A framework for sustainable and integrated municipal solid waste management: barriers and critical factors to developing countries

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Journal of Cleaner Production 312 20 Aug 2021

https://www.sciencedirect.com/science/article/abs/pii/S0959652621017352?via%3Dihub

Abstract

Developing countries adopt policies to reduce the negative impacts of large amount of waste generated by accelerated industrialization and rapid urbanization, but these actions are far from establishing procedures that meet society's needs, especially regarding the management of municipal solid waste (MSW), which requires the cooperation of numerous stakeholders, and a broad plan of action, in terms of sustainability cities' targets and policies. In this sense, sustainable and integrated solid waste management (S-ISWM) emerges as a solution to address the growing challenges of disposing of MSW in developing countries municipalities. However, to guide S-ISWM implementation there still a need of a framework with a multi-stakeholder and holistic perspective of the MSW management, considering the barriers and critical success factors (CSFs) to achieve it. To this end, a systematic literature review using the PRISMA diagram on the Scopus and Web of Science databases, and then, a content analysis of 75 articles, which met the eligibility criteria, were carried out. As a result, were identified eight barriers, 11 CSFs, which were grouped according to five pillars - public policies, disposal techniques, legal aspects, public-private partnership (PPP) and energy recovery – that affect the municipal S-ISWM and were pointed out ways of implementing these factors in practice. Finally, it was proposed a management artefact – a framework towards S-ISWM - based on state-of-the-art CSFs and barriers, mainly oriented to waste to energy, to the developing countries municipalities. This study offers theoretical, practical, and political implications, serving as a stimulus for the development of public policies with a multidisciplinary approach, providing environmental, economic, and societal contributions, and, thus, encouraging the achievement of the eleventh and the twelfth sustainable development goals.

Keywords: Integrated solid waste management. Sustainable development. Barriers. Critical factors. Systematic literature review. Municipalities.

1. Introduction

As urban populations continue to grow and consumption patterns change, solid waste management (SWM), which is the treatment of solid, liquid or atmospheric emissions before it is released into the environment, has become an issue of growing global concern (Marshall and Farahbakhsh, 2013). Additionally, greenhouse gas emissions related to waste have been recognized as a major contributor to global warming (Caiado *et al.*, 2017). Urban SWM is a central problem in the main cities of the world, which grows with massive urbanization and rapid development, and is affected by issues such as the weight of municipal budgets and high costs associated with their management (Azevedo, Scavarda and Caiado, 2019).

This section contextualizes the relationship between SWM and sustainability, between municipal solid waste (MSW) and integrated solid waste management, introduces the research gaps and the concept of sustainable and integrated solid waste management, and finally describes the research questions, goals, and contributions of this research.

1.1 SWM and sustainability

Current regulations on urban SWM face increasing challenges in relation to trade-offs and hierarchical stakeholder management (Guo *et al.*, 2019). Furthermore, separating, storing, collecting, transporting, processing, recovering and disposing of solid waste requires multidisciplinary skills (Rada, Ragazzi and Fredizzi, 2013), including the participation of public authorities, the community and members of municipalities (Chen, 2010). Any form of development can only be sustainable if the waste generated by it cannot accumulate, but is fully reused, recycled, and recovered. Strategies to achieve this goal include attempts to recover energy from waste (Abbasi, 2018). To this extent, processes that transform waste into energy can provide renewable energy and make SWM more sustainable (Tan *et al.*, 2015). On the other hand, although waste in developed countries is used as a resource for energy production, in developing countries the collection, transportation and disposal of waste are still current issues (Moya *et al.*, 2017).

Considering the public health impacts of residents, SWM is an international challenge (Jin, Wang and Ran, 2006), especially in urban areas of developing countries (Azevedo, Scavarda and Caiado, 2019). Depending on the country and its level of development, there are several options for the SWM. Developed countries, which enjoy a higher level of economic development, reach a high level of public awareness, adopting preventive approaches to waste more easily; while developing countries, where populations are more focused on short-term gain or survival, resort to less expensive low-tech approaches (Chalhoub, 2018)

European countries have considerably reduced the disposal of solid waste in landfills, giving priority to their energy recovery. In Portugal, Decree-Law no. 178/2006 points out the prevalence of waste recovery over its disposal (Portugal, 2006). On the other hand, developing countries face a socio-environmental crisis resulting from poor SWM, since the economic potential that could be extracted as reuse is lower than expected, making it difficult to adopt the perspective of sustainable management with social inclusion (Selau, 2018). Urbanization, inequality and economic growth; cultural and socioeconomic aspects; politics, governance and institutional issues; and international influences have complicated SWM in developing countries, limiting the applicability of approaches that have been successful throughout the SWM development trajectories of industrialized countries (Marshall and Farahbakhsh, 2013).

1.2 MSW and integrated solid waste management

In the municipal area, the tendency is to worsen, given the continuous expansion of waste and the need for correct disposal (Da Silva, Fugii and Santoyo, 2017). A deep reform in the municipal administration of developing countries is urgently needed (Azevedo *et al.*, 2020). It is estimated that the MSW generation rate - waste generated in residential, commercial and institutional areas that includes homes, offices, schools, stores, etc. (Elsaid and Aghezzaf, 2015) - is expected to increase to 2.2 billion tons per year by 2025 worldwide (Moya *et al.*, 2017). MSW systems differ worldwide and are influenced by social, financial, cultural, psychological, educational and technological factors (Elsaid and Aghezzaf, 2015). In addition to this, it is important to differentiate between domestic solid waste, which consists of mixed domestic waste collected through the collection by the curb, bulky domestic waste and urban waste (e.g., street cleaning waste, market waste and illegal dumping) (Jacobsen, Buysse and Gellynck, 2013), from industrial solid waste which, due to the nature of the industries, which emit more concentrated pollutants by discharge and greater pollution discharges by source, and for this reason it is generally associated with more dangerous and risky constituents, with the greatest potential to exceed the natural limits of self-recovery or the self-healing capabilities of the ecosystem (Mbuligwe and Kaseva, 2006). Thus, the quantities and contents of MSW also differ according to the standard of living and the degree of urbanization (Elsaid and Aghezzaf, 2015).

Brazil's National Solid Waste Policy (NSWP) can provide lessons in SWM based on its opportunities and barriers to other developing and developed countries (De Sousa Jabbour *et al.*, 2014). However, evaluations of public policies for SWM indicate the difficulty of integrating different approaches and themes for a single model applicable in different contexts (Soltani, Hewage, Reza, et al., 2015). Also, even if foreseen in the NSWP, the themes on the incineration

and energy recovery of residues have shallow exploration both in the literature and in the academic research lines. As a result, the lack of technical and economic resources and general information on the problem demonstrates the reality that is still very common in developing countries, that is, the use of landfills as a way of final disposal of MSW, implying consequences such as the contamination of natural resources and public health problems (Ramos *et al.*, 2017). Besides, there is a lack of studies that specifically looks at integrated urban SWM, especially from the perspective of a developing country (Leal Filho *et al.*, 2016). In this sense, integrated solid waste management (ISWM) - which considers the entire MSW management chain and integrates interrelated processes to operationalize a complete waste management system (Marshall and Farahbakhsh, 2013) - is an emerging area for address the growing challenges of disposing of MSW in megacities (Asefi, Shahparvari and Chhetri, 2020).

On the other hand, well-designed waste plans are important at national, state, micro-regional, intermunicipal and municipal levels. Hence the relevance of ISWM for municipal enterprises, coordinated by good planning, which generates jobs, sustainability and high levels of popular acceptance (Machado, 2013), as they are instruments that guarantee that the common objectives of society and corporations are continuously achieved and reviewed (Schalch et al., 2015). However, the sanitation and integrated management plans in developing countries do not meet the minimum content, impairing municipal planning. The municipalities, for the most part, lack systematic information and specialized technical staff, which obliges them to prepare the plans briefly, being more concerned with the presentation than the quality of its content (Marotti, Santiago and Pugliesi, 2017). In addition, there is a lack of diagnoses containing the possibility of setting goals, actions and procedures that ensure the objectives of society selected in a manner compatible with the municipal reality (Schalch et al., 2019). Also, there is a lack of organizational resources and competitiveness (Mittal and Sangwan, 2014), strategic planning (Ravi and Shankar, 2005), and efficient performance measurement systems (Chin et al., 2000), as in the digital economy that evolves both in the corporate and services areas (Fleury, 2000), the interaction of the efficient human factor with information systems (Parasuraman et al., 2005).

Thus, the developing countries context demonstrates the presence of obstacles for ISWM (Leal Filho *et al.*, 2016). Many barriers, such as inadequate waste recovery and disposal methods are forming an obstacle to the development of waste to energy (WtE) (Chand Malav *et al.*, 2020). Such a scenario reveals in principle that the waste management frameworks used today are not effective and sustainable (Fuss, Vasconcelos Barros and Poganietz, 2018), due to several difficulties associated with public policies (services with economic and financial profitability), public-private partnerships (PPPs) allowing cooperation between different stakeholders with long-

term contractual models and shared risks, considering innovative aspects in favor of energy recovery, among other issues. The growth of the WtE sector was influenced by many political, economic and technological barriers, such as inadequate funds, the lack of regular national policies and legislation, as well as incomplete data collection and evaluation (Chand Malav *et al.*, 2020). To overcome these barriers and solve numerous liabilities related to the environment, especially the mountains of MSW discarded in an irregular way, it is necessary to apply facilitating instruments for the social control of public policies, emphasizing stractegic guidelines, institutional arrangements, legal aspects and financing mechanisms (Schalch and Leite, 2012). Also, to limit more environmental damage caused by MSW, the need now is to identify the ISWM alternatives available that must be the highest combination of accessible alternatives adapted to society (Chand Malav *et al.*, 2020).

