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Towards circular cities – exploring the circular economy approach in context of municipal solid waste[1]

W kierunku miast o obiegu zamkniętym – badanie podejścia gospodarki o obiegu zamkniętym w kontekście stałych odpadów komunalnych

Abstract

The objective of this research is to determine whether the city under investigation in a developing country is pursuing a "circular city" model based on various indicators and the city's current characteristics. The city under analysis was Xalapa, the capital city of the state of Veracruz in Mexico. To accomplish our research goals, we employed a qualitative methodology. We conducted interviews with the government representative responsible for municipal solid waste management during the designated period, as well as with the proprietors of the 18 most prominent private waste collection centers. Additionally, we obtained relevant information from the government through the transparency platform. For our assessment, we utilized the waste-focused indicators provided by L. Girard and F. Nocca. Our analysis indicates that the city under investigation is not on the trajectory towards adopting a "circular city" model. However, the context of municipal solid waste (MSW) offers valuable suggestions for future implementation of circular economy (CE) practices. The findings presented in this study offer valuable insights for researchers in other developing countries who are also engaged in exploring the issues discussed. Also, the lessons derived from this study hold relevance for cities in developing countries, as they grapple with environmental and economic degradation similar to the city studied.

Keywords:
circular economy, municipal solid waste, waste management

Streszczenie

Celem tego badania jest ustalenie – na podstawie różnych wskaźników i obecnej charakterystyki miasta – czy badane miasto w kraju rozwijającym się realizuje model „miasta o obiegu zamkniętym". Analizowanym miastem była Xalapa, stolica stanu Veracruz w Meksyku. Aby osiągnąć nasze cele badawcze, zastosowaliśmy metodologię jakościową. Przeprowadziliśmy wywiady z przedstawicielem rządu odpowiedzialnym za zarządzanie stałymi odpadami komunalnymi w wyznaczonym okresie, a także z właścicielami 18 najbardziej znanych prywatnych centrów zbiórki odpadów. Ponadto uzyskaliśmy odpowiednie informacje od rządu za pośrednictwem platformy przejrzystości. Do naszej oceny wykorzystaliśmy wskaźniki dotyczące odpadów dostarczone przez L. Girarda i F. Noccę. Nasza analiza wskazuje, że badane miasto nie znajduje się na ścieżce prowadzącej do przyjęcia modelu „miasta o obiegu zamkniętym". Jednak kontekst stałych odpadów komunalnych (MSW) oferuje cenne sugestie dotyczące przyszłego wdrażania praktyk gospodarki o obiegu zamkniętym (CE). Wyniki przedstawione w tym badaniu oferują istotne spostrzeżenia dla badaczy w innych krajach rozwijających się, którzy również są zaangażowani w badanie omawianych zagadnień. Ponadto wnioski wyciągnięte z tego badania mają znaczenie dla miast w krajach rozwijających się, ponieważ zmagają się one z degradacją środowiskową i gospodarczą podobnie jak badane miasto.

Słowa kluczowe:
gospodarka o obiegu zamkniętym, stałe odpady komunalne, gospodarka odpadami

JEL: Q01, Q53, O54

Introduction

Municipal solid waste or MSW is a heterogenous (Hussieny et al., 2022; Mäkinen et al., 2019; Ndou & Rampedi, 2022; Siles-Castellano et al., 2021) subcategory of low liquid content waste, generated, collected, treated, transported or disposed of within the jurisdiction of a municipal authority (Periathamby, 2011; United Nations, 1997). Management of MSW is a part of Sustainable Development coverage which can contribute to sustain long-term growth and profitability in a competitive environment when value manifested by improving efficiency (Antonowicz & Jarzebowski, 2018; Noga et al., 2020).

