sufficient to pay the service provider, meet the costs of efficient operation and maintenance, and provide necessary investments (ANA, 2021).

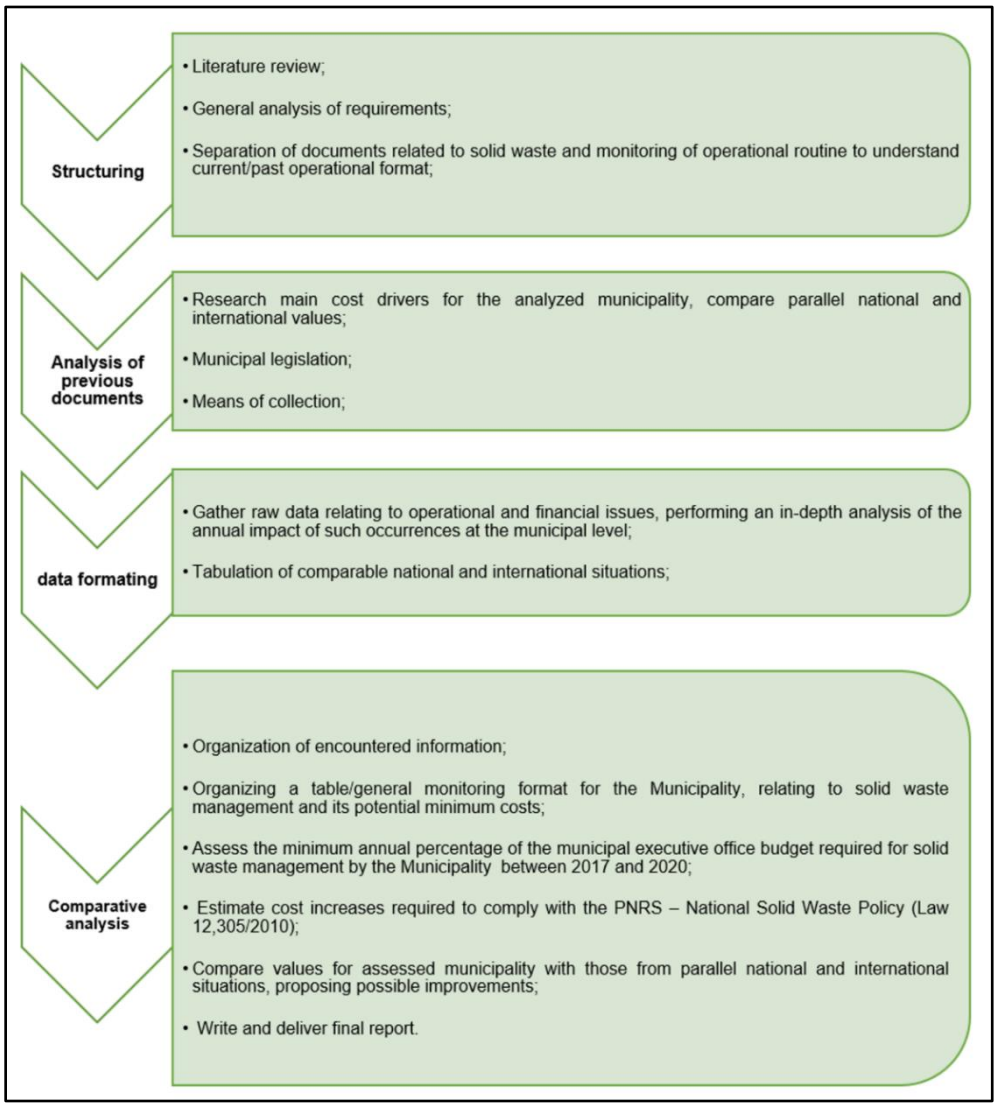
Many variables affect the cost efficiency of municipal solid waste management, like characteristics of the customers served and of the municipality, as well as the collected households and operational service specifics (Guerini *et al.*, 2017). The impact of selected variables on budget estimates varies based on such item-specific costs as proper solid waste management facilities. Such impact plays a notable role in the variation and determination of costs since they can change values on a larger scale. Under such circumstances, it may be crucial to design specific regulations for each analysed item based on the legislation for the region (Di Foggia; Beccarello, 2020).