1.3 Sustainable and integrated solid waste management (S-ISWM)

Moreover, to achieve a sustainable and integrated solid waste management (S-ISWM), a system must be designed as an integrated system, market oriented (recycled materials and recovered energy for end users) and flexible (capacity for continuous development) with the contribution of stakeholders in relation to their expectations (Marshall and Farahbakhsh, 2013). To guarantee the sustainability of an ISWM system: it must be economically reasonable, environmentally friendly, and socially and legally responsible (Asefi, Shahparvari and Chhetri, 2020). In the study of Pietzsch, Ribeiro and de Medeiros (2017), the authors map the benefits, challenges, and enablers to Zero Waste, but there are theoretical overlaps regarding S-ISWM. Additionally, in the study of Ma and Hipel (2016), the authors critically evaluate the published literature on the social dimensions of MSW management. Still, there is still a lack of clarity regarding the barriers and CSFs to the integration of SWM, involving multiple stakeholders and their responsibilities (e.g., PPPs). Thus, academia does not provide a clear view on the barriers and critical success factors (CSFs) to sustainability and integration in SWM (Marshall and Farahbakhsh, 2013). CSFs, (also known as facilitators, enablers or drivers) are considered as the key points or conditions (Julianelli *et al.*, 2020) that must be met to facilitate the achievement of a sustainable ISWM.

Furthermore, although the critical review of Iqbal, Liu and Chen (2020) provides valuable insights to develop a sustainable municipal SWM, there still a need to build a framework to guide its implementation (Azevedo, Scavarda and Caiado, 2019), pointing out constraints (barriers) and enablers (CSFs) to achieve it, with practical implementation guidelines (Fuss, Vasconcelos Barros and Poganietz, 2018). In view of that, it is of latent need to proceed to a deeper analysis on the theme, especially regarding the S-ISWM in developing country municipalities (Azevedo *et al.*,

2020). Also, according to Asefi et al., (2020) pre-2000 studies identified deficiencies present in previous models developed in MSW management, such as greater emphasis on economic efficiency and ecological management and neglect of the community and social welfare; inadequate understanding of the MSW management decision process from a multi-stakeholder perspective (Azevedo *et al.*, 2020). In addition, so far, few models have a holistic perspective of the SWM system (Leal Filho *et al.*, 2016); most focus on isolated problems within the larger system and are of little use to decision makers (Marshall and Farahbakhsh, 2013). Thus, there is still a need for holistic and integrated frameworks that address the interconnection of the socio-cultural, environmental, economic and technical spheres. This need is particularly strong in developing countries, where the complexities of SWM systems are often greater (Wilson *et al.*, 2015).

1.4 Research questions, goals and contributions

To fill these gaps, the main objective of this study is to propose a novel framework towards S-ISWM, considering the state-of-the-art of the barriers and CSFs to establish the S-ISWM in developing countries' municipalities. The framework is built based on taxonomies of barriers and CSFs, to achieve an interdisciplinary (Cunha and Guerra, 2013) and holistic approach (Pietzsch, Ribeiro and de Medeiros, 2017) to implement S-ISWM. Thus, to build the components of this artifact, the present study needs to answer the following research questions (RQs):

RQ1: What are the barriers to S-ISWM in municipalities of developing countries?

RQ2: What are the CSFs for S-ISWM in municipalities of developing countries?

In this context, to answer these central questions, this paper uses a systematic literature review (SLR) method to identify (i) the barriers, and (ii) the CSFs to enable S-ISWM implementation, as well as, (iii) to point out ways of implementing the factors identified in practice. The theme substantially addresses the purpose of developing country municipalities in terms of the effectiveness and applicability of services in sustainable cities and communities, sustainable production and consumption, placing at a strategic level the fight against open-air dumps and proper disposal of MSW.

This study has theoretical and practical contributions. From a theoretical point of view, this research explores the subject of the recovery of waste, providing CSFs to mitigate environmental impacts, both detailed in the concepts of sustainability (Julianelli *et al.*, 2020). In addition, from an academic angle, the research also contributes to the literature on S-ISWM, barriers and CSFs, investigating the link of these themes through a holistic and systemic view focused on developing

country municipalities. It also offers a comparison of Brazil, one of the largest producers of waste in the world (Alfaia, Costa and Campos, 2017), with other developing countries (e.g., from BRICS - Brazil, Russia, India, China, and South Africa), as Brazilian municipalities face a dichotomy - structural barriers (e.g., governance problems, sources of financing) and disciplined good practice legislation (e.g., NSWP), which also occurs in major of developing countries, and thus Brazilian trends could be relevant to these countries, especially in South America, by providing variables characterized in the taxonomies of barriers and CSFs that may guide S-ISWM initiatives for other developing countries. From a practical point of view, as this study focuses on MSW and is mainly oriented to WtE, it offers a management artifact based on CSFs and barriers for practitioners (e.g., public and private managers) who wish to transform the underutilization of solid waste discarded inappropriately into input for energy production, that is, the garbage produced on a large scale currently discarded in dumps and landfills could be reused, generating income, employability for municipalities in a new stage of reuse.

Finally, the study contemplates the proposal of a framework with a holistic (Fuss, Vasconcelos Barros and Poganietz, 2018) and multi-stakeholder (Azevedo, Scavarda and Caiado, 2019) perspectives, aligned with the 2030 Agenda. Among the main sustainable development goals (SDGs), providing cities with a significant reduction in the negative environmental impact per capita of communities (SDG#11) and encouraging recycling and reuse of solid waste, that is, sustainable consumption and production (SDG#12), are those whose adherence is applicable to organizational strategies, and plausible execution of municipal public services. Thus, substantially reducing the generation of waste by 2030, through prevention, reduction, recycling, and reuse, in addition to reducing environmental impacts, including paying special attention to air quality, municipal waste management, among others, are imperative and fundamental measures, all led by S-ISWM.

We have arranged the remaining section of this paper as follows. In the next immediate section, theoretical background is narrated describing the pillars that affect municipal solid waste management. Section 3 describes the research methodology used in the systematic review. Then, the descriptive results and content analysis are presented in section 4. In section 5 there is a proposal of a framework for integrated and sustainable waste management in municipalities in developing countries. Finally, section 6 deals with the conclusions and suggestions for future research.

2. Theoretical background

Sustainability and integration of SWM in municipalities of developing countries is related to different factors. It can be considered that natural resources are being compromised, either by social exclusion, but also by the lack of basic infrastructure in cities. In some developing countries, the high population rates, diversity, geographic size, and economic base, imply complex challenges in sanitation, infrastructure, health, among others, where solid waste is improperly disposed of, basically in landfills and dumps. In these municipalities, inadequate budgets for basic services prevail, such as collection, transportation and final disposal of waste in landfills, which is why SWM services can reach 20% to 50% of the municipal budget, most of which are related to garbage collection (UN Environment, 2018).

The use of urban planning policies prevails at the heart of economic and social balance, conserving sustainable natural environments (Lira and Candido, 2013), in which the degrading effects concern managers in developed and developing countries (Neto, 2013). Therefore, public agencies with a marked lack of treatment of waste need to develop integrated, efficient and sustainable management. Public policies correspond to rights constitutionally guaranteed or which are affirmed thanks to the recognition by society and public authorities as new rights for people, communities, things or other material and immaterial goods (Macedo and Alcantara et al., 2015). As the industrial process progresses, the ecological degradation present on the entire planet continues to grow in a surprising way.

Due to significant urban populations that are rapidly prospering and adopting high consumption lifestyles similar to those of developed countries, five developing countries, namely China, India, Brazil, Indonesia and Mexico, are among the ten most MSW-generating nations (Nanda and Berruti, 2020). Paved by consumerism and globalization, urban solid waste produced in India and China has an unprecedented evolution. It is so true that these countries occupy the second and seventh place of the largest producers of urban solid waste in the world. In India, SWM remained a neglected area until the intervention of the Supreme Court of India that resulted in the Municipal Solid Waste Management and Handling Rules of 2000 that required the involvement of actors such as community-based organizations, private contractors, and non-governmental organizations (NGOs) in the functions of SWM, under the Environmental Protection Act of 1986, as a solution to the inability of municipal authorities to deal with conservation operations (Singh, 2012).

From this perspective, the qualified induction of rational and ecologically fair production prevails with the desire to prepare, on a large scale, an inclusive, empathetic, and solidary society. Over the years, the concern with solid waste has grown dramatically, even after the United Nations

Conference on Environment and Development - Rio 92, both at the national and international levels (Gouveia, 2012). In addition, household SWM services, with few exceptions, do not have well-designed policies or sufficient resources, providing environmental impacts that are difficult to solve and pulverize public resources (Leite and Pugliese et al., 2012).