The availability of scientific articles addressing the circular economy (CE) in Mexico is limited, with just over 50 articles identified in a quick review of the Scopus database from 2017 onwards. However, there is a noticeable increase in academic interest in this topic within the country, particularly since 2020. This presents a valuable opportunity for further research to be conducted in this area. Additionally, it is worth noting that there is currently no existing literature on the topic of CE specifically focused on the city of Xalapa, according to the Scopus database by the time of conducting this research.

The transition to a CE can yield a healthier urban environment and cities are in a prime position to help scale-up the circular economy. Additionally, the adoption of CE principles can lead to the creation of new jobs, new sources of income, cost savings, and reduced exposure to risk, with tangible advantages in terms of competitiveness (Enel Distribución Chile et al., 2023). Nonetheless, despite the recognized advantages, a research gap exists regarding the implementation and impact of CE principles within urban settings (Cavaleiro de Ferreira & Fuso-Nerini, 2019; Domenech & Borrion, 2022; Petit-Boix & Leipold, 2018; Vanhuyse et al., 2021). Therefore, further investigation is warranted to delve into the intricate dynamics of circular cities, enabling a comprehensive understanding of their potential and informing evidence-based strategies for their successful adoption.

The circular city is a metaphor for a new way of looking at the city and of organizing it which derives from CE. The idea is that in a city, linear processes can be at least partly replaced by circular processes and that long-term connections can be established between flows (Girard & Nocca, 2019; Kamińska, 2022; Ruimtevolk, 2015). These flows (i.e., people, food, waste) are at the basis of the city's metabolism that represents the engine for the functioning of the city and its economy (Girard & Nocca, 2019; Gravagnuolo et al., 2019; Ruimtevolk, 2015).

Some cities are defining themselves explicitly as circular city due their activities on CE and are starting to produce systematized reports on their strategies and indicators related to moving towards CE direction – i.e. Budapest, Freiburg, Genoa, Gent, Grenoble, Harlem, Hoje-Taastrup, Ljubljiana, Maribor, Marseille, Prague (Girard & Nocca, 2019; ICLEI Europe, 2022). The European Commission points out that developing and emerging countries face the same challenges as more developed economies to push CE but with less financial or institutional resources to overcome them (Langsdorf & Duin, 2022).

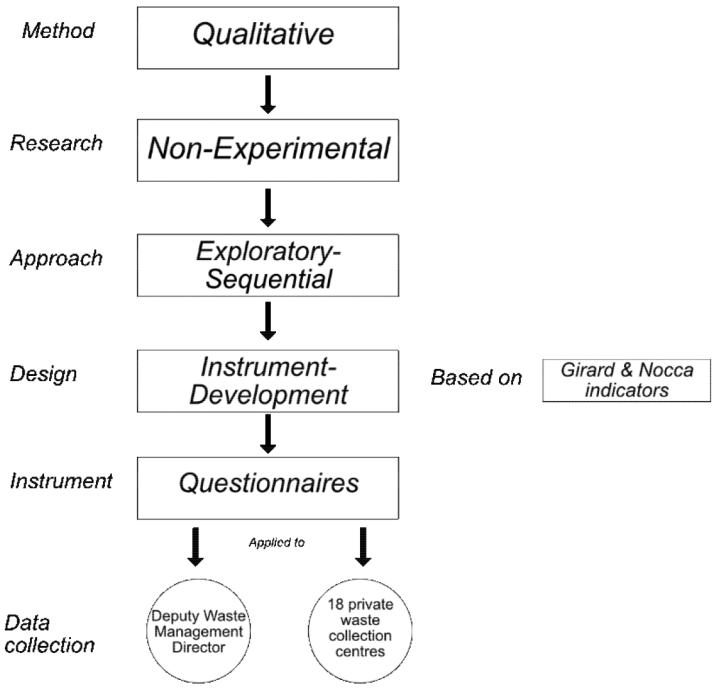
Xalapa, the main city of the state of Veracruz in Mexico, is facing environmental and economic degradation due a several problems related to MSW management (BID et al., 2014; Farfán, 2015; H. Ayuntamiento de Xalapa, 2019a; Topete, 2018). The Xalapa City Council and various national and international institutions, are making local investments in programs (Comunicación Social del H. Ayuntamiento de Xalapa, 2019) and infrastructure for the proper management of their waste (H. Ayuntamiento de Xalapa, 2019a) to contribute to change the habits of citizens and the implementation of new public policies for Xalapa (H. Ayuntamiento de Xalapa, 2018b).