The current article discusses the operational routine's budgetary impact and the total costs of solid waste management, using data from a small Brazilian municipality from 2017 to 2020. In addition, the waste management costs for this municipality to comply with the National Solid Waste Policy were projected. Finally, the difference between ideal and real is discussed, and suggestions are made on making solid waste management economically sustainable and environmentally adequate, considering the challenges and opportunities in developing countries such as Brazil.

2 MATERIALS AND METHODS

Figure 1 shows the research methodology, based on structured steps, analysis of previous documents of the selected municipality from 2017 to 2020, data formatting, and final analysis of results. Oliveira, Wartchow and Silva (2023) proposed a model based on multiple linear regression for six small municipalities (under 30,000 inhabitants) to estimate their household waste collection costs.

Figure 1 – Phases for implementing the proposed methodology



The authors worked with official data published in the national diagnosis and, according to them, the low data quality hindered obtaining a robust model.

2.1 The selected municipality

Rio das Pedras municipality is situated in São Paulo state, Brazil (22° 50' 36'' S, 47° 36' 22'' W), a region with logistics infrastructure and industrialisation conditions that far exceed the mean for the country (Mancini *et al*., 2021). It can be considered a small municipality with an estimated population of 35,738 (SEADE, 2020). It has a Municipal Human Development Index (MHDI) of 0.759 and no specific legislative collection instrument related to solid waste services. As mentioned, this situation is found in almost 60% of Brazilian municipalities (SNIS, 2021). The population of the municipality for each year considered in this study (2017) was 34,704 (2018), 35,228 (2019), and 35,738 inhabitants (2020) (IBGE, 2020).

Eleven waste services that should be provided for the population by the municipality or supported by it were studied based on Schalch *et al*. (2019):

- household waste – municipality's responsibility – the collection is made by a private company without any prior segregation. The destination is a private landfill located 65.3 km from the city centre;
- waste from urban cleaning - encompasses the cleaning and maintenance of streets and other public areas within the city (such as squares and public buildings) – municipality's responsibility;
- construction and demolition waste (C&D waste) – the generator's responsibility, but the municipality collects, despite its own, the waste mistakenly disposed of in various parts of the city. It is estimated that more than half of the amount collected would not exist if all generators did their part.
- healthcare waste – the generator's responsibility, but the municipality collects such waste generated not only by public health services (about 60%) but also by private healthcare providers (about 40%);

- waste from public sanitation services (from sewage treatment plant)– municipality's responsibility – there is no service provided for this kind of waste;
- cemetery residues – municipality's responsibility.
- reverse logistics (lamps, waste tires, and electronics) – generator's responsibility, and there are national systems to collect those waste, but the municipality supports them in the city with a storage warehouse. For lamps, the municipality pays the final destination treatment;
- recycling and selective collection – the municipality's responsibility, but there is no service provided, not even by waste pickers cooperatives supported by the municipality, a common feature in Brazil;
- environmental monitoring of the decommissioned landfill – there is no such monitoring despite being the municipality's responsibility;
- environmental education – there is no action supported by the municipality specifically regarding solid waste;
- environmental infrastructure and inspection – there is some inspection and a minimal structure, with one direct employee and one vehicle.

The provision of services directly or through contracted companies was taken into account. The cost of each service was calculated based on values raised *in loco*.

