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How can the city of Querétaro in Mexico adopt a more sustainable solid waste management system from an economical and environmental standpoint?

**Bachelor Project submitted for the degree of
Bachelor of Science HES in International Business Management**

by

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Disclaimer

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Executive Summary

This report analyses the solid waste management system of the city of Querétaro, a medium size city in the center of Mexico. It investigates economic and environmental sustainability in the solid waste management sector and addresses the following question: “How can the city of Querétaro adopt a more sustainable solid waste management system from an economical and environmental standpoint?” The objectives are to understand how the solid waste management system of this city in particular is organized, to identify the challenges faced by the different stakeholders involved in the process, and to propose initiatives that could enhance the sustainability of the system.

In order to reach the defined objectives of this study, a qualitative data collection process was undertaken in the city of Querétaro and in Switzerland. The interviews in Querétaro have been conducted with the different stakeholders involved in the solid waste management system of the city. In Switzerland experts in solid waste management were interviewed in order to discuss the best practices in the sector and the possible recommendations for the city of Querétaro.

During this research, various challenges preventing the city of Querétaro to reach an optimized solid waste management system in terms of economic and environmental sustainability have been identified. Amongst them we can note a lack of coordination and communication between the different stakeholders, a lack of institutional memory and political will, a low recycling rate and an under capacity of the treatment plant, an uncontrolled informal sector, a rapid population growth and a lack of education of the population on the topic.

Finally, this report studies some initiatives that the city could undertake in order to move its solid waste management system towards a more economically and environmentally sustainable one. The four main initiatives that are presented in this report are 1) the establishment of a separate collection system, 2) the integration of the informal sector, 3) the implementation of a programme to reduce the quantity of waste generated in the city and 4) an improvement in the solid waste related data collection system. The proposed initiatives have an economic, environmental, and sometimes social dimensions aiming at reaching an optimum solution for all the stakeholders.

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1. Introduction

Solid waste management is a global issue and one of our biggest challenges as a society since it has serious consequences on public health, on the environment and on the economic development of a region when inappropriately managed (Letcher, 2019). It needs to be adapted to each region's specific conditions as it implies economic, environmental and social considerations, and it tends to reflect the level of governance of a region since a city that does not manage effectively its waste is usually not able to manage other more complex public services (Letcher, 2019). Improving solid waste management can help addressing more than half of the sustainable development goals set up by the United Nations such as health, climate change, poverty reduction, food and resource security or sustainable production and consumption showing how big of a challenge or an opportunity it can be (Wilson, 2015).

Waste management is considered today as a major issue because of the impressive increase in the quantity of waste generated. Solid waste is projected to grow from 2 billion tones generated per year globally in 2016 to more than 3 billion tones in 2050 under a "business-as-usual scenario" demonstrating the importance of the issue (Kaza et al. 2018). This impressive increase is due to global rapid population growth, urbanization, production processes, and changes in lifestyle and consumption patterns (Wilson, 2015; Ribic, Voca, Ilakovic, 2017).

A lot of work has been done in developed countries in order to put in place efficient as well as economically and environmentally sustainable solid waste management systems. However, properly managing waste remains a challenge for many cities in developing countries (World Bank, 2019). Indeed, due to rapid population growth and urbanization, developing countries are faced with increasing challenges when dealing with the waste their population generates.

This work will focus on the solid waste management system of the city of Querétaro in Mexico, by addressing the following question: how can the city of Querétaro adopt a more sustainable solid waste management system from an economical and environmental point of view? Over the past years Mexico has experienced economic and population growth leading to a higher rate of urbanization and a change in consumption patterns which has consequently led to an increase in the quantity and the heterogeneity of the solid waste generated in the country (Buenrostro, Bocco, 2003). The city of Querétaro was selected because it is a modern city that represents

an important economic center for Mexico and that is facing a rapid population increase leading to new challenges when managing solid waste.