Xalapa's scenario has not been widely researched using CE as a main subject, especially given the novelty of the concept in Mexico (Córdova Preciado et al., 2021; López Pérez et al., 2020; Munoz-Melendez et al., 2021). The situation of the city represents an opportunity to explore the implementation of the circular city model in a developing country context. Therefore, the goal of this work is to highlight the current state of Xalapa towards a circular city model using the information on MSW and based on the indicators of L. Girard and F. Nocca (2019). The hypothesis of this work states that Xalapa is not currently pursuing a circular city model.

Material and methods

This work is focused on the city of Xalapa, which is the capital of the state of Veracruz in Mexico. Its population is 457,928 inhabitants (Sistema de Información Municipal, 2016). According to the Xalapa City Council, the municipality generates three quarters of the solid waste in the region, collecting 95% of it, with approximately 84% being susceptible to recycling; of which, 34% are inorganic and 50% organic (H. Ayuntamiento de Xalapa, 2018a). In Xalapa, the public area in charge of the collection, transfer, recovery, separation, and use of urban solid waste is the sub-directorate of

Figure 1
Methodological path followed



Source: self-made based on: Edmonds & Kennedy, 2017.

Integral Management of Solid Waste (H. Ayuntamiento de Xalapa, 2019b), also known as GIRS (in Spanish), belonging to the City Hall of Xalapa.

This research was conducted during the period between 2019 and 2021 and it is of a mixed type (Edmonds & Kennedy, 2017). Given that semi-structured interviews allow the interviewers to ask each interviewee the same questions, while providing room to clarify and contextualize certain issues, we decided to use that approach (Walker et al., 2022). Also, we collected historical data about waste management by requesting it to the transparency platform of the Mexican government (Doyle et al., 2009). That information helped to fulfil de requirements of the indicators selected (Figure 1).

We obtained a database from the government to find the names and coordinates of the collection centers (INEGI, 2014; Lune & Berg, 2017). Then, the maps creation tool of Google Maps was used to geolocate them across the city (Figure 2). We used the quota sampling based on the activity of the private waste collection centers which was labeled by INEGI. Due the difficulties to access to all private waste collection centers, the refusal of most of the owners to provide information, and the outdated address catalog, out of the 54 private waste collection centers, we selected 18 based on their biggest facilities size and their availability to be interviewed (Table 1 and Figure 2). We addressed the owners of the collection centers for the interviews promising anonymity to avoid sanctions or organized crime actions.

A semi-structured interview was conducted with the Deputy Director of Waste Management of the city of Xalapa due his knowledge, expertise and his availability to provide relevant information and because he was the representative of the government area responsible for MSW during the period. A group of indicators related to MSW were selected from the paper of L. Girard and F. Nocca (2019). The indicators chosen mentioned waste management explicitly. These indicators were separated into three dimensions: environmental, economic-financial, and socio-cultural. Each indicator is listed in Table 2.