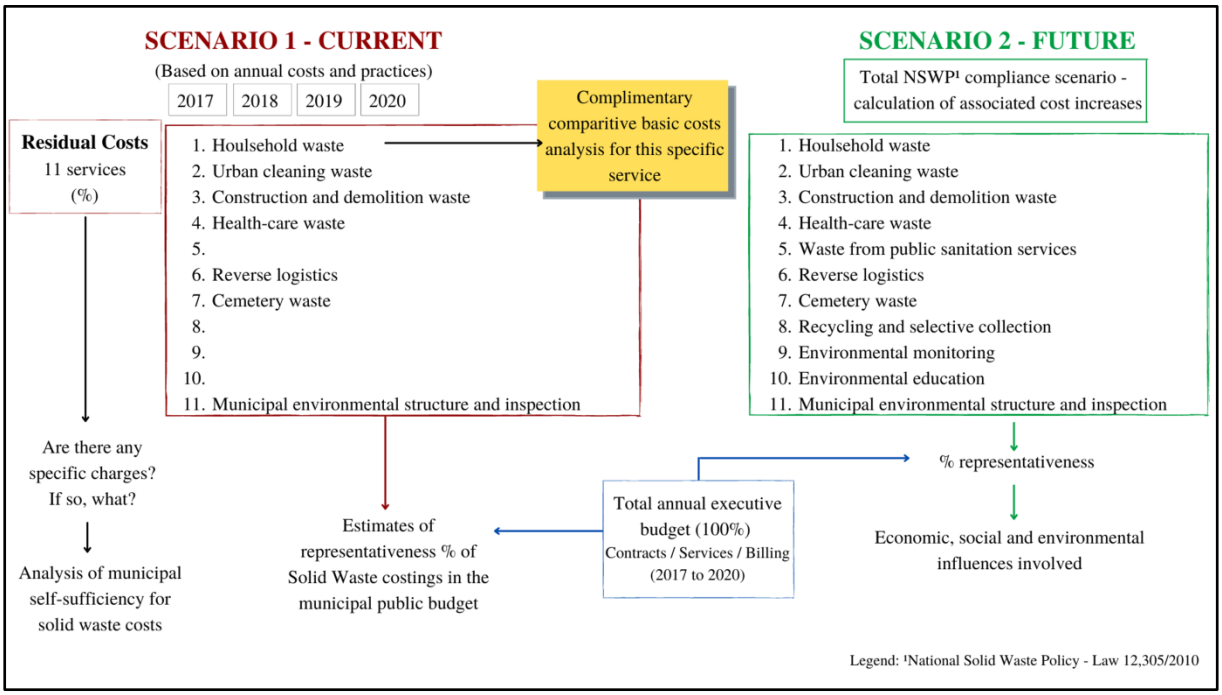
2.2 Scenarios evaluation

Two scenarios were evaluated: Scenario 1 (current) and Scenario 2 (future). Scenario 1 referred to the costs and practices performed during each year of the assessment period (2017 to 2020). In both cases, comparisons were made by considering how much the cost of a specific service and all 11 services represent or would represent in the municipality's total budget.

We also calculated the costs necessary to run a basic service within the analysed municipality, involving domestic waste collection, transport, and final destination. This accounting aimed to quantify the costs for this type of waste only, focusing on investigating the effects of charging for its management.

In Scenario 1 (Current), the information was collected from the municipal transparency internet portal and publically-available state databases, municipal legislation, public administration contracts, and via on-site visits. During the studied period, there were no services offered to the population by the government in terms of sanitation waste, recycling and selective collection, environmental monitoring, and environmental education (4 of the 11 services studied).

Figure 2 – Proposed scenarios for evaluating the economic sustainability of the solid waste management system studied



Scenario 2 (Future) corresponds to meeting all requirements associated with Brazilian legislation for all 11 services. The annual value used for this period took into account the last year evaluated (2020) plus the average value of inflation in the period considered, calculated using the official Brazilian index

(4.52%) (IBGE, 2021). The value for the 2020 population was used when calculating future scenarios. Figure 2 presents the proposed scenarios.

For evaluating values related to Scenario 2 (Future), the necessary cost increments were tabulated considering the operational reality for the 11 types of waste and services. These were compared with the costs incurred in operations that are more in line with the region's legislation, considering the increased need for labour, machinery, and specific services. These costs were based on similar services offered by the municipality (e.g., labour), other cities' information, direct inquiring of companies that offer a service, and internet research.

3 RESULTS AND DISCUSSION

Figure 3 shows the percentage of costs by waste type or management activity from 2017 to 2020 in the studied municipality. It can be seen that the percentage of costs for the household waste category varied between 2017 to 2020, from 54.01% to 43.88% of municipal waste management costs. In the same period, there was an increase in costs linked to urban cleaning waste, from 25.48% to 37.93%.

The management of only these two waste services, municipal solid waste, represented around 80% of the entire budget spent by the city on waste management over this period. The most significant fluctuation occurred between 2018 and 2019 when the outsourced company responsible for the highest added cost service (collection, transport, and disposal of household waste) was changed, with lower charges for the service resulting from a new bidding process. In 2019, the urban cleaning activities were expanded, ad new employees and machinery were necessary, increasing this cost.

