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STRATEGIES FOR FINANCIAL SUSTAINABILITY OF MUNICIPAL SOLID WASTE MANAGEMENT SYSTEMS

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ABSTRACT

Purpose: Evaluate the charging strategies for recovering the costs of municipal solid waste (MSW) management used in the world, identifying the characteristics of each charging model implemented.

Theoretical framework: The integrated management MSW is a complex activity that requires significant financial resources. A fundamental point for urban planning is the need for users to be charged for the correct management of MSW, moving from the current waste landfill model to energy recovery systems.

Method: A systematization of the scientific literature was developed in order to relate the collection strategies implemented with the maturity of the legislation, the level of income, human development index (HDI), and degree of social inequality (Gini coefficient) of each country.

Results and conclusion: With the evaluation of data from 27 countries, it was noted that developed countries have chosen the Pay-As-You-Throw model (PAYT), while developing countries have chosen the fixed fee models.

Research implications: The New Legal Framework for Basic Sanitation requires Brazilian municipalities to establish charging models for MSW management services. The results found can help public managers when making decisions about which model should be implemented in each Brazilian city.

Originality/value: Data from 27 countries were evaluated to identify patterns, characteristics, advantages and disadvantages in charging models for recovering the costs of MSW management.

Keywords: Integrated Management, Municipal Solid Waste, Financial Sustainability, Recover the Costs, Charging Strategie.

ESTRATÉGIAS PARA SUSTENTABILIDADE FINANCEIRA DOS SISTEMAS MUNICIPAIS DE MANEJO DE RESÍDUOS SÓLIDOS

RESUMO

Objetivo: Avaliar as estratégias de cobrança para recuperação dos custos do manejo de resíduos sólidos urbanos (RSU) utilizadas no mundo, identificando as características de cada modelo de cobrança implantado.

Referencial teórico: A gestão integrada de RSU é uma atividade complexa que necessita de expressivos recursos financeiros. Um ponto fundamental para o planejamento urbano é a necessidade de cobrança pelos usuários para que haja o correto gerenciamento dos RSU, passando do atual modelo de aterramento de resíduos para sistemas de aproveitamento energético.

Método: Foi realizada uma sistematização da literatura científica de modo a relacionar as estratégias de cobrança implementadas com a maturidade da legislação, o nível de renda, de desenvolvimento humano (IDH) e grau de desigualdade social (coeficiente de Gini) de cada país.

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Resultados e conclusão: Com a avaliação de dados de 27 países, verificou-se que países desenvolvidos têm optado pela cobrança por utilização, enquanto países em desenvolvimento tem escolhido modelos de tarifa fixa.

Implicações da pesquisa: O Novo Marco Legal do Saneamento Básico exige que os municípios brasileiros de instituam modelos de cobrança pelos serviços de manejo de RSU. Os resultados encontrados podem auxiliar os gestores públicos no momento de tomada de decisão de qual modelo deve ser implementado em cada cidade brasileira.

Originalidade/valor: Foram avaliados dados de 27 países para identificar padrões, características, vantagens e desvantagens nos modelos de cobrança para recuperação dos custos do manejo de RSU.

Palavras-chave: Gestão Integrada, Resíduos Sólidos Urbanos, Sustentabilidade Financeira, Recuperação de Custos, Estratégias de Cobrança.

1 INTRODUCTION

Among environmental issues, matters related to the generation of municipal solid waste (MSW) and its proper disposal are discussed globally, driven by economic factors, as well as environmental, social, and public health concerns. The scarcity of natural resources, soil degradation, surface and groundwater pollution, and the contamination of individuals through direct or indirect contact with waste have affected both developed and developing countries, each with its own specific challenges (Dutra et al., 2018).

The increasing urbanization, coupled with rising consumption levels, has contributed to the exponential growth in the amount of waste generated in cities. This can lead to the proliferation of improper waste disposal if proper planning by institutions is not observed (Chaves et al., 2014; Grazhdani, 2016; Marshall & Farahbakhsh, 2013). According to data from the World Bank, it is estimated that the global population generates approximately 2 billion tons of urban solid waste annually, which translates to an equivalent of 0.74 kg of waste per person per day (World Bank, 2018).

To address this issue, governments have been implementing MSW management systems aimed at keeping cities clean and promoting the proper disposal of waste. However, while MSW management is a highly significant task, it is important to emphasize that the financial and environmental costs of managing the substantial volume of generated MSW are substantial for societies. Among the costs inherent to the urban solid waste management (USWM) system, noteworthy are those related to capital expenditures (CAPEX), such as the acquisition and licensing of collection, transportation, transshipment, and final disposal facilities, including landfills or treatment and recycling units, as well as the acquisition of vehicles, machinery, furniture, and equipment. Additionally, there are operational expenses (OPEX) for labor, energy, fuel, equipment maintenance, and other inputs necessary for the operation, the combined total of which can account for up to 20% of local government budgets (Kaza et al., 2018).