An interdisciplinary and holistic approach is necessary (Kruger *et al.*, 2018) for a perfect understanding of the environmental issue, given the complexity and uncertainties (Azevedo, Scavarda and Caiado, 2019). Another relevant point is the lack of rigor in the implementation of pollution control regulations in developing countries. In addition, under these conditions, about three quarters of all MSW are 'landfilled' in developing countries (Abbasi, 2018).

From this perspective, both law - considered as a system of norms of human conduct and a tool for resolving social conflicts - are present, as well as legal science, understood as a study and interpretation of normative texts, legal principles and institutions (Cunha and Guerra, 2013). The ethical-legal dimension of environmental issues, it is duly recognized to make the protection of ecology rooted in the dignity of the human person, by means of the consecration of fundamental rights (Macedo and Alcantara et al., 2015).

It is possible to verify good sustainable management practices in Latin America. The Renew Program that promotes renewable energy in Argentina, the “Training of Trainers” project containing strategic planning for waste management in Chile, the sustainable production and consumption to reduce food waste and waste generation in Bogotá / Colombia, the Plan District Environmental - PAD of Quito / Ecuador, whose content encompasses the Master Plan for Integrated Waste Management as a guiding strategy strategy for MSW. Brazil has the NSWP and the recommendations of the municipal plans for integrated MSW management, Conama Resolution No. 481 (UN Environment, 2018). The aforementioned Resolution brought the concept of tailings (Brazil, 2017). Therefore, the Brazilian legal framework frames the environmentally appropriate final disposal of solid waste, after all the possibilities for treatment and recovery by available and economically viable technological processes have been exhausted. There is also the PPP institute in Law No. 11.079 (Brazil, 2004) in the Brazilian scenario, with a view to overcoming the rigidity of their contractual models and allowing cooperation between the State and the private sector in financing the provision services and in the execution of long-term ventures (Guimarães, 2013). This administrative concession model brings long-term solutions, overcoming the issue of deadlines and administrative contracts of Law no. 8,666 (Brazil, 1993), removes the drama of budgetary limitations, which always create the risk of contracts with unfinished objectives for works and services according to a typically private efficiency standard. Finally, it

allows obtaining works and services according to a typically private efficiency standard. The administrative concession is, therefore, a great answer to the satisfaction of a relevant need whose fulfillment, according to traditional contractual models, is not feasible (Milaré, 2013).

The choice for one of the thermal processes for pre- or post-recycling waste treatment must be guided by technical, social, economic and political issues, in line with the strategies relevant to the integrated management of solid waste, which prioritize the reduction, selective collection, recycling, composting, anaerobic digestion and energy generation from waste (Themelis, 2013a). Although the incineration of urban MSW in China is currently highlighted by its lack of operational experience, insufficient funds for compliance with the emission standard and the lack of reliable supervisory measures, as well as the low capacity for harmless treatment and disposal of MSW, the SWM of Chinese municipalities are improving recently, from the improvement of air pollution control systems, with China's new emission standard for pollution control in urban MSW incineration (Alfaia et al., 2017). The Chinese government provides unconditional support for power generation from waste incineration, publishing a series of plans, preferential policies, and subsidies. In recent years, the incineration industry has entered a phase of rapid development, resulting in the large-scale emergence of waste to power plants (Yun, 2015).

Incineration is also one of the main routes for the treatment of MSW in France (Tiébauth, 2017). In this way, the use of energy can represent an important element of diversification of the energy matrix, and the conversion of installed power in the supply of energy from waste, conservation and generation, can reach 25% of national consumption, with relatively lower investment costs than the available alternatives (Oliveira, 2014). So, energy recovery and reuse start from the idea that solid waste does not necessarily cease to have value, in view of recovery, the hypothesis of reusing and recycling a significant part, being reintegrated into the economic cycle, both for industry or externally (Bartholomeu and Caixeta et al., 2011). As a consequence, the high generation of MSW results in heated debates, whether due to their increasing generation in cities, as well as the adoption of effective management strategies, especially in developing countries, even in the BRICS, where the growth of waste is associated with the Gross Domestic Product (GDP), industrialization, population growth, together with urbanization and a general increase in living standards (Gonçalves et al., 2018).

Therefore, the lack of updated methods, technical and economic resources, a decision support tool for long-term contractual adjustments, as well as the lack of resources and qualified labor are factors that contribute to the use of dumps in the sky and landfills as the final destination for MSW. In addition, the lack of knowledge about waste energy recovery technology are indicators that

SWM in developing countries is influenced by five pillars, namely: (a) Public Policies; (b) Disposal techniques; (c) Legal Aspects; (d) PPP; and (e) Energy Recovery. These pillars, the gaps and, consequently, the research questions (derived from the gaps pointed out in section 1) that guided this study, have been identified and sorted according to a scoping review (Arksey and O'Malley, 2005), which was used to scope S-ISWM body of literature and clarify concepts. According to Munn *et al.* (2018), the scoping review is indicated as a precursor of a SLR, to identify knowledge gaps and to identify key factors (pillars) related to a concept (municipal solid waste management). The following subsections present a description of these five pillars and highlight the impacts of each pillar in SWM.

2.1 Public policy to SWM

The Public policy pillar is motivated by the marked lack of treatment of municipal waste, which requires public agencies to develop an integrated, efficient, and sustainable management. In developing countries such as those in Latin America, institutional governance problems are evident, including against environmental authorities to mitigate significant losses in population centers, in urban and rural areas (Gouveia, 2012). Although governmental procedures in different ministerial portfolios are carried out to generate effective and timely economic resources to serve the population in future demands, the gap lies in the real capacity to establish articulated and coherent interventions between the different social, public and private actors that intervene in the management risk factors (Quintero and Thomas, 2018).

This pillar aims at the government to act with a business vision, executing services, optimizing the use of natural resources with a focus on the economic and financial profitability of the activity in the control of expenses in parallel with the preservation of the environment. In addition, it seeks government programs implemented through specific and vigorous procedures, structuring relationships between people, public and private institutions (Amorim and Boullosa 2013). Based on "well-being", economic relations or activity must be founded on the valorization of human work and free initiative, ensuring everyone a dignified existence (Grau 2018). As a driver of public policies and laws that bring together economic growth, the State ends up exercising the protection of the environmental good (Milaré 2013). Hence the capacity of the public power to harmonize, according to a business vision, the attendance and performance of services, optimizing the use of natural resources and the impact on the environment, without neglecting the economic and financial sustainability of the activity (Romeiro and Maia 2011).

2.2 Disposal techniques to SWM

The Disposal techniques pillar is motivated by the lack of ISWM models that emphasize planned guidelines for developing countries. Developing countries lack ISWM models that emphasize strategic guidelines, institutional arrangements, legal aspects, financing mechanisms and facilitating instruments for the social control of public policies (Schalch et al. 2012). The importance of diagnoses lies in the possibility of setting goals, actions and procedures that ensure the objectives of society listed in a manner compatible with the reality of the municipalities (Schalch and Leite, 2019). Solid waste with inadequate destination aggravates socio-environmental impacts, degrading the soil, compromising water sources, polluting the air, in addition to aggravating the unhealthy conditions of urban centers (Besen, Günther et al., 2010).

This pillar seeks to implement effective management models to overcame waste management paradigms. Robust models, such as stochastic optimization, highlight the importance of recovering the value of waste bins (Beigl, Lebersorger and Salhofer, 2008). Based on schedule with opportunity restrictions, it is developed to optimize the planning of waste collection operations. Existing studies address SWM problems in cities, basically on routes for garbage collection trucks, operating costs, energy consumption, polluting emissions in transport, etc (Shah *et al.*, 2018).

2.3 Legal aspects to SWM

The Legal aspects pillar is motivated by the need for the environmental manager to make use of legal and financial law rules to inform society, applying legal sanctions in cases of non-compliance. The environmental imbalance requires measures capable of changing the culture and the interest of the citizen for the preservation of the environment for present and future generations having as priorities the pedagogical character, among others. The development of the energy sector and the increase in energy efficiency must be considered a top priority, as well as modernity (Beylot, Hochar and et al., 2017). Therefore, there is a need to harmonize legislation at various levels of economic management, in the areas of energy saving and innovative activity, among others based on organizational, financial, economic and legal support (Melink and Lukishina, 2016).

This pillar seeks to coercive, stable and transparent rules for the public power, private companies and society. The right to protection of the environment clearly shows the overcoming of individual ideals, characteristics of contemporary society (Piovesan 2013). The budgets, repositories of the essence of the State's financial activity, express during the period of its validity "the calculation of the authorized revenues and expenses for the functioning of public services".

The accounting system recommended by the legislation is responsible for providing the elements resulting from the State's financial achievements. It seeks to supply the Administration with information that allows it to verify whether the programmed goals are being achieved as planned and to provide the necessary measures in case deviations are detected (Martins 2011). By making the protection of ecology rooted in the dignity of the human person, through the enshrining of fundamental rights, the ethical-legal dimension of environmental issues is duly recognized, basically in relation to the terms "ecology" and "human dignity" (Macedo and Alcantara et al., 2015).

2.4 PPP to SWM

The PPP pillar is motivated by the lack of improvements in financing, in the management methodology to achieve profitable results goals. Therefore, the contract for the administrative concession of PPPs, and its peculiarities, have the potential to beat old contract models, serving as an alternative for long-term projects. PPP is an approach adopted to increase the economic value of public sector infrastructure products, improving efficiency through systematic processes (Yong and Hope, 2018).