The study identifies the main stakeholders and the functioning of the waste management value chain in Querétaro in order to better understand the main challenges to which it is confronted. In a second instance, this project proposes some areas of initiatives in order to move the current solid waste management system of the city towards a more economically and environmentally sustainable one. These initiatives have been based on the analysis of the city's waste management system as well as on best practices in other regions facing similar challenges, and on other studies discussing the topic.

2. A global picture of solid waste management

Solid waste – also called municipal waste – regroups all waste produced by households and similar waste produced by industries, institutions, and public spaces, but excludes waste coming from industrial processes and hazardous wastes (UN-Habitat, 2010). Solid waste management (SWM) is a public service and refers to all the activities related to the handling of solid waste from its collection and transport to its disposal, and passing by the treatment or processing of waste (Nathanson, 2019). When not appropriately managed, waste affects heavily the public health as well as the economic development of a region (World Bank, 2019). It also has serious repercussions on the environment which is why it is very important to manage it properly from its generation to its final disposal (World Bank, 2019).

Each city or region has different economic, social, cultural and environmental characteristics that need to be taken into account when designing a waste management system. Waste collection is usually carried out door-to-door at regular frequency or through central collection points, and the waste collection rates vary widely depending on the region and the income level of the population going from nearly 100% down to only 39% in low income countries (Kaza et al. 2018).

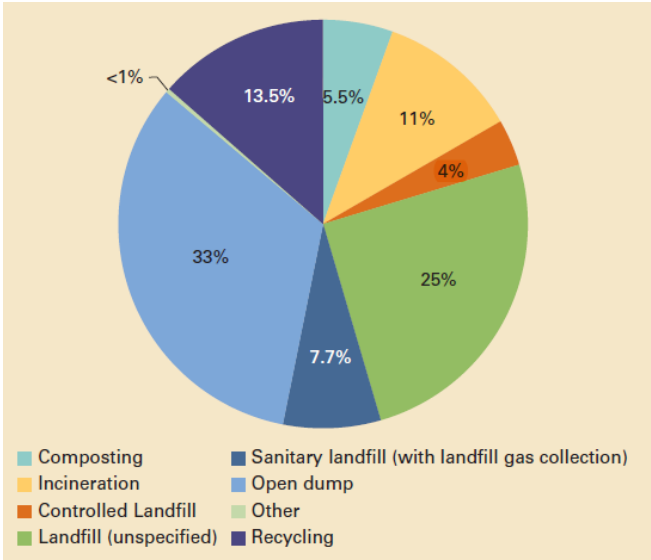
Once refuses have been collected, they are sometimes treated or processed before being sent to final disposal sites. The different methods to process waste or to recover materials from waste are mostly composting and recycling which concern 19% of global waste, but also incineration for 11% of waste generated globally (Kaza et al. 2018). Incineration can produce energy and is the preferred method of many European cities which often prohibit landfilling waste if options such as reuse, recycling or energy recovery are available (UN-Habitat, 2010). Switzerland has put in place such a policy since 20 years now, forbidding the arrival of any combustible materials to the landfills because of its high population density and limited space.¹ In brief, processing waste not only reduces the quantity of waste reaching final disposal sites which in turn decreases the environmental impact of waste, but also generates energy, fertilizer or recycled materials.

As illustrated in Figure 1, many different ways of disposing waste are used depending on the income level and the specific region, but the most common are to dispose waste in landfill which is the case for 40% of waste around the world, or in open dump sites

¹ Interview with an engineer at the territory and environment department of the Canton de Vaud, Lausanne, 23 March 2020

which is the final disposal method for 33% of global waste, mostly in low-income countries where landfills are not available (Kaza et al. 2018). Open dump is the least desirable method of disposing waste since it pollutes heavily air and water resources as well as the soils (UN-Habitat, 2010). It also leads to significant health risks for the population living near the open dumps (UN-Habitat, 2010). Sometimes, final disposition sites are equipped with waste-to-energy systems such as landfill gas collection or anaerobic digestion allowing the cities to generate biogas out of waste (Kaza et al. 2018).