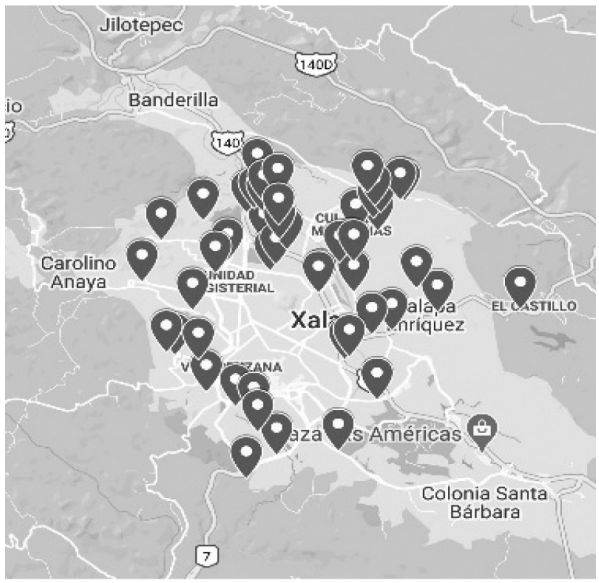
Two additional indicators were added due their importance for the municipal public administration (Universidad Veracruzana, 2019b): amount of waste collected by truck route and amount of waste collected by type. The questionnaire for the private waste collection center' owners was designed as a semi-structured interview to get information about their labor to fulfil the requirements of the indicators selected. The questionnaire had 8 questions related to the amount of waste collected by type, sale price, number of workers and

Table 1
Activity of the private waste collection centers

Activity	Population	Sample
Wholesale of stationery	1	1
Wholesale of paper and cardboard waste	9	3
Wholesale of plastic waste	8	3
Wholesale of metal waste	27	5
Wholesale of packaging in general, paper and cardboard for the industry	1	1
Wholesale of other waste materials	4	2
Collection of non-hazardous waste by the private sector	3	2
Waste recovery by the private sector	1	1

Source: self-made based on: INEGI, 2014.

Figure 2
Map of the private waste collection centers in the municipality of Xalapa, Veracruz



Source: self-made, based on Google Maps, 2022.

frequency of sale which belong to the economic-financial dimension of the selected indicators.

The questionnaire for the deputy Director of GIRS was based on Girard & Nocca indicators and was mainly focused on the next topics: 1) budget, 2) the municipal recycling rate and residual packaging, 3) the amount of garbage dumped in the sanitary landfill, 4) the amount of waste collected by truck route, 5) the percentage of composted waste, 6) the sales of the recycled products, 7) the amount of waste generated in the city, 8) the waste separated and 9) the food waste type (Universidad Veracruzana, 2019a). Additionally, extra information was requested to the Transparency Portal of the Mexican government, about the number of waste collection and bulk sale companies, number of urban gardens and number of people trained through environmental education measures.

Results

We present the results obtained based on the information provided by the 18 owners of the private waste collection centers, the answers of the Deputy Director of Waste Management of Xalapa, the Mexican Platform of Transparency and the information obtained from secondary sources like BID et al. (2014) and Universidad Veracruzana (2019a).

Environmental dimension

The indicators of municipal waste, recycling rate and packaging waste recycling rate, have a value of zero. This occurs because there are no recycling companies in Xalapa, so all the material collected for recycling must be sent to companies in other cities. As for the indicators related to the amount of waste dumped into the landfill, the amounts rise to 313.00 t per day, that is, 114,245.00 t per year. In other words: of the 449.00 t per day or 163,868.61 t per year of waste that is generated, 69.72% ends up in the municipal landfill.

Table 2
Characteristics of the CE indicators focused on waste management used in this research

Indicator	Unit of measurement
Environmental dimension	
Municipal waste recycling rate	%/year
Packaging waste recycling rate	%/year
Amount of waste discharged to the landfill	%/year or tonnes/year
Amount of waste collected per truck route	%/year or tonnes/year
Amount of waste collected by type	%/year or tonnes/year
Percentage of solid waste dumped in the landfill	%/year
Percentage of domestic waste dumped in the landfill	%/year or tonnes/year
Percentage of solid waste material incinerated	%/year
Percentage of composted solid waste	%/year
Number of recycled products sold	Quantity/month or year
Percentage of household waste reused or recycled	%/year
Food waste treated in small and medium enterprises (SMEs)	%/total food waste
Separated waste (recovery and treatment of waste generated in the city)	Kilogrammes/year or %/year
Amount of waste generated in the city	Tonnes/year, tonnes/per capita/year
Amount of waste generated per capita	Tonnes/year, tonnes/per capita/year
Economic-financial dimension	
Municipal distribution for waste management	USD/year
Revenue from recycled products sold	USD/month, USD/year
Potential value of the material after recovery or reuse	USD
Value of waste that could be reusable or recyclable sent to landfill	USD
Sale of local products	USD/year
Socio-cultural dimension	
Number of events and dissemination activities on circular economy	Quantity/year
Participants in events on circular economy (including public bodies, companies, universities, research centers, professional associations, etc.)	Quantity/year
People involved in the informal waste recycling sector	%/total inhabitants
Number of people in formal jobs related to recycling	%/Economically Active Population (PEA)
Number of people trained through environmental education measures	Quantity/year
Number of new circular initiatives	Quantity/year
Number of local "green" businesses	Quantity/year