This pillar, seeks to overcome the obstacles of traditional contractual models, stimulating the interaction between the contractor (public power) and the contacted (Private Companies). One of the mechanisms that can contribute to the conservation of the environment and to its sustainable exploitation is precisely that of PPPs. Administrative concessions are PPP's modality in which the tariff collection from the user is not viable, either because it is legally prohibited or not considered convenient by the government (Milaré and Morais et al., 2016). The contractual models of the Administrative Concession of Law no. 11.079 / 04 (Brazil, 2004), provides a long-term solution, exceeding the time limits of traditional contracts governed by Law no. 8.666 / 93 (Brazil, 1993). The demand for infrastructure is clear there in the municipalities, where people live, and which has a huge plexus of services housed under its competence, despite its low financial capacity (Guimarães, 2013).

2.5 Energy recovery to SWM

Finally, the Energy recovery pillar is motivated by the adequacy of energy recovery projects for urban waste to enhance the sustainable and integrated SWM, basic sanitation related to infrastructure. Therefore, the thermal treatment of solid urban waste with energy recovery means to diversify the energy matrix, through technological processes currently available and economically viable. Any form of development can only be sustainable if the waste generated is

not accumulated, but fully reused, recycled and recovered (Abbasi, 2018). Energy waste is challenging management in developing countries. However, several technologies to generate electricity or heat from waste can be applied, as a fraction of wasted waste can be used in energy recovery (Peerapong and Limmeechokchai, 2016).

This pillar seeks the WtE approach, through the recovery and integration of part of the waste in the economic cycle. The choice for one of the thermal processes for pre- or post-recycling waste treatment should be guided by technical, social, economic and political issues, in line with the strategies relevant to integrated waste management, which prioritize reduction, selective collection, recycling, composting, anaerobic digestion and energy generation from waste (Themelis, 2013b). The Chinese government provides unconditional support for power generation from waste incineration, publishing a series of plans, preferential policies, and subsidies. With China's rapid development in recent years, the incineration industry has entered a development phase, resulting in the large-scale emergence of waste for power plants (Li *et al.*, 2015)

3. Methodology

In this article, a SLR was conducted to disseminate a detailed and critical analysis of SWM in developing countries, in accordance with the objective listed in the introduction section (Cunha, Ceryno and Leiras, 2019). It is a method that gathers primary studies on the topic, which meet the eligibility criteria to answer the specific research question with explicit and systematic methods (Caiado et al., 2018) in order to minimize partiality aligned with the objective, providing reliable results in which they are withdrawn conclusions and decisions taken (Antman *et al.*, 1992). This review is in line with the systematic typology, with a view to following the four principles of Briner & Denyer (2012), which are: (a) adopt a systematic system or method; (b) present a transparent and explicit method; (c) be replicable and up to date, and (d) summarize and synthesize evidence related to the review issue.

For Thomé, Scavarda, & Scavarda (2016), SLR consists of eight steps: (i) research problem formulation, (ii) literature search, (iii) data collection, (iv) quality assessment, (v) data analysis and synthesis, (vi) interpretation, (vii) presentation of results, (viii) and updating of the review. This research followed the first seven steps indicated and is detailed in five stages: (1) question formulation, (2) study location, (3) study selection and evaluation, (4) analysis and synthesis, and (5) report and use of results, as defined by (Denyer and Tranfield, 2009).

In this way, the evaluation of the present study begins with the research questions (RQs) properly formulated in section 1 which aims to guide this review and select the studies that adhere to the theme (Saieg *et al.*, 2018), linked to management S-ISWM in municipalities of developing countries. To obtain a more comprehensive and SLR, the search covered all terms and terminologies relevant to the object of study (Lins, Zotes and Caiado, 2019). The bibliographic survey process comprised multiple combinations of keywords associated with joining the pillars (shown in Table 1) to the central RQs. These sets of concepts were combined in different ways to obtain more relevant and adherent searches to the study. Therefore, these pillars, duly substantiated, pave the keyword combinations aligned with the points presented in subsections 2.1 to 2.5. The authors used the word tree method (Saieg et al., 2018) to derivate the axes of keywords from the five pillars that were found through the scoping review (Arksey and O'Malley, 2005).

Then, the keywords were combined with Booleans "AND" and "OR", with searches being carried out from April to May 2019 in the electronic databases Scopus and Web of Science (WoS), as they have a significant number of indexed relevant journals alingned to the research theme (Mongeon and Paul-Hus, 2016). Scopus is considered by the academic community as the largest interdisciplinary base and, according to Azevedo, Scavarda, Caiado (2019) WoS helps to complement Scopus results, achieving a more complete and systematic survey. Searches on Scopus and WoS databases were limited to the period from June 1996 to May 2019, in titles, abstracts and keywords of articles published in English or Portuguese. This time limitation is due to the fact that the 1990s are characterized by intensifying the use of economic instruments in environmental protection, such as the recommendation described in the European Union's 50th Environmental Action Program in 1992.

In addition, criteria and filters were used to restrict types of sources and documents object of the publications, both in line with SWM in developing countries. In this sense, the following inclusion / exclusion criteria were used: a) year - articles from the last five years, until May 2019; b) relevance of publications - JCR indexed journals; c) accessibility - content of the article available digitally in the search base; and as a final filter of adherence to the scope of the research - adequacy of the theme in relation to the central questions and the three basic axes of the combinations (public policy, public-private partnership, energy recovery), after the full-text analysis. Table 1 summarizes the combinations of Booleans with keywords, the gross results and net results, after considering the exclusion criteria.

Table 1 – Search results for combining booleans with keywords

Search	Base	Boolean combinations with keywords	Gross result	Net result
Public Policies and Solid Waste	Scopus	“Public policies” AND “solid waste”	297	100
	WoS		71	51
Public-Private Partnership and solid waste	Scopus	"Public-private partnership" AND "solid waste"	105	10
	WoS		73	01
Sanitary Landfill and Waste Incineration	Scopus	"Landfill" AND "solid waste incineration"	182	10
	WoS		183	05
Public Policies, Integrated Management and solid waste	Scopus	"public polic*" AND "integrated" AND "solid waste"	28	15
	WoS		12	08
Energy Recovery, Controlled Incineration and solid waste	Scopus	"Energy recovery" AND "incineration" AND "solid waste"	451	0
	WoS		492	87
Legal Aspects and Solid Waste	Scopus	"Legal aspect" AND "solid waste"	69	02
	WoS		11	02
		Total Scopus	1132	227
		Total WoS	842	154

Thus, after removing duplicate documents in both searches, the screening process for selecting articles began with the reading of titles and abstracts that was performed independently by more than one researcher, who were instructed to select only articles that presented research questions and results related to the objectives of this study. The entire sample was divided between the researchers. Then, there was a complete evaluation of the texts, considering the adherence to the theme, the research question and the five pillars, and, finally, the inclusion of articles, using the backwards citation search through ‘snowball’ approach, which consists of reviewing the literature cited in the articles (Thomé, Scavarda, & Scavarda 2016). Thus, at the end of the eligibility process, the number of publications to be used in the systematic review was reduced to 75 articles that effectively addressed the topic. Figure 1 contemplates the sequence of the SLR step by step in the PRISMA structure.