Figure 1: Global waste treatment and disposal



Source: Kaza et al. 2018

2.1 Stakeholders in solid waste management

National governments usually set up the policies and the financial and administrative framework, while the municipalities are directly responsible for the waste management of the cities and set the legal, regulatory and financial conditions (UN-Habitat, 2010). The service providers, whether informal or formal, are also important stakeholders to consider in waste management, as well as all the users of the service which are the households, businesses and institutions (UN-Habitat, 2010). Finally, NGOs, unions or organizations representing the users in the policy and governance process are also part of the stakeholders in solid waste management (UN-Habitat, 2010).

Even if municipal solid waste is usually managed at the municipal level, different models of solid waste management exist; it can be completely managed by public entities, by public-private partnerships or by private operators depending on the regions

(Kaza et al. 2018). Waste management is expensive due to the required investments in physical infrastructures and the cost of the long term operations (Kaza et al. 2018). Municipalities in low income countries allocate around 19% of their total budget for solid waste management expenditures including capital investments and operational costs, against 4% for high income countries (Kaza et al. 2018).

2.2 Solid waste management in developing countries

Waste management is a significant issue to be addressed by both developed and developing countries; however developing countries are often more heavily impacted by poor solid waste management systems (World Bank, 2019). On average, one to two thirds of the solid waste generated in developing countries is not collected (Zurbrugg, 2003). Once collected it is most of the time dumped in arbitrary dump sites lacking appropriate norms or burnt to reduce its volume since it is often the most affordable option (Khatib, 2011). The urban poor areas are the ones suffering the most from poor solid waste management since authorities tend to allocate their resources to richer areas with higher tax yields (Zurbrugg, 2003). The material recovery process is usually done by informal workers in unsafe and unregulated working conditions who collect and sort around 15 to 20% of the total amount of generated waste (World Bank, 2019). The informal sector regroups the street- and dump-pickers, the itinerant waste buyers, the truck pickers, and the junk shops which can be small, medium or large traders of recyclables (UN-Habitat, 2010). Concerning the composition of waste, 45 to 80% of the total waste generated in developing countries accounts for organic waste (Di Maria, Lovat, Caniato, 2018) which translates a high potential for composting (Wilson, 2015).

The previously mentioned practices in terms of solid waste management have heavy consequences on the population's health and safety, and on the environment. Indeed, waste "leachate" contaminates the soils and the water resources, while waste burning causes significant air pollution (Mahajan, Vakharia, 2016). Solid waste when poorly managed is also a vector for diseases, it increases global climate change through the generation of methane, and it can even increase urban violence (World Bank, 2019). As a matter of fact, adequate waste management practices can decrease crime and violence since, in some cases, uncollected big waste has served to block roads to prevent police from accessing high-crime spots (Kaza, Banna, 2014). Waste such as glass bottles have also been used as weapons (Kaza, Banna, 2014). These issues are linked with the "broken window" theory that argues that, if an area looks neglected, it induces a perception of abandonment and fear which in turn leads to higher rates of violence (Kaza, Banna, 2014). When waste is not appropriately managed by the

authorities in charge, crime organizations such as mafias can “regulate” waste management affecting legal and illegal markets and leading to cases of exploitation and an increase in violence (D’amato, Mazzanti, Nicolli, 2015). It has been the case in the south of Italy where the biggest illegal dumpsite in Europe has been created by the local waste mafia (Livesay, 2015).