Source: Girard & Nocca, 2019.

Comparatively, it is estimated that, on average at the national level, 74.5% of the waste generated ends up in a sanitary landfill or in a controlled site (SEMARNAT, 2016), so Xalapa sends less waste to its landfill than the national average. Mexico City for example, generates approximately 12,893.00 t of waste per day, which, considering its population in 2015, would be equivalent to 1.46 kg per inhabitant daily (SEMARNAT, 2016) an amount higher than that held by the city.

Currently, all states of the country have sanitary landfills to deposit their waste (SEMARNAT, 2016). Veracruz is one of states with the highest amount of landfills (18), along with the fact that it is one of the five states that generates most waste: 7,813 t per day (SEMARNAT, 2020) or 2.3 million t per year (5.5% of the national total) and the one that collects most waste: 6,102 t daily and with an average coverage of 78.00% (SEMARNAT, 2020).

The vehicle fleet for waste collection is of 16,615 vehicles operate in the country, of which 759 are in the state of Veracruz and at least 66 in Xalapa (SEMARNAT, 2020). Although each route of the City Council's collection truck service reaches 3.5 t per day or 1,277.50 t per year, these amounts may vary depending on the month or time of year, the day of the week, whether it is a holiday date or not. and circumstantial and unexpected aspects, such as street blockades or the recent COVID-19 pandemic.

Concerning to the indicators related to the amount of waste produced in Xalapa, on an annual basis, the information found was divided into the following categories: special and dangerous (376.94 t), organic (93,299.73 t), inorganic (68,094.22 t) and others (2,097.73 t). It was found that, of the more than 160,000 t of waste generated annually, 114,245.00 t end up as garbage, being dumped in the El Tronconal landfill, that is 69.70% which already surpassed its life-expectancy (García, 2023; H. Ayuntamiento de Xalapa, 2018a).

Comparatively, in 2013, the final disposal of waste in sanitary landfills and controlled sites at the national level, reached 74.50% of the volume of waste generated. While, in 2017, it was estimated that an average of 86,352.70 t of garbage per day entered the final disposal sites from the 1,722 municipalities of the country, except for Mexico City (SEMARNAT, 2020). This means that Xalapa contributes 0.36% to the amount of garbage that ends up being deposited in landfills nationwide.

The indicators related to the amount of domestic waste dumped into the landfill indicate that the approximate amount is 54,495.00 t, which represents 47.70% of all the waste dumped into the landfill in Xalapa. While, in the case of incineration, the City Council does not carry out such an action, although this can happen informally in a limited way, in some points of the city. It is estimated that the amount of reused or recycled solid waste amounts to 30.00% per year, while the amount of composted is 20.00%. No information was available regarding the number of recycled products sold per year or the percentage of food waste treated in small and medium-sized enterprises (SMEs).