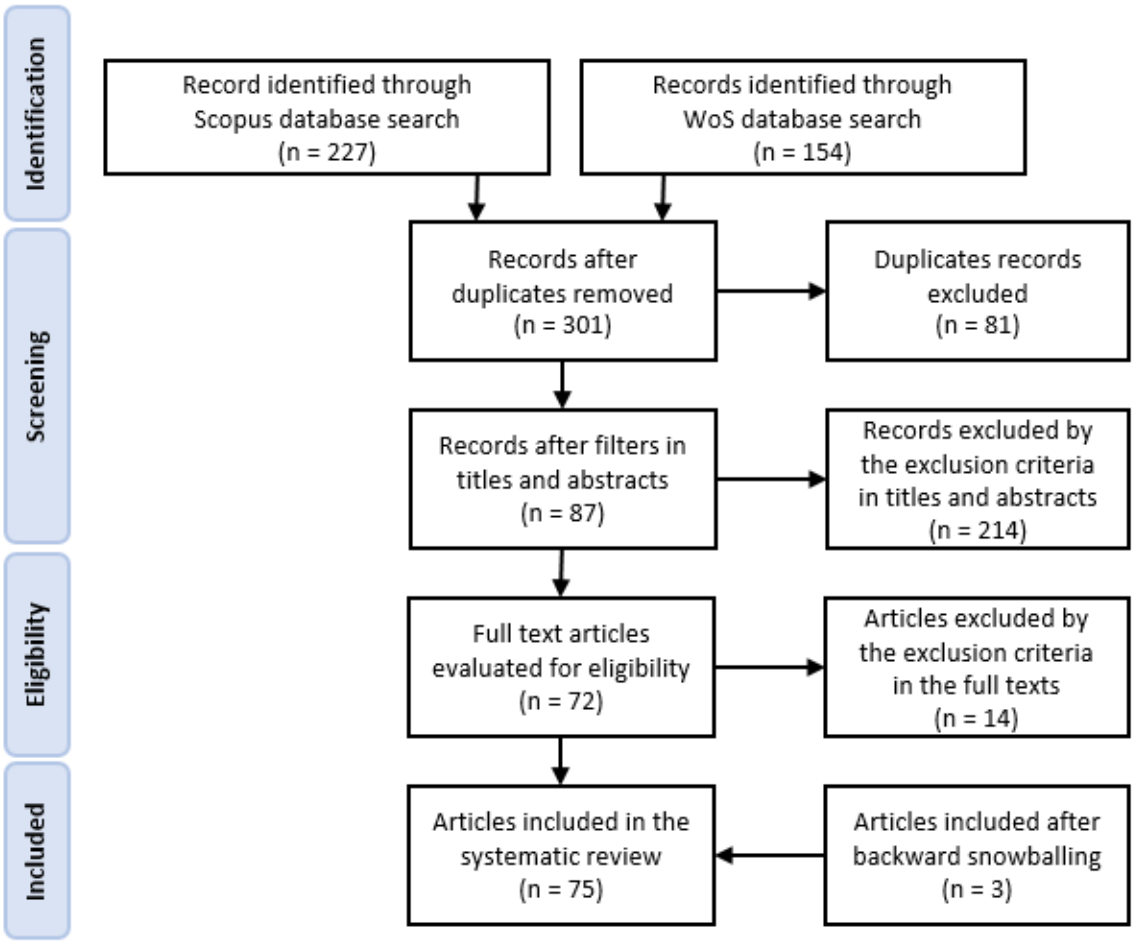

Figure 1 – SLR flow of information through PRISMA diagram proposed by Moher *et al.*, (2009)

Therefore, 75 articles met the selection criteria and represent the bibliographic portfolio of this research. These were all articles that, to a certain extent, referred to CSFs and barriers to S-ISWM in the Municipal level and from the developing countries context. After the identification of the relevant articles, the data collection was derived in a Microsoft Excel spreadsheet. The articles were coded according to these categories. The results were initially analyzed through descriptive analysis, which considered the distribution of selected articles by year of publication, and the frequency of publications per journal.

Then, a content analysis guided by Mayring (2004), in which each document in the selected literature was critically evaluated by the authors to build the taxonomy of barriers and critical factors (Julianelli *et al.*, 2020) for S-ISWM in municipalities. The proposed categories were defined based on content analysis that represents an effective tool to analyze a sample of research documents in a systematic way (Seuring and Gold, 2013). The definition of these categories followed an inductive approach (Mayring 2004), had an iterative process of category construction, testing, review and constant comparison of categories and data, and involved all authors of this research. Three authors defined the categories and then other three authors validated the analysis,

to avoid bias in the group decision. The synthesis of data and the reporting of results through barriers and critical factors are covered in section 4. Finally, Figure 2 introduces the structure of the proposed framework that will be discussed in detail in section 5, combining both barriers (section 4.2.1) and CSFs (section 4.2.2) taxonomies.

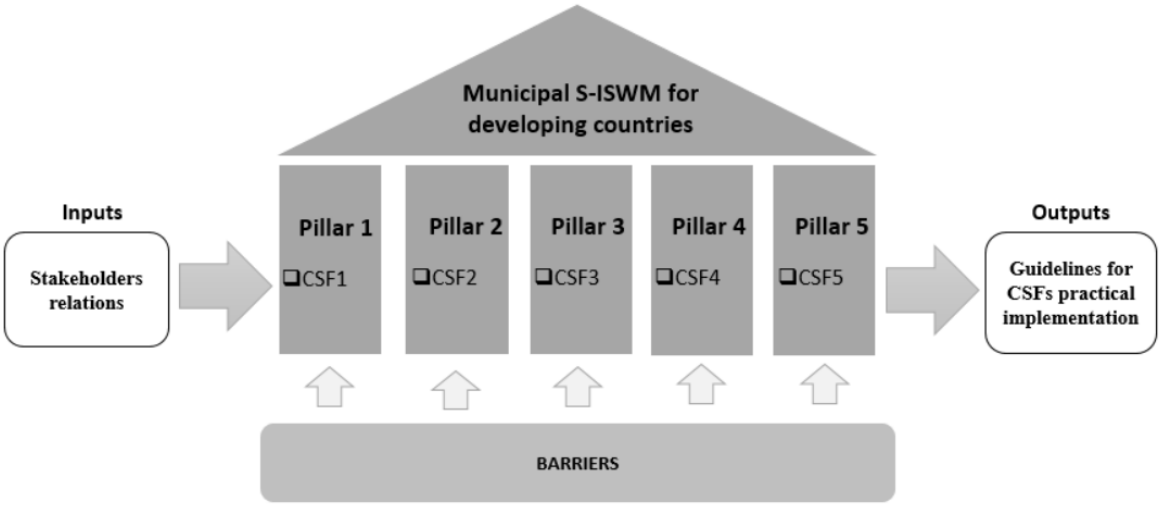

Figure 2 – Framework Proposal linking taxonomies

4. Results

In this section are presented the descriptive results, by bibliometric analysis related to the thematic axis and the year of publication, and the content analysis results, pointing out barriers and CSFs taxonomies for the S-ISWM of municipalities in developing countries.

4.1 Descriptive analysis

As seen in the bibliographic portfolio, it was observed that more than 50% of the selected articles on S-ISWM in developing countries addressed barriers and CSFs in Brazilian municipalities. The focus of research in Brazil may be related to advances in Brazilian legislation related to the environmentally appropriate final disposition, the use of PPPs, the energy recovery and reuse of waste. On the other hand, as well as many developing countries, there are still perceived governance problems that justify obstacles in the low efficiency in MSW management. Thus, it is observed that although Brazil is far from achieving sustainable conduct in its cities, there is great applicability of Brazilian trends to other developing countries, , such as Argentina, Chile, Colombia, Ecuador, among others. In addition, there is a predominance of the “energy recovery” (n=34 or 46%), “private public partnership” (n=19 or 25%) and “public policies (n=22 or 29%) axes associated with solid waste. Regarding WtE, the waste incineration energy industry contributes to environmental protection, economic growth, providing a large number of related

industrial opportunities (Yun, 2015). It is an attractive outlet for MSW management, in view of several benefits, including the reduction of mass and volume of waste and the recovery of energy from combustion (Beylot, Hochar, Michel et al., 2017). As for PPPs, they represent an indispensable alternative for the economic growth of the municipalities, since the remuneration system for the financial provision of the PPP modality "administrative concession", is attractive and suitable for private companies that work in urban cleaning (Di Pietro, 2017). Added to this, the fact that they are viable instruments for public and commercial service providers that seek to co-execute and guarantee maintenance in the public or commercial system (Vasconcelos and Costa, 2017).

For this reason, it is relevant for municipalities to know International Technical Cooperation Agreements for PPP's projects (Marques, 2018). So, public policies have to be pre-ordered to provide a harmonious and timely way of harmonizing environmental, social and economic vectors (Freitas, 2015). This result supports the adoption of strategic guidelines, in addition to facilitating mechanisms through the use of public policies and social control. Then, Figure 3 shows the number of publications per year, from 1996 to 2019.

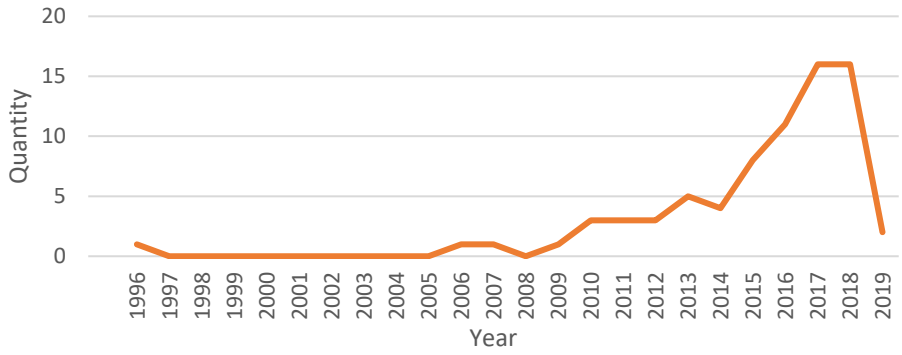

Figure 3 – Number of publications per year

From the publications presented, the primacy of themes related to Public Policies, Solid Waste and Energy Recovery is perceived. Despite the growth and importance of models for evaluating the actions of the municipal government, in view of public policies for the management of MSW, there is a turning point for the local development of municipalities, given the existence of several models on planning, management and technology applied to MSW, but no plan has been identified that proposes to evaluate the development of municipal public policies in this area in Brazil (Silva, Paraíso and Junior, 2017). In light of this emerges the increase in the environmental ban responsible for the restructuring of open dumps since 2011 (Ma *et al.*, 2018). Since 2014, energy recovery from waste has played an important role in most modern solid waste management systems (Allegrini and Boldrin et al., 2014). According to Peerapong and Limmeechokchai,

(2016), as of 2016, there were increasing incentives and investments in electricity generated through renewable sources of waste, with the creation of potential jobs. On the other hand, for Guo *et al.* (2019) the daily processing capacities of the existing landfills are insufficient to meet the volume of MSW. Finally, since the research in the databases (Scopus and WoS) was carried out until May 2019, it was only considered part of the year 2019, which had an influence on the drop in the number of publications compared to 2018.