Figure 3 - Percentage of costs by waste type or management activity in the studied municipality from 2017 to 2020

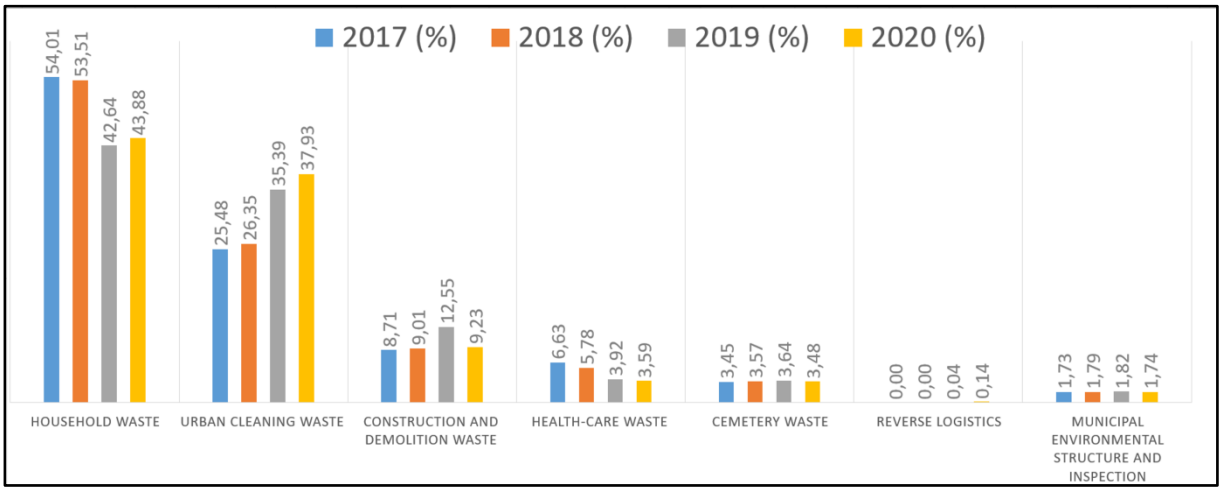


Table 1 shows the relative importance of the total cost of managing the 11 categories evaluated in the municipal budget (remembering that four services were added in Scenario 2, as they were not covered under current municipal waste management). Table II shows the actions (and costs) to comply with the legislation requirements, adding these four services and improving the others.

It can be seen from Table 1 that the percentage spent by the municipality to manage solid waste is above the Brazilian average of 2.95% (SNIS, 2020) in all years evaluated under Scenario 1 and even more for Scenario 2. However, it is below the value range of 7% to 15% reported for some larger Brazilian cities (Cardoso, 2016), such as Sumaré (9.05%), Indaiatuba (8.55%), and Piracicaba (7.87%), which range from 250,000 to 400,000 inhabitants (SNIS, 2020). According to the national diagnosis, the minimum representativeness value in small municipalities was 0.07% (Morro Grande, 3,000 inhabitants), while the maximum value was 20.0% (Antônio Dias, Mantena, and Sapucaí-Mirim, from 7,000 to 27,000 inhabitants). The city of Rio de Janeiro (with almost 7 million inhabitants), which has 100% self-sufficiency for all costs, has a representative percentage of 7.76% (US$ 435,273,953 waste-related expenses compared to a total City Hall budget of US$ 5,605,807,448) (SNIS, 2020).

Table 1 - Municipal budget –and its percentage- spent on solid waste management for each evaluated year in the studied municipality

Scenario	Year	Municipal Budget (US$/yr)	Cost of solid waste management (US$/yr)	%*
1	2017	16,133,613	796,826	4.94
1	2018	17,668,496	770,350	4.36
1	2019	20,049,277	755,053	3.77
1	2020	21,695,042	789,503	3.64
2	Future NSWP	22,675,658	1,696,853	7.48

Table 1 also shows a percentage reduction in the municipality's costs under Scenario 1 from 2017 (4.94%) to 2020 (3.64%). In addition, no complaints about changing the service quality were reported in this period. This indicates that there has been an increase in efficiency, with similar standards of service to the population, due to the new bidding process for household collection, transport, and final disposal in 2019 (Figure 1). Furthermore, in this period, more inspections were made, mainly regarding healthcare waste. Obviously, the search for greater efficiency should be continuous.