There are many reasons for the lack of well-functioning waste management systems in developing countries. In urban areas the rapid population growth makes it complicated for the municipalities to provide sometimes even basic services such as waste collection (Zurbrugg, 2003). Lack of technical competencies, lack of coordination, insufficient financial resources, municipal short term view or political constraints are other aspects that can explain poor solid waste management systems (Di Maria, Lovat, Caniato, 2018; Mahajan, Vakharia, 2016). Once an adequate system is in place, socio-cultural aspects can also lead to its failure if the population does not adopt a new behavior pattern to reduce, reuse or recycle waste (Maldonado, 2006). In summary, what most low- and middle-income countries tend to lack in their solid waste management system is a well-functioning institutional framework backed up with a sustainable financial system and a clear process to improve the system’s performance (UN-Habitat, 2010).

2.3 Sustainable solid waste management

Sustainable solid waste management has been advocated by many researchers as a way to tackle the waste crisis that we are facing today (Ribic, Voca, Ilakovac, 2017; Moustakas, Loizidou, 2018). These practices focus on the reduction of the greenhouse emissions generated by waste and on an upward shift in the management hierarchy of waste illustrated in Figure 2 (Ribic, Voca, Ilakovac, 2017). International Conferences on Sustainable Solid Waste Management that aim at promoting safe and effective practices and technologies in terms of sustainable solid waste management and inform scientists and citizens about the latest development in that field take place every year since 2013 showing the scientific and popular interest for more sustainable practices in the field of solid waste management (Thessaloniki, no date).