4.2 Content Analysis

4.2.1 Barriers to municipalities' S-ISWM

Sustainable development calls for growth, an equitable redistribution of the results of the production process and the eradication of poverty in order to reduce disparities in living standards and improve the understanding of the population (Silva, 2019). Therefore, good planning of MSW management generates employment, sustainability and popular acceptance (Machado, 2013). On the other hand, the absence of management models with results and the budgetary imbalance identified in practice, are indicators of restrictive forces linked to deficiencies in governance (public policies), in the absence of innovative contractual regimes (e.g., PPPs) and the need for reuse and enhancement of MSW (energy recovery). As can be seen, there are significant barriers to the exercise of municipal waste management that includes the performance of multiple stakeholders. Based on the content analysis of the 75 articles, three groups of macro barriers were identified: (i) Public Policies, (ii) PPPs and (iii) Energy Recovery.

The first group is related to the rights that are affirmed thanks to the recognition by the society and by the public authorities as new rights of people, communities, things or other material and immaterial goods (Macedo and Alcantara et al., 2015). In turn, the increase in the production of solid waste is related to the economic capacity of consumers, in addition to the values and lifestyle habits of the population. As a result of this exacerbated generation and inadequate management, there are significant environmental and social damages (Silva and Paraíso et al., 2017). The second group, highlights the dynamics of PPPs, the contractual peculiarities of risk sharing, the bidding processes, among others as an alternative to the rigid and traditional systems that cause obstacles to the provision of long-term services (Guimarães, 2013). The third group represents, within the context of sustainable waste management, the recovery of solid waste to generate electrical or thermal energy, by using gases from landfills, biodigesters, incinerators, plasma technology, gasification or even co-processing. In this vein, NSWP foresees the use of energy recovery technologies for solid residues, provided that the technical and environmental viability is proven,

with monitoring of toxic gases (Schalch, 2009). Based on this, Table 2 summarizes the barriers that compromise the practical application of analytical models of integrated management capable of identifying and remedying social, environmental, and economic deficiencies, according to the energy use of waste, as well as financial and environmental education.

Table 2 - Taxonomy of barriers identified

Groups	ID	Barriers	Description
Public policy	B1	Financially unfeasible projects	Lack of coordination between public, private and social actors (Moore, Boardman and Vining, 2017), in which public policies are far from economic sustainability and social well-being (Quintero and Thomas et al., 2018).
	B2	Poor public policies	Institutional actions do not serve most municipalities (Ramos, 2017), including collection, transportation (Shah, Anagnostopoulos et al., 2018), and disposal of MSW (Sanches and Neto, 2017). Government programs without specific procedures (Ramos, 2017).
	B3	Municipal plans lacking diagnostics	Non-systematized information, teams lacking specialized technical staff (Da Silva, Fugii and Santoyo, 2017), without prioritizing integrated management Ramos, (2017). Non-vigorous procedures structuring relationships between people, public and private institutions (Bagatini, 2017).
PPPs	B4	Temporal limitation of contracts	Governance instruments that are not measurable (Yong and Hope, 2018), unenforceable, especially in infrastructure projects (Hueskes and Verhoest et al., 2017). Mechanisms for insufficient waste management (Liu and Wang et al., 2016).
	B5	Restricted funding sources	Lack of financial, economic and legal support for the energy recovery of solid waste (Berezin 2015) with difficult means of interaction between the public power (Diaz, 2017) and private companies (Melink and Lukishina, 2016).
	B6	Linear and reductionist risk management	Financial statements with superficial assessments, without exploring risks, impacts and probabilities (Lopes and Caetano, 2015). Economic activities that do not ensure a dignified existence for all (Keers and van Fenema, 2018).
Energy recovery	B7	Deadlock in waste management	Wrong predominance of landfills (Sun *et al.*, 2016), without prioritizing the energy recovery of MSW (Yun and Zhao, et al., 2015). Complexity that permeates SWM (Abbasi, 2018).
	B8	Waste of energy	Devaluation of waste from incineration (Margallo *et al.*, 2015), without highlighting the lack of space for landfills (Peerapong and Limmeechokchai, 2016). Mistaken valuation of landfills (Kosuke, 2014).
	B9	Depreciated solid waste reuse	Mismatch in waste management systems, without aligning their energy recovery (Allegrini and Boldrin et al., 2014). Unawareness of exhausting the treatment (Peerapong and Limmeechokchai, 2016) and recovery of the MSW and then discarding it (Margallo *et al.*, 2015).

Thus, the first group of barriers to be overcome and corrected are projects that are not financially viable, public policies that do not serve most municipalities, and municipal plans that lack diagnoses. Based on the literature, the following insights emerged from the first group of barriers:

- **Financially unfeasible projects** - Regarding the thematic of waste in the municipal basic sanitation and integrated management plans, it was observed that the plans do not meet the minimum content, impairing the municipal planning (Bagatini, 2017). Economic and sociodemographic factors continue to have a negative impact, increasing the MSW, in addition to hindering the use of growth and development policies (Quintero and Thomas et al., 2018).

- **Poor public policies** - Regarding environmental public policies covering the scope of relative waste collection or basic sanitation, few municipalities stand out (Sanches and Figueiredo Neto, 2017). The management of urban solid waste has become a turning point for the local development of municipalities (Da Silva, Fugii and Santoyo, 2017).

- **Municipal plans lacking diagnostics** - A very common reality in developing countries is the use of landfills, which must work, establishing remediation priorities. The final destination of solid urban waste is the landfill that determines negative consequences such as the contamination of natural resources and public health problems. It is necessary to develop a support tool to promote the proper destination of urban solid waste and the remediation of landfills (Ramos *et al.*, 2017).

In addition, the second group of barriers consists of non-measurable governance instruments, strict contracts, restricted sources of financing, as well as linear and reductionist risk management. The following insights were observed for each barrier:

- **Temporal limitation of contracts** - The governance of the PPP contract is essential to verify that the stages are being fulfilled and successful (Marques, 2018). The moderating effects of contractual complexity can bring new explanations for disputes with the supplier. Contractual control, including term, can mitigate behavioral uncertainty (Diaz, 2017).

- **Restricted funding sources** - The use of the PPP predetermines the need for modifications and additions to the standard legal basis that regulates the order of interaction between various parts of the partnership (Berezin 2015). Whoever controls the public infrastructure must establish the necessary requirements for the private partner's investment obligations (Melink and Lukishina, 2016).

- **Linear and reductionist risk management** - There are difficulties in the conceptual framework and doctrinal views on the concepts and forms of PPPs. The economic and legal aspects of its operation tend to the implementation of national priority projects, to justify the various forms of interaction between government and private companies able to

overcome the consequences of the global financial crisis and economic sanctions (Berezin 2015).

Finally, the third group of barriers exposes the mistaken predominance of landfills, without prioritizing the energy recovery of MSW, the waste of energy, in addition to the mismatch in waste management systems, without aligning their energy recovery. The following insights were realized for the third group of barriers:

- **Deadlock in waste management** - Many cities are facing a serious waste crisis, as in China, where the technique of waste incineration is relevant. The recovery and use of energy, as well as the control of emissions is the subject of debate, and it is necessary to disclose the topic of energy recovery (Li *et al.*, 2016).
- **Waste of energy** - The fight against energy waste in developing countries can start with the investment and incentive of electric energy generated from renewable sources and waste. The generation of electricity from waste has the potential to reduce CO2, creating potential jobs (Peerapong and Limmeechokchai, 2016).
- **Depreciated solid waste reuse** - Energy recovery from waste plays an important role in most modern waste management systems (Allegrini *et al.*, 2014). A large number of municipalities lack specialized personnel, technical, economic and social criteria to address the issue of solid waste. The energy generated from waste has the potential to solve the problem in practice (Margallo et al., 2015).

Moreover, the barriers described attest to the complexity of the management models explicit in the literature, as well as the inability of municipal managers to assimilate or put them into practice, which is why it is essential to carry out elements of interest aimed at training, relevance and adequacy. Examples of influencing barriers can be identified, such as poor waste management resulting from a lack of updated methods (Ramos, 2017), techniques and systems, specialized technical staff and systematized information (Bagatini, 2017).

In addition, the treatment and energy recovery of solid waste involves specific and economically viable procedures (Abbasi, 2018; Shah *et al.*, 2018). Thus, treating, eliminating and managing solid waste represents an impasse surrounded by convergences and divergences (Moore, Boardman and Vining, 2017). In this sense, convergences and divergences contribute to delay organizational solutions (Quintero, Thomas and et al., 2018). Among the main convergences, it is possible to highlight the effective interaction between public and private sectors (Berezin, 2015), the systemic transition from old waste management models to attractive, integrated formats

(Melink and Lukishina, 2016), with new opportunities and value creation (Keers and van Fenema, 2018). In turn, the divergences lie in the applicability of public policies that help municipalities to diagnose the damage caused by open dumps and sanitary landfills, in addition to the hypotheses of solutions (Yun Li *et al.*, 2015).

4.2.2 Critical factors for S-ISWM of municipalities

Currently, the treatment of MSW has become a dilemma of complex solution. Integrated waste management involves the implementation of PPPs, including the effective cooperation of stakeholders (Zotos *et al.*, 2009), companies (McCormick *et al.*, 2013), services (Pitkänen *et al.*, 2016), and other actors that seek sustainable management. Hence the need to identify CSFs, as these, properly assimilated and implemented, can serve as facilitating instruments for the integrated and sustainable management of municipalities in developing countries.