The indicators focused on the amount of waste generated in the city per capita and show that approximately 449.00 t of waste are generated per day, that is, 163,868.00 t per year which, per capita, means that each person generates around 0.3212 t (or 321.20 kg) annually or 0.88 kg a day. The amount of waste separated for recovery and treatment in Xalapa ranges between 50,671.86 t and 54,321.86 t per year, which is carried out with the support of the collectors and privately, by the private waste collection centers, representing approximately 33.14% of the waste generated. The amount of waste separated by type on an annual basis, is estimated as follows: between 7,300.00 t and 10,950.00 t by the City Council staff and an estimate of 43,371.86 t by the 54 private waste collection centers (quantity assumed assuming that all the centers were operating at an average capacity).

In comparison, according to (SEMARNAT, 2020) at national level, the generation of waste amounts to 120,128 t per day, equivalent to between 43.8 and 53.1 million t in total, which, expressed per inhabitant, is between 0.94 kg and 1.20 kg per day on average (SEMARNAT, 2016). As can be seen at the national level, Xalapa contributes 0.37% of the average waste generation and its average per capita per day is slightly lower (0.88 kg). It stands out that, at the national level, only 5,281.00 t of waste per day are collected separately, which is equivalent to 5.00% of the total collected. In Veracruz, from 6,102 t of waste that are collected per day, only 13.55 t are collected separately, that is, less than 1.00% an average lower than the estimate held by Xalapa (33.14%) (SEMARNAT, 2020).

Economic and financial dimension

The results show the absence of companies or industrial installations for recycling, including the treatment of containers, so there are no people formally employed in this field, nor information available on income from recycled products sold. On the other hand, on an annual basis, the City Council has a budget of approximately MXN (Mexican pesos) 90 million or approximately EUR 3.60 million in 2020 for the management of the approximately 163,868.62 t of waste produced in the city each year (0.3212 t or 321 kg per capita per year). The classification by object of expenditure of the budget approved by the H. Congress of Veracruz-Llave for the year 2021, assigned USD 995,200.00 (EUR 47,510.85) specifically for the comprehensive management of waste. That amount represents 1.11% of the total assigned to the Government of Veracruz for that year.

The Mexican Government considers that the revaluation of waste contributes to reduce the consumption of raw materials, electricity, water, and other inputs, which are necessary for the extraction and processing of new materials (SEMARNAT, 2016). We found that the percentage estimated of reused or recycled household waste is close to 30.00%, whose potential value of the material estimated under the assumptions made in this paper is approximately MXN 152 million or EUR 6.08 million per year, not including, given the lack of information, the amount of food waste treated in small and medium-sized enterprises (SMEs), the value of waste that could be reusable or recyclable that has been sent to the landfill, and the income from the sales of related local products.

Social and cultural dimension

We found that the training activities through environmental education measures by the Xalapa

City Council in conjunction with other local organizations during 2019 and 2020 had an attendance of 52,644 people (DMAS, 2020). Meanwhile, non-governmental organizations like Universidad Veracruzana during 2020, hosted 7 CE events (MEAE, 2020; Peralta Vázquez, 2020). These events were attended by 329 participants in total and were held virtually due to the COVID-19 pandemic (MEAE, 2020; Peralta Vázquez, 2020).

The sum for the indicator on the number of local companies that can be considered as "green" is 538 companies. In this section, companies related to the repair, maintenance, purchase, and sale of discarded or second-hand materials and composure were considered. Finally, it was not possible to assign a value to the indicator of the number of new circular initiatives during the last year, while the number of people involved formally and informally in jobs related to recycling is zero, in the first case, since said activity is not carried out in the city and in the second, because there is no information available.

Lessons to transition towards a circular city

Based on the results, we prepared a SWOT analysis for Xalapa. Given the characteristics of the city, we summarize the main strengths, weaknesses, opportunities, and threats observed considering the waste context results towards the adoption of CE for the city.

The main strengths observed in Table 3 were "involvement of society in CE training activities" and "Government's specific departments focused waste management". For the first one, it was observed that local population is willing to participate in activities related to CE and on the other hand, Xalapa possess an environmental sub-department specifically dedicated to waste collection and management.