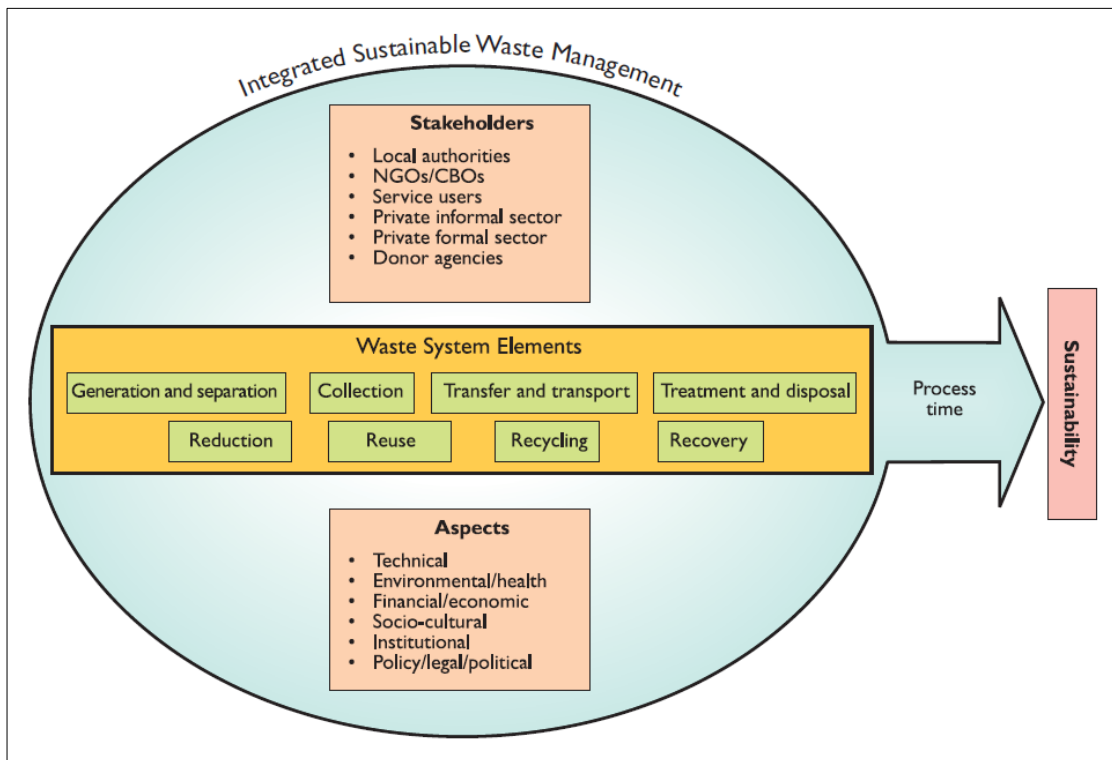
Figure 2: Waste management hierarchy



Source: UN-Habitat, 2010

Integrated sustainable waste management (ISWM) is mentioned by many researchers as a way to reach sustainable waste management (UN-Habitat, 2010; Wilson, 2015). ISWM is a framework to approach solid waste management that was first developed in the 1980s by the Dutch NGO *WASTE* (Khatib, 2011). It is an assessment method that aims at improving the performance of the solid waste system and supporting the decision making process by framing the solid waste process and considering short term concerns as well as long term goals (UN-Habitat, 2010). ISWM comprises three dimensions illustrated in Figure 3 that need to be addressed. First to be considered are the stakeholders, who consist of the people or organizations directly or indirectly involved in the system. Second, this framework implies considering the elements referring to the technical specificities of waste management, and third, the aspects to be considered for a sustainable system (UN-Habitat, 2010). The main elements of ISWM are the technical aspects that should be adapted to the local conditions, the environment and health impacts that should be minimized as much as possible, and the financial resources (Khatib, 2011). The socio-economic aspects are also considered in order to deliver adequate management independently of the population's income (Khatib, 2011). Finally, this framework studies the administration of the personal, and the supporting policies and legal framework (Khatib, 2011).

Figure 3: Integrated sustainable waste management framework



Source: UN-Habitat, 2010

ISWM's main goals are to achieve inclusivity amongst stakeholders meaning that there should be an adequate and equal service delivered to the users and equity among the service providers (UN-Habitat, 2010). The ISWM system should also be financially sustainable which means that it should earn more than it costs and reach the equilibrium between the supply and the demand for waste management services such as the collection of waste for example, as well as for waste as a material that can be sold and bought (UN-Habitat, 2010). Finally it should be responsive and well adapted to all users and providers (UN-Habitat, 2010). ISWM is based on governance and suggests that the solid waste sector can be used as an accurate indicator of a city's level of governance (UN-Habitat, 2010). In summary solid waste management should address all the technical and governance aspects in order to be sustainable in the long run (Wilson, 2015).

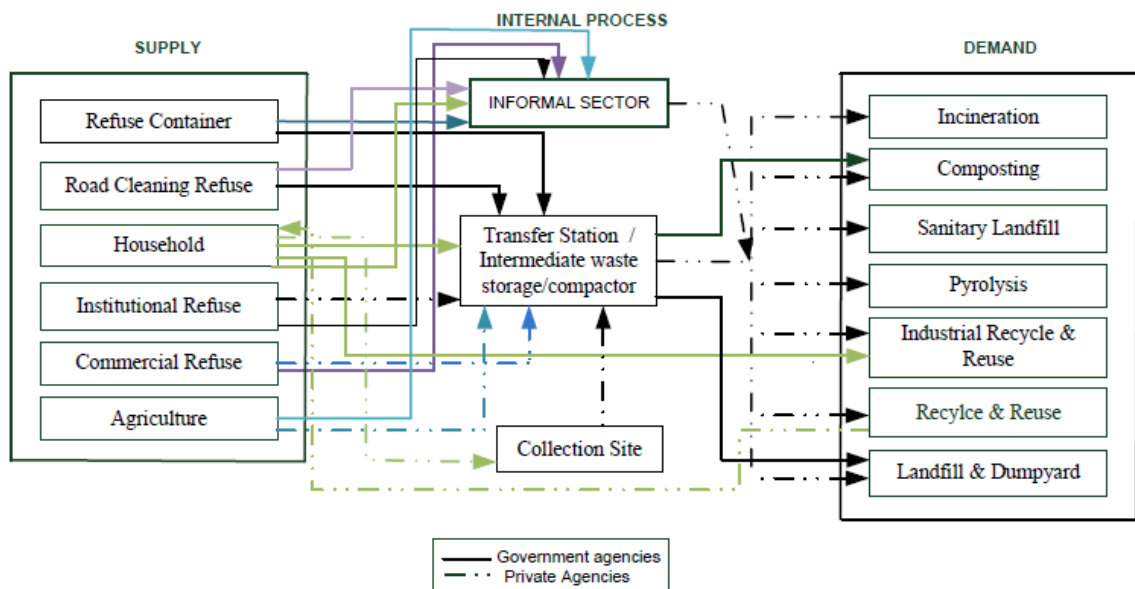
In order to have an efficient ISWM system, it is crucial to take into account all the above mentioned stakeholders and aspects, and to have an inclusive collection system and a safe and environmentally responsible final disposal. However, even if adequate final disposal systems are put in place, researchers have emphasized the importance of addressing the 3Rs (reduce, reuse and recycle) and to adopt new behavior patterns in order to avoid the saturation of the system (Maldonado, 2006). In conclusion, ISWM