Even so, appropriate regulation is required since this municipality lacks any form of fixed or variable charging for services related to solid waste. This resulted in an overall outlay from public coffers of US$ 3,111,732 for 2017-2020 with no specific remuneration. Furthermore, in Scenario 2 (full compliance), more expenses must be added for some services that simply did not exist until 2020, while improvements must be made for others. Therefore, complying with Brazilian legislation with no additional efficiency gains would require an additional US$ 907,350 to be invested annually or more than 7% of its budget in total.

As shown in Table 2, the reverse logistics index is of lesser budgetary relevance even under a scenario of total compliance with legislation (0.35%). There are reverse logistics systems in Brazil concerning 1) agrochemicals and their packaging, 2) fluorescent lamps, 3) lubricant oils and their packaging, 4) tires, 5) batteries, 6) e-waste, and 7) expired or unused medicine (BRAZIL, 2010; BRAZIL, 2020b). They are the producer's responsibility, and the public administration can monitor and support the collection points.

On the other hand, activities such as recycling/selective collection, and environmental monitoring, which had no budget allocated from 2017 to 2020, were included in Scenario 2 (3.54% and 2.83%, respectively) to comply with national legislation. As a result, the total cost of waste management for the 36,000 inhabitants municipality studied to comply with Brazilian legislation is US$ 1,696,853, more than twice the total cost from 2020 (Table I).

In Scenario 2, the amount allocated to domestic waste (still the largest percentage share of cost among all services in the future scenario - 37.91%) had lower values than any equivalent year between 2017 and 2020 under the S1 scenario. This supports the idea of leveling among the other necessary waste services analysed. The search for greater efficiency is also reflected in the drop in future percentages due to the higher segregation of materials and composting added into the process. The same situation occurred for urban cleaning waste, representing 28.29% of future costs, a percentage lower than the municipality's for 2019 to 2020. However, since the spending is higher in S2 than in S1 (Table I), all absolute values for each waste category were higher in the future than in previous years, even for the ones that had their percentage decreased in Scenario 2 (domestic, urban cleaning, healthcare, and cemetery waste).

Table 2 – Evaluation of the cost percentage by analysed waste service, emphasising future perspectives and activities accounted for in the scenario of compliance with legislation

(To Be continued)

Waste service	2017 (S1)	2018 (S1)	2019 (S1)	2020 (S1)	S2	Activities accounted for to be legislation compliant
			(%)			
Domestic waste (%)	54.01	53.51	42.64	43.88	37.91	Alternate collection with greater efficiency and cost before the final destination (thanks to selective collection/composting).
Urban cleaning waste (%)	25.48	26.35	35.39	37.93	28.29	Increased recovery and appropriate disposal of waste/Creation of 4 delivery points.
Construction and demolition waste (CDW) (%)	8.71	9.01	12.55	9.23	9.90	Division of responsibilities/Increased recovery and correct disposal of waste/Creation of 4 delivery points.
Healthcare waste (HSW) (%)	6.63	5.78	3.92	3.59	3.54	Division of responsibilities/raising awareness and monitoring.
Waste from public sanitation services (%)	0.00	0.00	0.00	0.00	7.29	Systematic collection and transport, with treatment and correct destination of 19m^3 of sludge (US$ 10,300/month).
Cemetery waste (%)	3.45	3.57	3.64	3.48	2.12	Systematic collection and transport with treatment and correct destination.
Reverse logistics (%)	0.00	0.00	0.04	0.14	0.35	Division of responsibilities/creation of 2 specific collection points.

Table 2 – Evaluation of the cost percentage by analysed waste service, emphasising future perspectives and activities accounted for in the scenario of compliance with legislation

(Conclusion)

Waste service	2017 (S1)	2018 (S1)	2019 (S1)	2020 (S1)	S2	Activities accounted for to be legislation compliant
			(%)			
Recycling and selective collection (%)	0.00	0.00	0.00	0.00	3.54	Organisation of a selective collection/social inclusion program. Warehouse and truck rental (US$ 5,000/month)
Environmental monitoring (%)	0.00	0.00	0.00	0.00	2.83	Appropriate and effective monitoring of the decommissioned municipal landfill (geotechnics, gases, underwater, and leachate): US$ 4,000/month.
Environmental education (%)	0.00	0.00	0.00	0.00	2.29	Organisation of an effective environmental education program, hiring one environmental educator, and other fixed costs. Total: US$ 3,230/month.
Municipal environmental structure and inspection (%)	1.72	1.78	1.82	1.74	1.94	Improve the municipal environmental inspection by hiring two new staff members and other fixed costs. Total: US$ 2,770/month.
Total	100	100	100	100	100	