As a result, governments have been guided by the central principle of the polluter-pays, in which it is understood that those responsible for generating solid waste should bear the costs for mitigating the impacts resulting from its management, similar to what is already done with services like water and electricity supply (Alzamora & Barros, 2020; Dutra et al., 2020).

In pursuit of this goal, a range of strategies for cost recovery in the MSW management system have been adopted worldwide, aiming for the financial sustainability of the system and encouraging behavioral changes among users to reduce waste generation and promote a circular economy for waste (Kaza et al., 2018; Slavik & Rybova, 2017).

Regarding the financial sustainability of the system, the literature indicates that there is no ideal model for cost recovery due to the diversity of local conditions (L. Dutra et al., 2020). However, the analysis of variables such as the maturity of local legislation regarding charging, income levels, the country's level of development, and the degree of social inequality can facilitate the selection of the most suitable model to be applied.

In this context, considering that the literature on charging for MSW management services is still limited, especially for developing countries, often confined to specific case studies without a broader scope (Alzamora & Barros, 2020), there is a need for more in-depth research on the charging strategies used worldwide for cost recovery in management systems. This research should also consider the time of implementation, the income and the development level of the country where it was adopted so that the advantages and disadvantages of each model can be assessed and the gaps and tools to aid decision-making can be identified.

2 THEORETICAL FRAME

The system of Integrated Urban Solid Waste Management (IUSWM) comprises two groups of services: (a) Urban Cleaning Services (UCS), which aims at keeping cities clean through actions such as sweeping, pruning, weeding, scraping, and mowing; (b) Urban Solid Waste Management Services (USWM), which provides the collection, transportation, transshipment, treatment, environmentally appropriate final disposal of solid waste, and environmentally appropriate final disposal of rejects.

Thus, IUSWM can be understood as a set of actions aimed at achieving environmental effectiveness, social acceptability, and economic sustainability in USW management (Marshall & Farahbakhsh, 2013; Rodi´c & Wilson, 2017; Soós et al., 2017; Wilson et al., 2017), reducing adverse effects on the environment and increasing material and energy recovery to preserve resources for the future (Liu et al., 2017; Soltani et al., 2016). Since it is a complex process involving multiple actors and dynamically interconnected dimensions, it cannot be described from a singular, static perspective. Its analysis requires suitable analytical tools to assist managers in decision-making (Di Nola et al., 2018; Hornsby et al., 2017).

IUSWM also requires the selection of the best methods and technologies to be adopted for each city, taking into account their territorial specificities, such as the income level of the entity responsible for ensuring expense sustainability, the cultural development of the entities involved, the available national space and technologies, and the commercially available forms of reuse and recycling. Slavik and Pavel (2013) further emphasize the need to motivate managers to develop public policies that expand waste prevention, recycling, and energy recovery systems, rather than opting for less expensive systems like incineration or landfilling.

It is important to highlight that while IUSWM involves various stakeholders such as governments, manufacturers, traders, and users, the execution of the steps for USWM is primarily the responsibility of local governments in most cases (Alzamora & Barros, 2020; de Souza et al., 2021; Kaza et al., 2018; Rodi´c & Wilson, 2017; Slavik & Pavel, 2013; Soltani et al., 2016; Wright et al., 2019). Other waste typologies, such as commercial and service provider waste (depending on the volume generated and municipal legislation distinguishing it from domestic waste), industrial waste, healthcare waste, construction waste, and others, are typically managed by their generators, giving IUSWM the characteristics of a public service.

In this context, it is the responsibility of local governments to control the costs of the steps required for USWM, to plan investments, to negotiate contracts with service providers, to educate users, to establish and enforce regulations, and to engage with producers and consumers (International Finance Corporation, 2014).

Because it is deemed a public service, the services required for USWM need to be carried out regularly, continuously, efficiently, safely, with reasonable tariffs, rational use of water resources, integration with other public services, and with the aim of universalizing and ensuring the comprehensiveness of services. Local governments may define diverse revenue collection methods to fund these services (Alzamora & Barros, 2020; Dutra et al., 2020; Kaza et al., 2018).

Due to the complexity of their activities, waste management costs, on average, account for 4% of local budgets in high-income countries, 11% in middle-income countries, and can reach 19% in low-income countries (Kaza et al., 2018). Among the stages of USWM, special attention should be given to collection and transportation, which can account for 80 to 95% of the total cost of the USWM service (Franca et al., 2019; Jaunich et al., 2016; Kaza et al., 2018). The International Finance Corporation (2014) asserts that, in low-income countries, the USWM system is one of the most critical services a city can offer and, along with UCS, employs the most workers.

Among the costs for implementing the MSW management system, notable ones include those related to infrastructure, such as equipment acquisition and the construction of disposal facilities, as well as operational expenses like labor, fuel, and equipment maintenance. In general, the operational costs (OPEX) of the services are significantly higher than the capital investment costs (CAPEX) due to the logistical nature of the activity and are often the most challenging to sustain (Dutra et al., 2020; Kaza et al., 2018).