does not only take into account the technology involved in the solid waste management system such as the infrastructure or the facilities, but many other elements such as the socio-economic setting, the environment, the growth in public demand and the management scenarios (Khatib, 2011).

2.4 Economics of solid waste management

From an economical point of view, solid waste management is a demand-driven business and a policy driven activity (UN-Habitat, 2010). It is also a public good since it cannot be produced effectively by the private sector only and needs the implication of the government in order to avoid market failures (Holcombe, 2000). Solid waste management can be considered as an industry like any other with a supply and a demand side that need to match in order to be well-functioning (example in Figure 4). The size of the global solid waste market from the collection to the recycling of waste was estimated in 2016 at US\$410 billion per year without counting the informal sector which shows the importance of this sector (Mahajan, Vakharia, 2016).

Figure 4: Supply Chain of the waste management in India and China



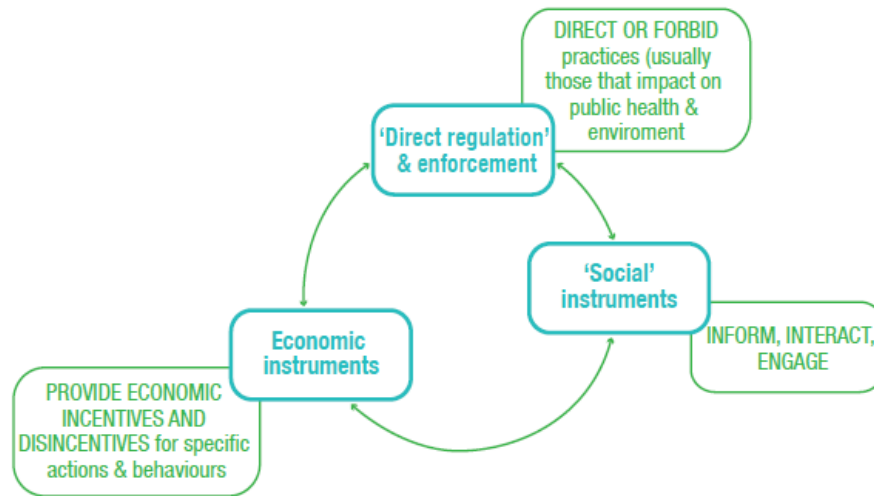
Source: Ghosh, 2016

Solid waste management can also be viewed as a sector with a reverse supply chain if we consider the material recovery phase that is induced by the recycling and reuse of waste. Taking advantage of reverse supply chains can be a source of profit and can also reduce the quantity of waste reaching final disposal sites such as landfills (Mahajan, Vakharia, 2016).

Solid waste management involves social, environmental and economic costs that need to be internalized by the authorities, the private entities involved in the process or other stakeholders involved such as the population or the environment. Cost recovery can also be achieved through government subsidies, taxes or user fees (Kaza et al. 2018). However solid waste management also generates benefits through resource recovery or energy creation for example, which is why it is important to make a cost-benefit comparison before choosing the best solid waste management option for a region. This comparison should consider economic variables such as the relative price of labour, plant, equipment, energy and land, as well as other costs and benefits less easily expressed in monetary terms but also important in the equation such as the opportunity cost of land, the savings from disposal costs, changes in public health or quality of air, water and land (Beede, Bloom, 1995).