S1: Scenario 1; S2: Scenario 2

In Scenario 2, the amount allocated to domestic waste (still the largest percentage share of cost among all services in the future scenario - 37.91%) had

lower values than any equivalent year between 2017 and 2020 under the S1 scenario. This supports the idea of leveling among the other necessary waste services analysed. The search for greater efficiency is also reflected in the drop in future percentages due to the higher segregation of materials and composting added into the process. The same situation occurred for urban cleaning waste, representing 28.29% of future costs, a percentage lower than the municipality's for 2019 to 2020. However, since the spending is higher in S2 than in S1 (Table I), all absolute values for each waste category were higher in the future than in previous years, even for the ones that had their percentage decreased in Scenario 2 (domestic, urban cleaning, healthcare, and cemetery waste).

In contrast, both C&D and healthcare waste treatment have similar cost percentages in both scenarios, demonstrating that they were within a reasonable costing range considering the previous periods. These types of waste are the producer's responsibility. However, the public administration is a great generator of them and has to manage them correctly, monitor healthcare services and private constructors, and even support low-income constructions or renovations by creating four specific delivery points.

Furthermore, the incorporation of costs for the recycling and selective collection category, estimated at around US$ 5,000/month for warehouse and truck rentals, as well as the structuring of a minimum workforce, has the potential to minimise the final destination of municipal solid waste to the order of 5%. This workforce would be a cooperative of waste pickers, widespread in Brazil and other underdeveloped countries. In this association, the workers can guarantee minimal social protection and better material selling prices, which is different from the situation until 2020, when they were working isolated.

Apart from the already mentioned selective collection (3.54%), the largest percentage changes in cost occurred for basic sanitation waste (7.29%), environmental monitoring (2.83%), and environmental education (2.29%) categories, a situation doubtless related to the absence of values for these

service fronts during the 2017-2020 period. On the other hand, municipal environmental structure and inspection attained a percentage (1.96%) similar to S1 scenario years despite cost increases.

For the environmental education category, the increase in future values comes from adding a specific employee (an environmental educator – US$ 1,230/month) and other fixed costs of US$ 2,000.00/month to maintain a specific place and related activities. It is believed that this could encourage an effective and well-structured environmental education program, with partnerships with schools, for instance. It is also proposed to hire an additional environmental fiscal officer (US$ 1,126/month) and a specific engineer (US$ 1,584/month) to monitor municipal plans and targets related to solid waste for the environmental structure and inspection service. Other improvements, such as those related to the maintenance of vehicles, computers, and field equipment, were also considered, with a total value of US$ 2,970/month. These three new municipal employees can work on all environmental issues, not only those related to solid waste.

For basic sanitation service waste, the costs of collection, transport, and correct disposal of approximately 15 m³ of sludge generated in municipal water treatment plants and 4 tons of sludge generated in the sewage treatment plant were considered, giving a total cost of US$ 10,300.00/month. For the environmental monitoring of the decommissioned landfill, the costs of US$ 4,000/month involved transporting and treating the leachate and hiring a team specialised in groundwater monitoring and geotechnical studies.

Figure 4 shows the *per capita* values for the scenarios and those involving only the portion spent by the municipality on solid domestic waste. For municipalities with no charge for waste management, as is the case in the municipality understudy, this seems to be a more rational way of starting discussions about a fixed or variable charge system since all inhabitants generate domestic waste. Rocha-dos-Santos, Leite and Schalch (2023), applying the activity-

based costing method to study the economic and financial sustainability of the solid waste services of a 240,000 inhabitants municipality, concluded that the fee charged covers the household waste service costs. This city has a charging system only for household waste and healthcare waste.