Both CAPEX and OPEX costs of USWM are also dependent on the technology adopted for final waste disposal. These costs may not be accounted for in the case of irregular disposals, such as controlled landfills or open dumps, or when high-cost technologies like anaerobic digestion and thermal processes, such as incineration, with or without energy recovery, are used (Kaza et al., 2018).

Around the world, while 50% of the investment costs (CAPEX) for these facilities can be covered by local governments, 20% come from federal governments, and 10 to 25% originate from partnerships with the private sector (International Finance Corporation, 2014; Kaza et al., 2018). On the other hand, the costs for operating the system (OPEX) are typically funded through service charges, including fees and tariffs, as well as other taxes or contributions, and often require subsidies through public transfers (Kaza et al., 2018; Soós et al., 2017; Wilson et al., 2017).

Soltani, Sadiq, and Hewage (2016) further add that local governments bear the costs of USWM services, while other stakeholders, such as businesses, service providers, organizations of recyclable material collectors, recyclers, and intermediaries, benefit from the services without contributing financially to the costs of the USWM system. They may, at times, dispose of waste or receive potentially recyclable materials without a financial counterpart.

Therefore, the financial sustainability of the USWM system can be defined as the pursuit of a balance between costs and benefits, where costs should be offset by user satisfaction (Slavik & Rybova, 2017). In this context, governments have adopted various strategies to generate revenue for the implementation and operation of the USWM system, as can be seen in Table 1.

Table 1 - Strategies for raising funds for the implementation of the USWM system.

Strategy	Description	Example of Implementation
Charging generators for the provision of the public USWM service	This strategy is based on allocating the total costs of services (OPEX and CAPEX) to those who use them.	In the United States, more than 7,000 communities charge a variable fee based on the amount of waste they generate (UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, 2016).
Trading in recyclable materials	This strategy aims to obtain funds through the sale of	In Barcelona, Spain, materials like plastic, metal, and cardboard packaging are sold to authorized recycling

Strategy	Description	Example of Implementation
and organic compounds	recyclable materials and organic compounds.	companies for the subsequent production of new packaging materials, generating an annual revenue of approximately 600,000 dollars (Medina-Mijangos et al., 2021).
Financing through carbon credits	This strategy aims to finance waste management projects that reduce certified greenhouse gas emissions (GHGs).	In Brazil, the installation of landfills with biogas capture was funded by selling carbon credits through the Forest Carbon Partnership Facility (FCPF) fund of the World Bank (World Bank, 2018).
Generating Energy/fuel from waste	This strategy seeks to generate funds by selling energy or fuel derived from waste.	In Switzerland, it is estimated that in 2012, the energy generated in waste-to-energy facilities was able to meet 2% of the national energy demand (Mannarino et al., 2016). In Japan, about 78% of the waste generated was used for energy generation (Mukherjee et al., 2020).
Implementing Extended Producer Responsibility (EPR) systems	This strategy aims to hold the manufacturer responsible for the disposal of post-consumer waste, as well as consumers who use the product.	In Tunisia, the National Eco-Lef Program levies a 5% tax on the net added value of post-consumer packaging, mainly plastic (Kaza et al., 2018).
Taxing imported goods and tourism	This strategy aims to generate revenue through the taxation of products and services.	In the city of Castries, the capital of Saint Lucia, services are funded through environmental taxes on imported goods and tourism (Wilson et al., 2017).
Levying Landfill	An additional charge imposed for final disposal in landfills, with the aim of encouraging recycling and extending the lifespan of landfills.	In Australia, since 2006, most states have imposed additional fees for waste sent to landfills, resulting in approximately 60% of the total waste generated being recycled (Dutra et al., 2020).
Taxing advanced disposal	The charge is embedded in the product's price and is used to finance services such as selective collection.	In Switzerland, products like plastic and glass bottles, cans, light bulbs, batteries, and printers have a post-consumer management fee included in their sale price. For example, 0.018 Swiss francs (SFr) are charged for each plastic bottle (Mannarino et al., 2016).

Source: Authors (2023).

Among the possibilities for financing, there is a predominant use of the generator-pay models worldwide, facilitated by the polluter-pays principle (Alzamora & Barros, 2020; Chung & Yeung, 2019; L. Dutra et al., 2020; Kaza et al., 2018; Kurniawan et al., 2021; Meng et al., 2018; Slavik & Pavel, 2013; Soós et al., 2017; Wilson et al., 2017; Wright et al., 2019). In this way, besides obtaining resources for the USWM, it is possible to raise awareness among generators about reducing their production, since they become directly responsible for the amount of waste they generate.

3 METHODOLOGY

The methodology focused on the systematization of published information that provided an examination of the literature on the cost recovery models of MSW management systems used internationally. To achieve this goal, it relied on the work stages described in Figure 1.