Considering the five pillars already contextualized, the following critical factors emerge: I - Public Policies: Public Consultation (CSF1), Articulated Actions (CSF2), Enhanced logistics (CSF3); II - Disposal techniques: Leaching (CSF4), Incineration (CSF5); III - Legal Aspects: Flexible Contract (CSF6), Integrated Legislation (CSF7); IV - PPP: Relevant and Current Contracts (CSF8), Enhanced Models for Infrastructure (CSF9); and V - Energy Recovery: Incinerated Solid Waste (CSF10), Incentives and Investments (CSF11). Table 3 lists the 11 CSFs aligned with the five pillars that support the S-ISWM in perfect congruence with the research questions.

Table 3 –Taxonomy of CSFs related to the five pillars

Pillar	ID	CSF	Description	Implementation
Public policy	F1	Digital public consultation	Technological feasibility in different regions using legislation for transparency (Chen, Geng and Fujita, 2010), control (Moore and Boardman et al., 2017) and cost containment (Ramos, 2017). Digital resources.	Update waste management systems, prioritizing digital transformation. Adapt and commercialize systems of products and services, design and mobilize ecosystems and integrate them in an Internet of Things (IoT) platform
	F2	Articulated Actions	Multidisciplinary approach Whitmore and Agarwal et al., (2015) with a focus on social benefit (Melink and Lukishina, 2016). Strategically planned methods (Quintero and Thomas, 2018).	Promote coherent interventions between different social actors, skills development and interdisciplinary articulations.
	F3	Enhanced logistics	Apply IoT, estimating the risks caused to the population by landfills and dumps (Li *et al.*, 2016). Specific analysis of landfills, collection and transport of MSW (Shah, Anagnostopoulos, et al., 2018).	Optimize waste management, with diagnostics and remediation mechanisms (Sanches and Neto, 2017).

Disposal tech-niques	F4	Leaching	Intensify energy recovery technology (Vaitkus and Gražulytė et al., 2019). Utilization of incinerated MSW ash (Sun *et al.*, 2016).	Multiply skills in the use of ashes for asphalt, concrete and the ceramic industry. Enhance the use of waste incineration by-products.
	F5	Incineration	Maximize the energy recovery of MSW (Pelesaraei and Bayat, et al., 2017). Incineration (Beylot et al., 2017). Present advantages of incinerated MSW (Mikic and Naunovic, 2013). Disseminate the reuse of MSW (Vaitkus and Gražulytė et al., 2019).	Publicize the reduction in weight and volume of solid waste, using landfill biogas to generate electricity (Lima *et al.*, 2017).
Legal aspects	F6	Flexible contracts	Meet eco-regulation with decision support factors in economic controls (Diaz, 2017). Develop projects through an adequate and convenient cost-benefit ratio (Marques *et al.*, 2018).	Establish governance with a focus on the thermal treatment of MSW (Marques, 2018).
	F7	Integrated Legislation	Propagate the energy efficiency of MSW and the respective legal (Diaz, 2017), and regulatory aspects (Rafailovich, Sergeevich and et al., 2017). Apply integrated management in municipal plans (Melink and Lukishina, 2016)	Use the financial, economic and legal support measures existing in the legislation.
PPP	F8	Current and Relevant Practices	Use projects focused on sustainability (Hueskes and Verhoest et al., 2017). Practical and feasible methods (Loosemore and Cheung et al., 2015) that can transform MSW into energy (Liu and Wang et al., 2016)	Explore and develop performance indicators.
	F9	Enhanced Models for Infrastructure	Promote engagement and integration between public and private actors (Lopes and Caetano, 2015). Modern conception of organization (Buso and Marty et al., 2017) and functioning of public services provided by the State to the administrated (Burke and Demirag, 2017).	Examine and adapt procedures aimed at efficiency and profitability of the parties involved in projects.
Energy Recovery	F10	Incinerated Solid Waste	Update and restructure open-air dumps, reducing the emission of greenhouse gases emitted by them (Ma *et al.*, 2018). MSW incinerated in landfills.	Disclose the degree of contamination from landfills (Margallo *et al.*, 2015) that are harmful to the health of the municipal population
	F11	Incentives and Investments	Implement opportunities to recover and use energy and heat from MSW (Peerapong and Limmeechokchai, 2016). Models of training, adequacy and relevance for power generation from MSW (Beylot, Hochar, Michel et al., 2017).	Use landfill methane gas to incinerate waste (Li *et al.*, 2016). Motivate investors to produce electricity from renewable sources and solid waste.

It appears that the Public Policies pillar has structural mechanisms for the relations between public, private institutions and society, that is, the application of articulated, transparent actions, through the control and containment of costs. Added to this is the digital transformation, properly articulated with industrial practices, using concepts from Industry 4.0 to improve waste management. From this interaction, it is possible to envision a robust and practical diagnostic tool (Caiado *et al.*, 2021). In addition, multidisciplinary approaches, enhancing waste management and social benefit, without prejudice to diagnosing and remedying existing environmental liabilities.

Regarding Disposal techniques pillar, the reduction of weight and volume of this pillar is essential, in view of the continuous expansion of the amount of waste produced today by the municipalities, moving away from the simplistic destination of MSW to landfills. Therefore, the energy recovery process (e.g., from incineration), by incinerated waste ash for the asphalt, ceramic and concrete industry, has the potential to transform solid waste by-products into profitable practical alternatives. The Legal Aspects pillar, on the other hand, starts from the premise that the valorization of waste goes in line with governance techniques, maximizing waste instead of eliminating it. To this end, the financial, economic, and legal support measures, well implemented, meet the dynamics of eco-regulation. PPP is the pillar that assists that helps the conservation of the environment, the respective exploration in a sustainable way, through current and relevant practices. There is also the possibility of developing performance indicators, examining and improving infrastructure projects with profitability and efficiency. Finally, the Energy Recovery pillar, which puts into practice technical, social, economic, and political issues, all aligned in an integrated management strategy. In this context, the production of electricity from renewable sources and solid residues takes place, in addition to publicizing the contamination and damage of landfills to the municipal population, instigating the debate on this topic among the academic community, society, business and public power.

In view of the pillars and respective CSFs, it is possible to present Energy Recovery and PPP contracts as alternatives to the dilemma that permeates the SWM of municipalities in developing countries, as long as the Legal Aspects are respected, in addition to being applied as practical tools of integrated management and analytical models, informing where resources are extracted for the training of the team, as well as the applicability of Public Policies compatible with the modus operandi of the municipalities, identifying, and effectively monitoring the gap between sustainable theory and practice over time.

5. Framework towards S-ISWM

In this section, a framework is presented to enable S-ISWM implementation in the municipalities of developing countries that was also built from the integration between barriers and CSFs for S-ISWM. As noted in the literature to address the barriers associated with municipal SWM, multidisciplinary skills are required, involving various stakeholders (e.g., government, industry and community) working together and waste management based on pillars (Azevedo, Scavarda and Caiado, 2019), such as policy employment with an emphasis on social benefit and measurement of economic cost (first pillar), use of Disposal techniques for using solid waste (second pillar), reducing waste and adding value (third pillar), implementing current contracting systems and involve shared risks, use of practices that consider the efficiency and profitability of the parties involved in projects (fourth pillar), and energy recovery, producing electricity from renewable sources and waste (fifth pillar).

As seen in Figure 4, the framework is structured in four parts: stakeholders' cooperation, barriers, CSFs associated with the five pillars, and practical implementations of the CSFs. When it comes to Public Policies, the public power needs to pay attention to new rights, prioritizing the use of new technologies for the benefit of people, communities, congruent with rational, ecologically fair, solidary and inclusive production. As for Disposal techniques, the use and reuse of ashes from incinerated waste in the asphalt, concrete and ceramics industry must be multiplied. Although there are poorly measurable governance instruments (Corvellec and Bramryd, 2012), maximized energy recovery from MSW is a viable implementation mechanism (Tan *et al.*, 2015). As for the Legal Aspects, the existing financial and economic support measures, worked on and adapted to the municipal management plans, duly implemented, can minimize the barrier of restricted funding sources and linear risk management. The PPP is the factor that promotes the interaction between the public power and private companies. In view of the obstacles related to the time limitation of traditional contracts, the implemented PPPs explore and enable projects with performance, profitability, and efficiency indicators. Finally, the Energy Recovery factor, incinerating solid waste from dumps or those deposited in landfills, includes the opportunity to recover and use energy from these. Even with the barrier that devalues the waste subject to incineration, and the lack of physical space for new landfills, when implementing opportunities to produce electricity from solid waste, one can seek incentives and investments in projects that reduce energy waste. Hence the multidisciplinary, articulated approach of the industries, the community, with a focus on digital transformation and social benefit. However, as already pointed out, the barriers hinder integration and sustainability in waste management, such as financially

unviable projects, lacking diagnoses, in addition to institutional actions that do not meet the dynamics of the municipalities. Moreover, the barriers can be mitigated by using the CSFs, such as the use of digital transformation, made possible in different municipal regions, cost control and transparent actions.