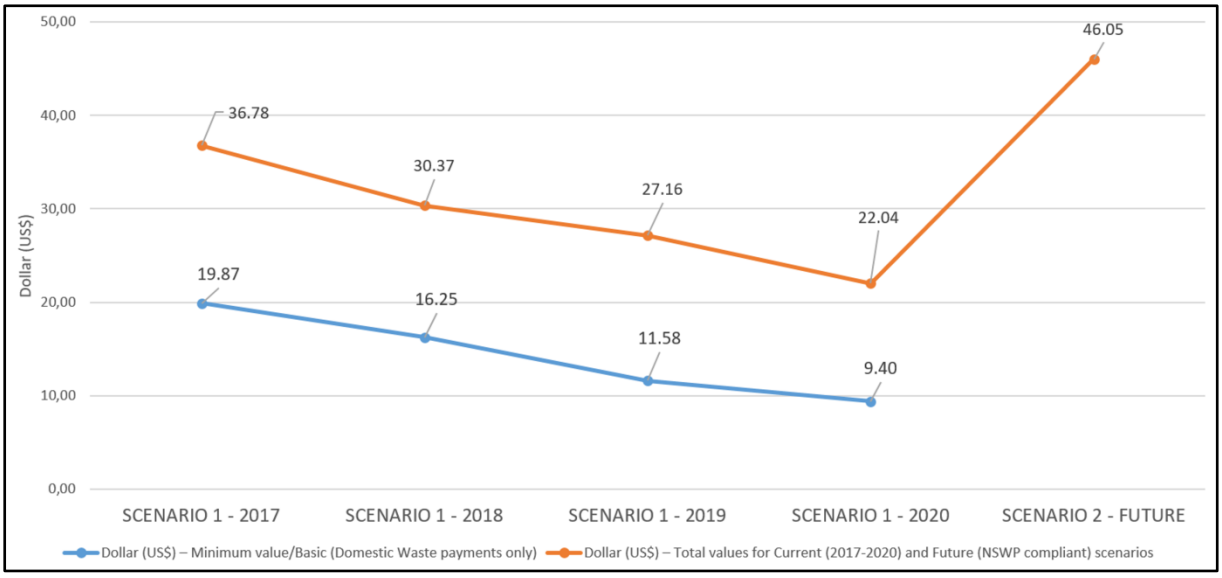
Results from Figure 4 show that the total and household waste costs have a declining *per capita* rate from 2017-20220 (mean of US$ 3.70 year^{-1} and 2.62 year^{-1}, respectively). This reduction may be related to the exchange value of the Brazilian currency against the US dollar, which ranged from R$ 3.19 per US$ in 2017 to R$ 5.16 in 2020 (BCB, 2021). Another factor influencing this trend was the operational decisions of the public administration during this period, which resulted in greater system efficiency. Examples of this were the decision to change a service provided directly by the government to an outsourced service and change suppliers, as already mentioned (Table I). The average *per capita* estimate between 2017 and 2020, US$ 29.09, is close to the national average (US$ 27.55). However, it is somewhat higher than the mean value for other municipalities with less than 50 thousand inhabitants, which is US$ 21.73 (SNIS, 2020).

From 2017-20220, the average value spent by the studied municipality considering only household waste was US$ 14.28 per inhabitant/year. However, as shown in Figure 4, the minimum *per capita* value obtained by collecting only the payment related to domestic waste would be US$ 9.40, representing 1.60% of the 2020 budget. This could form an initial regulatory alternative for municipalities where there is none. Such an option would have a less economic and social impact since the entire population pays, but it does not cover the total costs incurred by the services provided to the population and does not apply the pays-as-you-throw principle, which is considered fairer than the flat fee.

Per capita value of US$ 46.05 projected for Scenario 2 costs were above the national average of US$ 27.55 and even surpassed values for several larger Brazilian cities, including state capitals such as Maceió (about 1 million inhabitants, US$ 26.2 per inhabitant/year). On the other hand, it is only below

certain larger municipalities, such as Rio de Janeiro (US$ 64.78 per inhabitant/year) (SNIS, 2020).

Figure 4 – Variation in *per capita* values for current and future scenarios, showing *per capita* expenditure for the studied municipality for solid domestic waste only



The variation in values between Brazilian locations can be explained by the lack of national standardisation for calculating service costs, as each location uses its form of costing and accounting. However, this may change thanks to the recent regulation created by the federal government (ANA, 2021) and more effective action by regulatory agencies at all national government levels regarding this law and the National Plan for Solid Waste (Brazil, 2022).