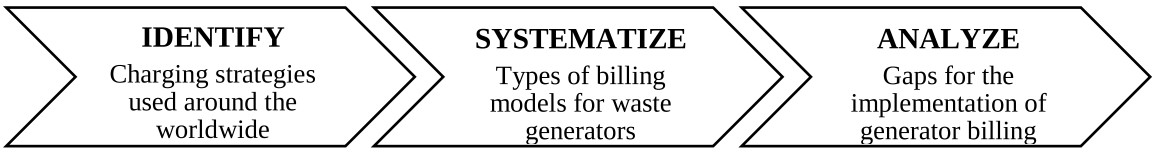

Figure 1 - Methodological Steps

3.1 Identification of billing strategies used worldwide

To identify the billing strategies for cost recovery in USWM systems, a bibliographic research was conducted on scientific articles published in the last 10 years. The research was planned to cover the universe of publications related to the topics of 'municipal solid waste' and 'billing strategies.' As some terms are used differently across countries, a wide range of terms was employed in the research.

In this regard, the following search terms and boolean operators were used to narrow down the universe of articles to be analyzed: 'domestic solid waste management' OR 'household waste management' OR 'municipal solid waste management' OR 'municipal waste management' OR 'residential solid waste management' OR 'solid waste management' OR 'urban solid waste management' AND charg* OR levy OR fee OR tariff OR tax OR 'pay as you throw' OR 'financial sustainab*'.

To organize the bibliographic portfolio, the subject of this study, a bibliometric analysis was conducted using the open-source quantitative analysis tool called Bibliometrix as presented by Aria and Cuccurullo (2017). Therefore, the search terms were inserted into the Scopus (Elsevier) and Web of Science (Core Collection - Clarivate Analytics) databases to obtain the necessary metadata for the proposed scientific mapping. The selection of these databases was due to their greater relevance in literature searches and to their provision of complete metadata required for utilizing the tool (Aria & Cuccurullo, 2017).

After removing duplicate documents, the metadata from articles obtained in the databases was inserted into an Excel spreadsheet. Subsequently, articles were filtered through an evaluation process where those with titles, abstracts, or keywords not aligned with the researched theme were eliminated. Once the articles were selected, a systematic reading and analysis were carried out to create the portfolio. The selection criteria involved identifying articles that addressed the financial sustainability of municipal solid waste management services.

3.2 Systematization of billing models for waste generators

From the publications obtained in the previous stage, different types of billing models for waste generators by the MSW management service were identified, relating their characteristics, advantages, and disadvantages.

Subsequently, the billing models implemented in 27 countries worldwide were systematized concerning the time of legislation implementation enabling billing (maturity), the average income level of the population, the Human Development Index (HDI), and the degree of social inequality (Gini coefficient). This was carried out to identify patterns that correlate local characteristics with adopted models.

To accomplish this, databases from the World Bank (World Bank, 2022) and data on the implemented billing models in the mentioned countries from the articles resulting from the conducted bibliographic research were utilized.

3.3 Analysis of gaps for implementing billing to waste generators

The research gaps analysis aimed to address issues that have not yet been studied or are under development within the international scientific community regarding the implementation of billing to waste generators by MSW management services. Thus, research gaps presented in the consulted publications were identified primarily based on suggestions for future work listed in the conclusions of the examined research.

The research gaps were subsequently classified into 5 categories: socio-economic conditions, environmental conditions, operational conditions, financial conditions, and governance conditions, as determined by the authors.

4 RESULTS AND DISCUSSION

4.1 Types of billing models for waste generators by MSW services

According to the consulted literature, billing models for waste generators by public MSW management services can be grouped into 3 basic types.

- Fixed billing: The fixed amount is calculated by allocating the overall cost of services based on waste generation estimates, correlating generation through parameters such as property square footage, water, or energy consumption;
- Usage-based billing (also known as 'pay as you throw' or PAYT): The amount is calculated based on the quantity of collected waste, which can be measured by volume or weight units. The waste generator determines how much service it requires. Billing can occur through the purchase of bags, labels, or official stickers (the bag's volume determines the fee), through the use of containers (the container's volume determines the fee), or through a weighing system (the weight of collected waste determines the fee);
- Combined billing: The fee is fixed for small generators like households and usage-based for larger generators like businesses. This is because the criteria used for fixed billing (such as square footage) may not be suitable for non-residential properties (a smaller commercial space might generate more waste than a larger one). Generally, usage-based billing in combined billing occurs when waste generation exceeds a certain volume.

Table 2 presents the advantages and disadvantages of each billing type.

Table 2 - Advantages and Disadvantages of billing models for waste generators by MSW services.