About the weaknesses, the city does not have an updated catalog of waste collection centers, nor a precise tracking of the waste input and output flows. Also, there is a problem with waste collection which is made by hand by the collectors in the trucks and it is difficulted by the civilians who do not segregate properly their waste. There are not enough facilities private or public for waste segregation and about waste recycling there are none. The finally important element about the weaknesses found is that CE is not included in the government municipal plan.

The city council receives every year financial resources exclusively for being to waste management. Also, we noticed that the amount of organic and non-organic waste collected by the government and the private waste collection centers can be reused in different ways. The activities of the private waste collection centers can be taken in consideration to improve the waste collection and to reduce the pressure of the municipal landfill. As the major threats, we consider that the end of life of the municipal landfill, which already surpassed its life expectancy, and the environmental and economic degradation due the inappropriate waste disposal are the most important ones to be addressed for the city.

Discussion

This paper addresses the problematic of measuring the transition towards more CE practices in a developing country city context, in other words to transition to a circular city. By the

Table 3
SWOT waste management situation in Xalapa towards the adoption of a circular city model

Strengths	Weaknesses
Involvement of society in CE training activities Government's specific departments focused waste management	Lack of updated information of private waste collection centers Lack of precise tracking of waste flows Lack of infrastructure for waste segregation Lack infrastructure for recycling Informal inadequate waste deposit Informal un-controlled waste collection Scarce citizen culture of separation and recovery CE is not present in the municipal plan
Opportunities	**Threats**
Annual government budget Organic waste and non-organic recoverable waste Private waste collection centers activities	End of life of the municipal landfill Environmental and economic degradation

Source: self-made, 2023.

time this research was carried out, it was found that the concept of CE has not been adopted yet in Xalapa, therefore, the city is not in the path to transform into a circular city so far. There is a lack of favorable conditions provided by the municipal authorities to even approach CE. Xalapa and other cities in developing countries can benefit from the adoption of the CE as part of the philosophy of the environmental education departments of their councils, especially in developing countries since it is still in a nascent stage. The unification of approaches under the Government can facilitate the inclusion and participation of the private sector in the design, development, and application of circular strategies.

Due to the number of private waste collection centers that operate in the city, the volume of separation and the value of the materials, the analysis of the information collected suggests the existence of a potential market for separated waste. So, it is possible to attract future investors to continue the path towards circularity in the city. That situation highlights the potential of the private waste collection centers even though they operate with limited resources and no government support, which is common in developing countries. To take advantage of their potential market and their activity, it will be necessary to make periodic estimates on the value of the separated material and to update the database to include recently created ones and eliminate those that no longer exist. Also, the authorities must establish communication mechanisms with the owners of private waste collection centers, neighborhood leaders, and community centers to collect information periodically and provide support, advice, and training in economic and organizational matters.

Neither the state nor the local government have sufficient information on the characteristics and the state of use of the waste. Future research might be focused on quantifying the volume of waste, and finding ways to automate various processes. This is important since it allows, based on the composition and location of the waste, to determine the by-products of the waste that can be used or recovered, and which would be the most appropriate systems for it. The design of strategies to reduce the amount of waste in the city depends on the ability to measure adequately the waste that is produced, recovered, or turned into garbage and ends up in landfills.

This research was complicated firstly by the lack of official data to satisfy the indicators and secondly, by the absence of updated information about the private waste collection centers and the reluctance their owners to give information alleging security problems against organized crime. That situation that is common in developing countries cities, must be addressed with the council help because to transitioning to a circular city it is necessary to obtain information related to the number of workers, collection volume and specially, financial situation, since it is considered sensitive by the private waste collection centers owners, and it is difficult to obtain it through unofficial means. The issue of security is not explicitly considered as an aspect of interest in the CE literature consulted, therefore, future research could be focus on the violence phenomena in developing countries and its implications to CE.