However, when compared with average annual values adopted in other locations around the world, the US$ inhabitant/year values for Scenario 2 lie far below those for developed locations, such as Spain - US$ 202.00 inhabitant/year, Sweden - US$ 121.25 inhabitant/year, Japan - US$ 125.53 inhabitant/year and the United States - US$ 81.00 inhabitant/year (Dutra et al., 2020). One of the reasons for this divergence is that, as already mentioned, the municipality studied does not have a specific fee related to solid waste. This situation is still common in Brazil.

Across 2017-2020, management costs in the studied municipality generated average annual spending of US$ 777,932.92, while the cost of domestic waste services represented US$ 377,763.82/year, or 48%.

Any municipality seeking environmental and economic sustainability for its waste management needs to conduct a detailed analysis of all aspects of solid waste management, including financial considerations. It is reasonable that the waste management costs do not reach levels that compromise other equally important actions. A thorough economic study of the municipality's revenues and expenses can identify areas where the percentage allocated to waste management can be increased and ensure that everything counted as being related to waste management only involves spending related to waste management.

As already mentioned, part of the cost of municipal solid waste management can also be reduced via a continuous search for efficiency in all sectors and from other sources, including public-private partnerships, inter-municipal cooperation, and international and national funding.

A clear definition of the rights and duties of citizens and effective inspection can also bring savings to local government since there are records in several large, medium, and small Brazilian cities of municipal resources being exploited for private purposes. A classic example in Brazil occurs when civil construction waste is clandestinely dumped on the street, and City Hall removes it due to complaints from citizens (Galvão, 2017). As already mentioned, there are some kinds of waste whose management is the producer's responsibility, and, despite the municipality may and should support the reverse logistics in the city, the producers have to pay for it.

All of this needs to be done to avoid or, at least, postpone charging for services, which is known to be unpopular for many reasons and, if adopted, would need to be very well explained to the population. In Brazil, for example, such an action would likely put considerable strain on an administration since it is

one of the countries with the highest tax burden in the world, at around 40% of GDP (Lima; Rezende, 2019).

However, disregarding the tax burden and the difficulties of charging for services rendered, whether fixed or variable, this can be seen as a conceptually viable –or even inevitable- measure. Failure to fully reimburse operating costs and related services (self-sufficiency) is one of the biggest obstacles to advances in waste management and potential improvements in this type of service in any city in the world.

4 CONCLUSIONS

The impact of solid waste management services costs on a municipal budget was analysed with the help of data from a small municipality in Brazil, Rio das Pedras (36 thousand inhabitants). During the evaluated period (2017-2020), such costs ranged from 1.60% to 3.64% of the total annual municipal budget. The analysed solid waste management involved 7 types of waste and related activities (domestic waste, urban cleaning waste, C&D waste, healthcare services waste, cemetery waste, reverse logistics, and municipal environmental structure/inspection). Domestic and urban cleaning waste consumed most financial resources (approximately 80%).

Given other municipal priorities, the current fiscal allocation would be insufficient to meet all the national legislation's requirements. For this to be possible and without any other changes being made (e.g., improving efficiency), the studied municipality would need to commit 7.48% of its entire annual budget to solid waste management. This increase was due to improvements in the current scenario and the inclusion of new services related to basic sanitation waste, recycling & selective collection, environmental monitoring of the decommissioned landfill, and environmental education.

Thus, the municipality needs more financial resources to provide a better quality service for the final consumer (the citizens). These resources can come from the constant search for the greatest possible efficiency of the services provided, indirect budget adjustments, inter-municipal cooperation, and new types of fundraising (such as national and international funding). Furthermore, population awareness-raising and improvements in the inspection structure must also be made, including the division of responsibilities between those involved. The municipality has problems with the responsibilities division, mainly related to C&D waste and healthcare waste generators. In addition, seven types of waste in Brazil have nationwide reverse logistic systems that usually need some support to work properly in each municipality.

At last, another alternative to be considered is the creation of new tax formats. More than half of the Brazilian cities, including the one studied, do not have any specific charge for waste services. Since all the inhabitants produce domestic waste, adopting an initial charge to pay the operational costs of this type of waste seems reasonable and even inevitable for these cities. In the city studied, in 2020, this fee would be US$ 9.40 *per capita*, 43% of the annual spending in that year with solid waste (US$ 22.04). However, this flat fee could be only the beginning of the discussions, which must aim for a pay-as-you-throw system since it is more effective and has more population's support.

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