Billing Model		Advantages	Disadvantages
Fixed		-Implementation and management are easier and less expensive - Provides better financial control for the service provider - The charged amount partly reflects the owner's income	- Does not incentivize waste reduction or non-generation - Depends on a good correlation between waste generation and the chosen parameter - Does not differentiate between small and large waste generators or the property's purpose (residential or commercial) - Requires good administrative capacity
Usage-based	Standardized bags	- Encourages waste reduction or non-generation - Increases recycling rates - Low implementation cost as there is no billing system - Equidade no pagamento	- Variable revenue - Hinders mechanized collection - Bags may be torn by animals - Possibility of improper disposal
	Official labels or stickers	- Encourages waste reduction or non-generation - Increases recycling rates -Low implementation cost as there is no billing system - Equity in payment	- Variable revenue - Hinders mechanized collection - System can be circumvented by the waste generator - Possibility of improper disposal
	Standardized containers	- Stable revenue - Facilitates mechanized collection	- High implementation and maintenance costs

Billing Model		Advantages	Disadvantages
		- Prevents animals from spreading waste - Equity in payment	- Requires a billing system - Need for standardization of containers - Possibility of improper disposal
	Weighing	- Encourages waste reduction or non-generation - Easy correlation between service value and waste quantity generated - Precise measurement of waste generation - Equity in payment	- High implementation and maintenance costs - Complex operational and financial systems - Requires a billing system - Possibility of improper disposal
Combined		- Differentiates between small and large waste generators - Encourages waste reduction or non-generation for users served by usage-based billing	- Increased complexity due to the coexistence of two models - Higher administrative cost for operation and supervision

Source: Compiled by the authors from data from Alzamora and Barros (2020); Dutra et al. (2020); Gradus et al. (2019); Slavik and Pavel (2013).

The literature describes that fixed billing aims to ensure the financial sustainability of collection services and environmentally adequate disposal, ultimately aiming to guarantee public health and environmental protection. Consequently, the authors assert the potential to eliminate open dumps and individualize user responsibility for generated waste (Alzamora & Barros, 2020; Dutra et al., 2020; Kaza et al., 2018). Dutra et al. (2020) describe that Peru achieved an 84% collection rate of all generated waste in the country by adopting a fixed billing model, which allocates system costs proportionally based on the area of the serviced properties. The authors mention that the allocation is typically calculated to be proportional to the property's usage type (commercial, industrial, service, or residential), aiming to cover the total service costs. However, its primary disadvantage lies in not incentivizing waste reduction or non-generation because users pay the same amount regardless of the quantity of waste generated during the period.

Alternatively, usage-based billing stands out for not only ensuring financial sustainability but also incentivizing a reduction in the quantity of waste generated and disposed of by individuals. This billing method involves payment proportional to the quantity of service used (Dutra et al., 2020; Wright et al., 2019). Furthermore, usage-based billing may provide financial incentives for segregating economically valuable waste at the generation source, thereby promoting increased recycling (Chung & Yeung, 2019; Gradus et al., 2019; Slavik & Pavel, 2013).

The literature suggests that once financial sustainability for collection and environmentally adequate disposal is established through a fixed billing model, the usage-based billing model can be adopted to encourage behavioral changes among users to further mitigate waste generation and boost the circular economy of waste (Alzamora & Barros, 2020; Dutra et al., 2020; Kaza et al., 2018; Slavik & Rybova, 2017).

It is observed that in most countries, the costs of MSW services are not fully recovered through charges to waste generators (fixed or usage-based) and often require subsidies through government transfers (Kaza et al., 2018; Rodić & Wilson, 2017; Soós et al., 2017; Wilson et al., 2017). These subsidies are commonly linked to a property tax (International Finance Corporation, 2014), indicating the need to adopt alternative forms of financing for these services.

4.2 Adopted billing models worldwide

According to Hornsby et al. (2017), choosing a billing model for a specific location depends on correctly assessing local socioeconomic conditions. Thus, there is no ideal model for implementing a billing system due to the variety of local conditions. Improving the system relies on the application of appropriate technology, advancements in environmental education, and user participation. In this regard, studying local socioeconomic conditions such as the maturity of legislation, user income level, and local development level can assist managers in deciding on the most suitable model for the local reality.

Therefore, Table 3 summarizes the billing models adopted in 27 countries, relating them to the implementation time, the country's income and its development level in which they were adopted. Meanwhile, Figure 2 presents the relationship between the billing type and the Human Development Index (HDI) and inequality index (Gini coefficient) of each country.

Table 3 - Comparison of generator charging strategies for providing MSW services around the world.