Conclusions

The objective of the paper is to study the current state of Xalapa towards a circular city model by integrating the CE concept with MSW. The hypothesis suggests that Xalapa is not on the path towards a circular city model. Given the current situation in the city, it is possible to conclude that by the moment of this research was carried out, Xalapa is not pursuing a circular city model. CE has not been considered as an alternative by the Xalapa's Municipal Development Plan, so it has no impact in the government areas and in practice is null. To consider the adoption of CE in the future, it will be necessary to take steps considering the context of a city in a developing country.

First it is necessary to create the legal bases for the adoption of CE. The legislation consulted is focused on assigning responsibilities and endorsing them on waste management, however, it lacks a focus related to CE since it is not included in their plans up to now. For their part the private waste collection centers, particularly the personnel who work there, requires urgent attention and support from the authorities, since it is generally unhealthy and poorly regulated. In some cases, the partial appropriation of the street for their activities was observed, as well as the total absence of protective equipment and a notorious lack of organizational structure, for which reason government intervention is required, not to restrict their operation, since it is important for the city, but rather to support the adoption of appropriate equipment and practices.

We consider that it is necessary to thoroughly quantify the volume of waste by type, by route and by area. Also, it is important to automate various processes since the design of strategies to reduce the amount of waste produced in the city depends on it, as well such as, the amount of waste that is turned into garbage ending up in the sanitary landfill and the increase in the amount of reused waste.

The lack of official methods for collecting information periodically from the private waste collection centers makes the path towards circular city model. The intervention of the authorities can guarantee the security of the donor's information and serve to establish a support link. Similarly, it is important to update the database of collection centers and establish communication mechanisms with owners, neighborhood leaders and community centers by the councils, to periodically collect information and provide support, advice, and training in economic and organizational matters.

We identified the importance of carrying out periodic estimates on the value of the separated material and investigate the number of recycled products that are sold annually in the city and that come from local producers. This will provide an idea of the size of the market and will help to identify the most important players in this area to lay the foundations for future private sector investment. Also, it will be necessary to develop a training, advisory and consultancy program in the adoption of circular economy strategies as well as exhaustive measurement methods on the type of waste generated in the city, its flows, quantity, and potential value for the promotion and adoption of CE.

In Table 3, we provide a SWOT analysis of the waste management situation of the city considering the idea for a future adoption of a circular city model. We consider that portraying Xalapa's context in that way, can help other similar cities from developing countries to consider their own path towards CE based on their own waste management characteristics.

This study faced limitations that may affect the generalizability of the findings. First, accessing all the waste collection centers in the city was challenging due to their dispersed locations and restricted schedules. Second, the scope and depth of the research were constrained by the available time, financial resources, and personnel. Third, the case of Xalapa, a small city in Mexico, may not reflect the situation of other cities in developing countries with different social, economic, and environmental contexts. However, this study provides a valuable insight into the potential of circular economy practices for waste management in urban settings.

Further investigation into the dynamics of circular cities to enable a comprehensive understanding of their potential and inform evidence-based strategies for their successful adoption, especially in developing countries. Also, it would be valuable to research into the violence phenomena in developing countries and its implications for CE. We also suggest studies on the adoption of CE strategies on cities as well as measurement methods on the type of waste generated in cities, its flows, quantity, and potential value for the promotion and adoption of CE. Research about the estimations on the value of separated material and the number of recycled products sold annually in cities from local producers could be useful to provide an idea of market size and identify important players in this area to lay foundations for future private sector investment.

We believe that this paper can be useful for academics, practitioners, and policy makers. For the first, we think that this document provides a clarification about useful potential indicators to be used for CE measurement on cities based on MSW behavior. Also, this document highlights some of the challenges that researchers may face when conducting similar studies in their own context. For the second, it can help them to identify critical points on CE application on cities, especially in developing countries, and insights for potential application on their own businesses, especially on waste management sector. And for the last ones, this paper stresses the importance of unifying approaches under the authorities to facilitate the inclusion and participation of the private sector in the design, development, and application of circular strategies.

Notes/Przypisy

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