5.1 Discussion and implications of S-ISWM

The focus of this paper is to emphasize the need to reduce the volume of urban waste produced on a large scale in open dumps, as well as to overcome the landfill paradigm, used systematically despite being harmful to the health of the population. In this sense, the pillars and barriers are aligned with the lack of planning, with the precariousness of resources and the central aspects of municipal budgets, necessary for the execution of public undertakings claimed by the community. The CSFs and the Framework, on the other hand, synthesize technological alternatives, social, economic and technological impacts, based on the hypothesis of transforming MSW into energy, reducing the mass and the high volume of urban waste in developing countries.

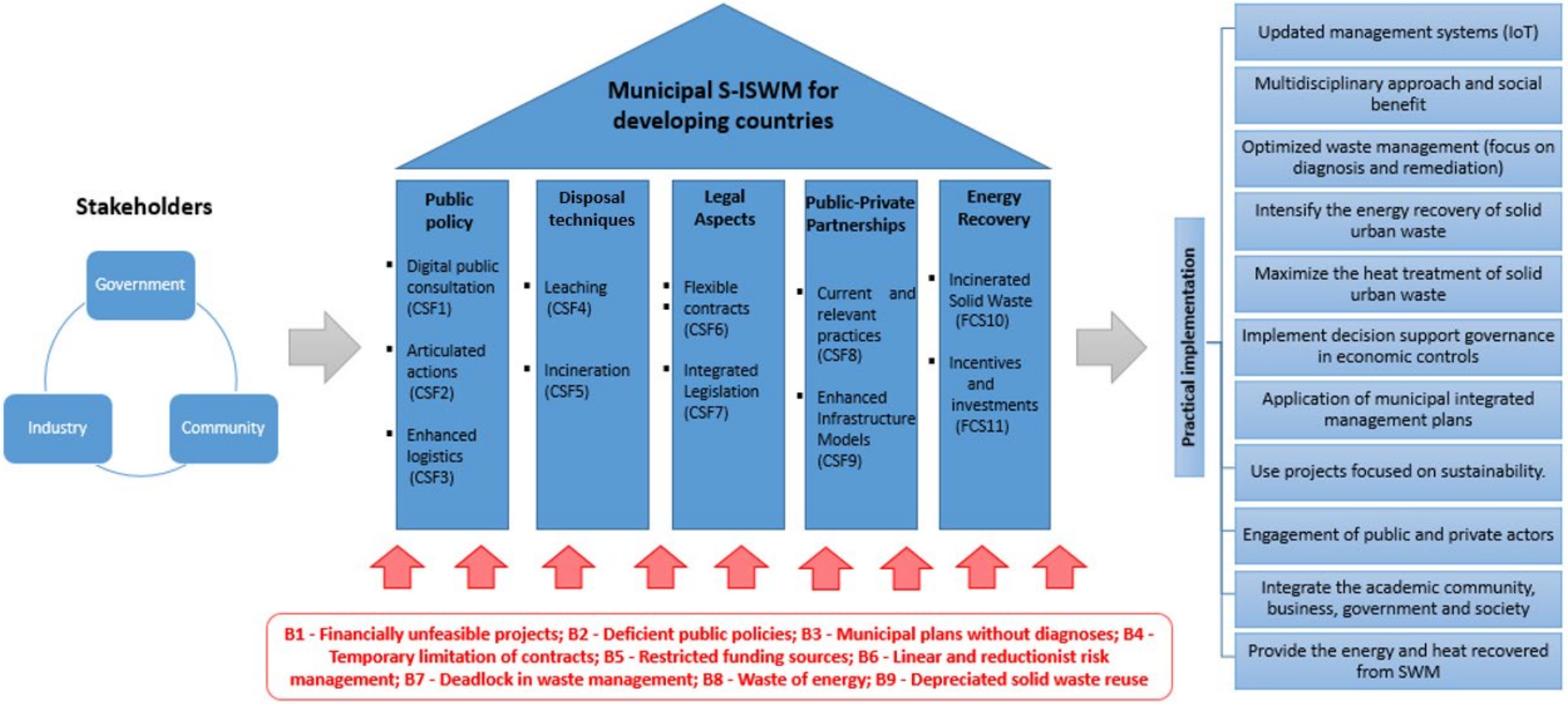

Figure 4 –Framework for S-ISWM of municipalities in developing countries

In the present case, the CSFs can be implemented from initiatives that enhance the SWM system with diagnostics, remediation mechanisms, including with regard to the estimates of risks caused by landfills to the population. Furthermore, the proposed framework has implications for the three dimensions of sustainability. From a social point of view, the framework can be used to generate personal and income skills for public and private managers, engineers, administrators, technicians, employees and planning specialists, working in the solid waste segment, private cleaning conservation companies, and energy recovery industries, in addition to the municipalities. From an economic point of view, it can help diversify the energy matrix, including as an option to reduce the price of energy resulting from fossil fuels. From an environmental point of view, the reduction of weight and volume of MSW, providing opportunities for variables to recover and use energy from solid waste. Thus, the framework contemplates, in a synthetic way, the relation between the stakeholders, the five pillars and respective CSFs (enablers to S-ISWM), the barriers that hinder the applicability of S-ISWM and the summary of CSFs' practical implementation ways.

As can be seen, the implications of the framework are linked to sustainability, reducing the negative environmental impact of communities, as well as the reuse of solid waste, energy to feed homes, steam in industrial production, in which the stakeholders involved can incorporate, improve, and transfer innovative knowledge. Regarding MSW and ISWM, there is a deficient perception of the practical applicability of analytical management models, both in the field of adherence and operational feasibility, given the complexity, high dimension of waste produced, among other factors. The search for a solution to the obstacles related to the theme is visible and integrates the Municipal Waste Policy of India, the NSWP of Brazil, the specific legislation of China, and other BRICS countries, consecrating the inadequate management, damage to public health and natural resources in these countries. Although with innovative legislation, the real problems of MSW are far from a solution.

On the other hand, a planning structure is necessary to allow the integration of various decision support processes and models. Attention should be paid not only to operational efficiency, but also to the objectives of financial management and the strategy of market competition, both in line with the PPPs and the Energy Recovery of MSW. Otherwise, the alternatives of governance, with the development of programs in Argentina, Chile, Colombia, Ecuador, and BRICS member countries such as Brazil, would not be sufficient. In this sense and to explain the main applications of organizational practices and analytical models to be used by the municipal secretariats, a new framework towards S-ISWM is elaborated for the existing demands in the municipal public management, especially regarding the dilemma of the treatment and destination of MSW. It is expected to contribute to the practices of municipal SWM, whose management models address the

problem and implement transformations, without prejudice to the socio-cultural, economic and operational aspects, both in Brazil, in developing countries in Latin America and in the BRICS.

6. Conclusions

The objective of this article was to propose a framework that enables both integration and sustainability of MSW, considering the state-of-the-art of barriers and CSFs necessary to achieve the S-ISWM of municipalities in developing countries. In this sense, to build this framework, nine barriers were identified through a SLR to prove deficiencies in the treatment of waste, such as the predominance of landfills, the lack of methods with diagnostics and remediation mechanisms, specialized technical staff and systematized information, among others, all in response to the first central question of the study. In the same way, 11 critical success factors were also identified, and their respective forms of implementation aligned with the pillars of Public policies, Disposal techniques, Legal aspects, PPP, and Energy recovery. All of them properly implemented can represent a viable way to overcome the current dilemma that surrounds the management of MSW, attending to the second central question of the research. This article contemplates the SLR methodology to disseminate a critical analysis on municipal SWM in developing countries.

The CSFs showed that the transformation of waste into renewable energy, even with economic, institutional, and organizational barriers, could represent the survival of future generations with viable alternatives to reduce the proliferation of open dumps, the predominance of landfills, reducing weight and the volume of waste. In this vein, the study provides an overview of rational practices for targeting MSW to apply energy recovery. The form of implementation of the CSFs contributes to the body of knowledge, revealing means that address the problem and implement transformations with reference to the socio-cultural aspects and the economic and operational contests of developing countries, and even those countries that are part of the BRICS, in view of the similarities that both implement for integrated and sustainable management of MSW.

The limitations present in the research are inherent to the chosen methodology, that is, SLR does not cover all possibilities, and the choice of examples and situations mentioned goes through the subjectivity of the researchers in the elaboration of instruments and the peculiarity of the sample used. As in any SLR, this research also has limitations, regarding the choice of keywords, which was related to the five pillars of S-ISWM. Thus, we also suggest further research investigate each pillar more in depth using more keywords.

The main applications of this work, on the other hand, are aimed at supporting and guiding municipal solid waste management practices, in which factors can be articulated and added to industrial practices, improving and systematizing the implementation of S-ISWM to the concepts

of sustainable development. As a proposal for future work, aligned with the proposed CSFs, it is suggested the study of the application of digital transformation in municipal waste management as an alternative for waste management, applying, in a compatible way, the use of the IoT and other digital technologies of the fourth industrial revolution, as well as the implementation of waste recycling plants in landfills with simplified PPPs for small and medium-sized municipalities. From the methodological perspective, we suggest that the proposed framework and its CSFs and barriers be applied, through an empirical study, containing interviews or focus groups with multiple stakeholders of a Municipality of a developing country (e.g., Brazil) to test and validate the framework in a real case study.

Acknowledgements

This work was supported by the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) - Finance Code 001, and the Brazilian National Council for Scientific and Technological Development (CNPq) – 300007/2019–1.

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