Location	Billing Model[1]	Billing Implementation Date[1]	Income Level[2]	HDI[3]	HDI Classification[3]	Gini Coefficient[3]
Argentina	Fixed	2004	upper middle income	0.845	very high	41.4
Australia	Usage through containers and bags	1971	high income	0.944	very high	34.4
Belgium	Usage through bags	1990	high income	0.931	very high	27.4
Brazil	Fixed	2010	upper middle income	0.765	high	53.9
Chile	Fixed	2005	high income	0.851	very high	44.4
China	Indirect - through exclusive taxation of the productive sector	2018	upper middle income	0.761	high	38.5
Colombia	Fixed	2016	upper middle income	0.767	high	50.4
Costa Rica	Fixed according to property size	2013	upper middle income	0.810	very high	48.0
Czech Republic	Fixed	1991	high income	0.900	very high	24.9
England	No billing	n/a	high income	0.932	very high	34.8
France	Fixed and Usage	2005	high income	0.901	very high	31.6
Ghana	Fixed and Usage	2008	lower middle income	0.611	medium	43.5
Greece	Fixed	2015	high income	0.888	very high	34.4
Ireland	Usage	2003	high income	0.955	very high	32.8
Japan	Usage through bags	1970	high income	0.919	very high	32.9
Mexico	Fixed	2003	upper middle income	0.779	high	45.4
Netherlands	Usage	1990	high income	0.944	very high	28.5
New Zealand	Usage through containers and bags	1971	high income	0.931	very high	s/d
Peru	Fixed	2000	upper middle income	0.777	high	42.8
Portugal	Fixed	2007	high income	0.864	very high	33.8
South Africa	Fixed	2009	upper middle income	0.709	high	63.0
South Korea	Usage through stickers and bags	1995	high income	0.916	very high	31.6
Spain	Fixed and Usage (Barcelona) through	1992	high income	0.904	very high	34.7

Location	Billing Model[1]	Billing Implementation Date[1]	Income Level[2]	HDI[3]	HDI Classification[3]	Gini Coefficient[3]
	vacuum collection system & containers					
Sweden	Fixed and Usage through containers and bags	1975	high income	0.945	very high	28.8
Taiwan	Usage through the sale of official garbage bags	1991	high income	0.885	very high	33.6
Thailand	Usage through bands	1994	upper middle income	0.777	high	36.4
United States of America	Fixed and Usage	1970	high income	0.926	very high	41.4

Source: Compiled by the authors using data from [1]Alzamora and Barros (2020); Dutra et al. (2020); Mannarino, Ferreira and Gandolla (2016); Slavik and Pavel (2013); [2]World Bank (2022); [3]UNDP (2020); n/a: not applicable; s/d: no data available.

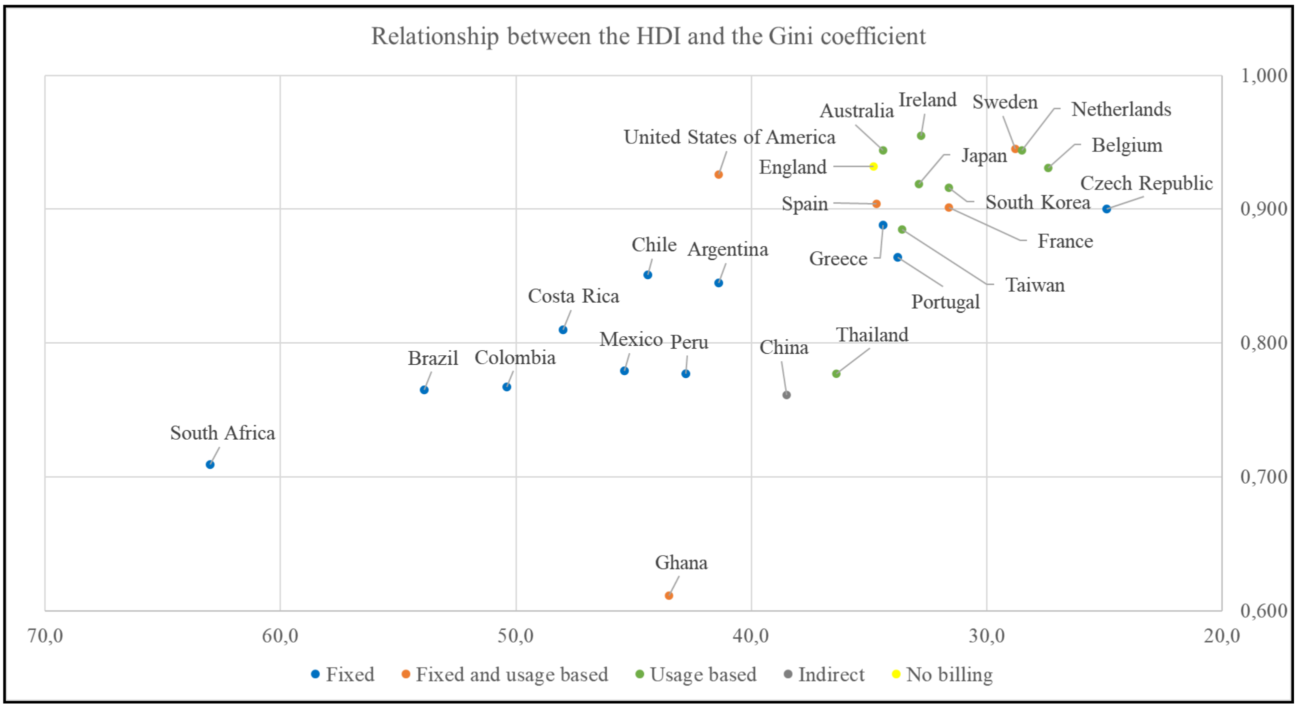

Figure 2 - Type of billing adopted in relation to the HDI and Gini Index.
Source: Compiled by the authors with data from Alzamora and Barros (2020); Dutra et al. (2020); Mannarino, Ferreira, and Gandolla (2016); Slavik and Pavel (2013); and UNDP (2020).

From Table 3, it is evident that some countries have more than one model for billing waste generators by MSW management services. Additionally, it's important to highlight that the composition of Table 3 was based on the studies presented, and there might be other revenue collection methods in the researched countries.

Regarding the maturity of legislation concerning billing, it's observed that 85% of countries that implemented their billing policy more than 20 years ago adopt the usage-based system, while 92% of countries that implemented their billing policy less than 20 years ago adopt the fixed billing system. According to Slavik and Pavel (2013), usage-based models are progressively replacing fixed billing models due to requirements from national governments (motivation), local governments (enhanced efficiency), and users (payment equity).

However, the existence of a legal framework is not sufficient for the implementation/improvement of the billing system, as there are several challenges to its effectiveness. This starts with the need for local governments to establish their billing mechanisms, and extends to municipal managers that need to be trained to handle service costs and revenues collected through billing (Alzamora & Barros, 2020; International Finance Corporation, 2014), alongside the necessity for adequate public awareness.

Regarding income levels, it is observed that 47% of high-income countries have usage-based billing systems, 24% adopt combined systems, 24% utilize fixed billing, and 6% have no charges. Meanwhile, among upper-middle-income countries, 78% have fixed billing systems, 11% adopt usage-based systems, and 11% have indirect billing. In the sole low-middle-income country in the study (Ghana), a combined system is employed.

It is also evident that usage-based billing models charge on average 4 to 5 times the amount billed per capita in fixed billing models. This discrepancy can be attributed to higher operational and maintenance costs in usage-based models. Despite an increase in collection costs, Slavik and Pavel (2013) argue that these are offset by savings in landfill costs, making usage-based billing more environmentally effective than fixed billing.

It is essential to note that some European countries do not charge for the disposal of recyclable waste such as plastics, glass, paper, metals, and even organic waste when delivered voluntarily by the generator, reducing the amount to be paid by the generator and simultaneously improving the recycling rate (Mannarino et al., 2016).

Regarding the Human Development Index (HDI) and the Gini Coefficient for inequality, Figure 2 demonstrates that countries with higher human development (very high HDI) and lower inequality between rich and poor (lower Gini Coefficient) predominantly employ usage-based systems. Conversely, in developing countries (with high and medium HDI) and higher inequality (higher Gini Coefficient), fixed billing systems prevail. This could be explained by their simplicity in implementation and easier comprehension by the population.

One of the main reasons for this, especially in developing countries, is the lack of data or reliable data, which hinders the implementation of usage-based models since information availability is crucial for proper system management (Mannarino et al., 2016).

According to Wilson et al. (2017), developing countries show a low level of user inclusion, lack financial capacity, and have institutions that do not adequately monitor and oversee services, making it difficult to adopt usage-based models.

Lastly, even in developed countries where usage-based billing is more common, cases of fixed billing still exist, indicating that the implementation of usage-based billing requires not only legal support but also environmental awareness among the population, a well-established selective collection system, and a strong administrative capacity on the part of municipal management (Alzamora & Barros, 2020; Chung & Yeung, 2019). Therefore, Slavik and Pavel (2013) point out that usage-based billing models need to be accompanied by socio-environmental communication programs that encourage population participation in waste segregation.

In contrast to global practice, England does not have any billing system as national legislation prohibits direct charging to the generator. The necessary resources for service execution come from indirect property taxes (Alzamora & Barros, 2020; Rodi´c & Wilson, 2017).

Finally, regardless of the chosen model, Soós et al. (2017) highlight the need for financial transparency so that users and operators are aware of service costs and available budgets, creating a service-payment relationship.

4.3 Gaps for the implementation of generator billing

From the consulted studies, it was possible to identify gaps in research for the implementation of billing models for waste management services. These gaps were grouped into 5 categories, as evidenced in Table 4. It is worth noting that some items could be listed in more than one category; for instance, the need to define guidelines and strategies for meeting the local environmental agenda could belong to the environmental conditions or governance category. However, to avoid repetition, the category most closely related to the item discussed was chosen.

Table 4 - Gaps for the implementation of billing models for waste management services.

Category	Observed Items
Socioeconomic Conditions	- Need to understand local socioeconomic conditions[1,17,18,21] - Embracement of the polluter-pays principle by the local government[1,3,17] - Public awareness for genuine responsibility regarding waste generation[1,17] - Implementation of socio-environmental communication programs that encourage community participation in waste segregation[2,17] - Assessment of user satisfaction[8] - Identification of stakeholders (such as recyclable material collectors, recyclers, and intermediaries) operating in the area[9,17,18,20] - Need for public consultations to choose the billing model to be adopted[10,17,17] - Identification of the willingness to pay for MSW[10,13,14] - Fair distribution of costs and benefits among stakeholders[20]
Environmental Conditions	- Definition of guidelines and strategies to meet local environmental agendas[11,16,17] - Evaluation of increased illegal waste dumping in landfills due to billing implementation[1,17] - Adoption of environmentally suitable disposal methods[1] - Evaluation of recycling rates to meet predetermined targets[1,3] - Assessment of environmental impacts to define the appropriate billing model[19,20]
Operational Conditions	- Need for an updated database on the services provided for each generator[3,4] - Assessment of local administrative capacity to manage services, costs, and revenues collected from billing[3,4,5,10,17,21] - Determination of weighting parameters (property size, water consumption, service usage frequency, location in urban zoning; socioeconomic reality) in the fixed billing model[1] - Accuracy in weighing or volume measurement for fairness in the variable billing model[1] - Need for monitoring and oversight of services[6,7,15,17] - Availability of infrastructure, equipment, and personnel for service operation[6,7,17,21] - Assessment of expanding waste management services to underserved areas and new developments[17]
Financial Conditions	- Determination of costs for each stage MSW[3] - Evaluation of the need for public budget supplements during system implementation[1,5,6,17] - Possibility of obtaining credit from funding sources such as the World Bank for CAPEX[6,17] - High maintenance cost of the billing system in the variable billing model[1] - Determination of incentives for participation in voluntary delivery programs[4] - Evaluation of service demand with an increase in fees charged to generators[12] - Rate reduction through total or partial exemption categories for low-income users[6,17] - Evaluation of compensation methods for communities near waste disposal sites of MSW[17]
Governance Conditions	- Existence of legal framework enabling billing[5,15,17,18] - Payment for services based on predetermined outcomes[6] - Definition of technologies used for waste disposal of MSW[6,7,19] - Compliance with other cost recovery mechanisms such as extended producer responsibility (EPR) systems, landfill taxes, etc.[1,4,17] - Need for financial transparency to inform users and operators about service costs and available budgets[6,7,17] - Involvement of stakeholders in the decision-making process[20,21]

Category	Observed Items
	- Definition of decision support tools in the waste management[2,6,21]

Source: Compiled by the author with data from: [1] Dutra et al. (2020); [2] Slavik and Pavel (2013); [3] Alzamora and Barros (2020); [4] Mannarino, Ferreira, and Gandolla (2016); [5] International Finance Corporation (2014); [6] Kaza et al. (2018); [6] Soós et al. (2017); [7] Wilson et al. (2017); [8] Slavik and Rybova (2017); [9] Dutra, Yaman, and Siman (2018); [10] Chung and Yeung (2019); [11] De Lorena Diniz Chaves, Dos Santos, and Rocha (2014); [12] Grazhdani (2016); [13] He, Yu, and Fukuda (2021); [14] Subhan, Ghani, and Joarder (2014); [15] Cetrulo et al. (2018); [16] Bing et al. (2016); [17] Rodi´C and Wilson (2017); [18] Meng, Wen, and Qian (2018); [19] Liu et al. (2017); [20] Soltani, Sadiq, and Hewage (2016); [21] Hornsby et al. (2017).

5 CONCLUSIONS

Inferring from the growing generation of MSW, various alternatives have been sought to finance MSW management services. These seek to ensure the economic sustainability of these services by recovering costs incurred by local governments. This approach also aims to encourage waste minimization while emphasizing that the responsibility for waste management needs to be shared among waste generators.

Among the alternatives for financing MSW management services, governments have increasingly opted for charging waste generators for the provision of services. These models often include fixed tariffs, user fees, or a combination of both. The intention behind such measures is to hold waste generators accountable for system costs and incentivize waste reduction. Many countries have adopted multiple strategies for cost recovery within their systems.

The study delineated the advantages and disadvantages of each waste generator charging model and made comparisons across countries. It was observed that countries with more mature legislation tend to prefer user fee models, whereas those with more recent legislation (less than 20 years old) lean towards fixed tariff systems. Additionally, it was noted that user fee models are progressively replacing older billing systems to achieve greater efficiency and fairness in payment.

Similarly, countries with higher per capita income, greater development levels (higher HDI), and lower social inequality (lower Gini coefficient) tend to opt for variable charging models due to their equity (payment is proportional to waste generation) and their encouragement of waste reduction. On the other hand, countries with middle-to-high-income, those still in development, and those with higher social inequality (higher Gini coefficient) tend to choose fixed tariff models to ensure financial sustainability for waste collection services and environmentally sound final waste disposal for non-recyclables.

The identified gaps for implementing waste generator charging models in the management of MSW, as indicated in the consulted studies, have been categorized to foster future studies proposals.

This study mainly focused on waste generator charging. Future studies might consider assessing the synergy with other revenue-generating strategies, such as energy generation from waste, the sale of recyclables and by-products, Extended Producer Responsibility (EPR) systems, and other potential approaches.

It's also important to note that the data presented for the 27 countries in this study may not fully represent the realities of less developed countries (with medium to low HDI). The lack of studies on these countries also signifies a gap that should be addressed by future research.

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