Another important point to be addressed when looking at the economics of solid waste management is the role of the government and the external costs of waste disposal which have important impact on public health and the environmental. Private companies in charge of the collection and disposal of the waste oftentimes internalize some of the cost of their activity but they are unlikely to come up with a socially optimal outcome (Beede, Bloom, 1995). Households may prefer to avoid investments in sustainable waste management systems even if it would mean causing more damage to future generations, which is why government interventions are needed to correct those market failures (Beede, Bloom, 1995). Considering those markets failures, the role of the governments is to align the private and social incentives for solid waste management with policies (Beede, Bloom, 1995). Pricing garbage by the bag as it is currently the case in some regions in Switzerland, recycling subsidy where the municipality pays to marketing the recyclable materials, or host fees and disposal taxes are a few concrete examples of policies that help governments to internalize external costs of managing solid waste (Kinnaman, 2009). The instruments that governments can use to regulate waste are economic, but also social or legal as illustrated in Figure 5 (Wilson, 2015).

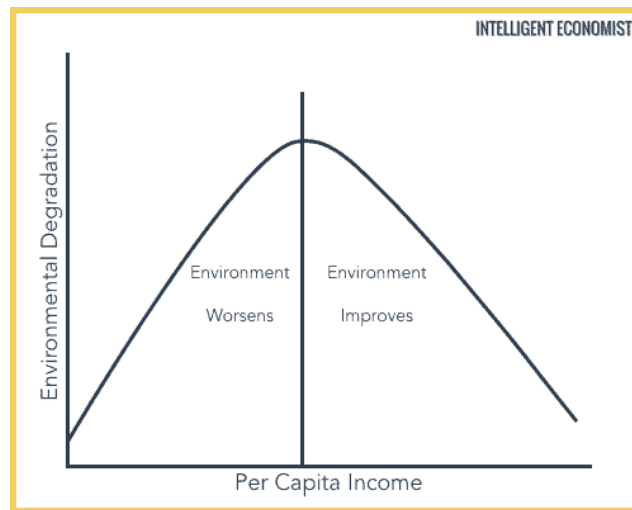
Figure 5: Policy instruments for waste and resource management



Source: Wilson, 2015

An important point to mention when considering economics of solid waste management is the link between the income level of a region and the quantity of waste that it produces. The Environmental Kuznets curve usually used to illustrate how environmental pollution first increase with GDP before reaching a turning point where it starts decreasing can also be used for reflecting on solid waste management (see Figure 6). Indeed, when transferring this curve to solid waste management, it has been proved that the quantity of waste generated in a region would first increase with GDP before reaching a ceiling where recycling and green technologies would reduce the environmental impact of managing solid waste with growing income (Kinnaman, 2009). Thomas Kinnaman stated that a 1% increase in income would on average increase the generation of solid waste by 0.69% and that the quantity of waste generated starts decreasing when the income level reaches three times its initial level (Kinnaman, 2009). The link between solid waste generation and the level of income was already established in 1995 when Mr. Beede and Mr. Bloom wrote *The economics of municipal solid waste* for *The World Bank Research Observer* in which they stated that “higher wages affect not only the quantity of municipal solid waste (MSW) that is generated but also its composition and the degree to which households process it before discarding the residue” (Beede, Bloom, 1995). More recently, the link between the economic situation of a region and its waste management has also been made in the book *What a waste 2.0* where the authors mention that “As nations prosper economically, waste is managed using more sustainable methods” (Kaza et al. 2018, p.34). They add that construction of landfills is usually the first step toward sustainable waste management (Kaza et al. 2018).

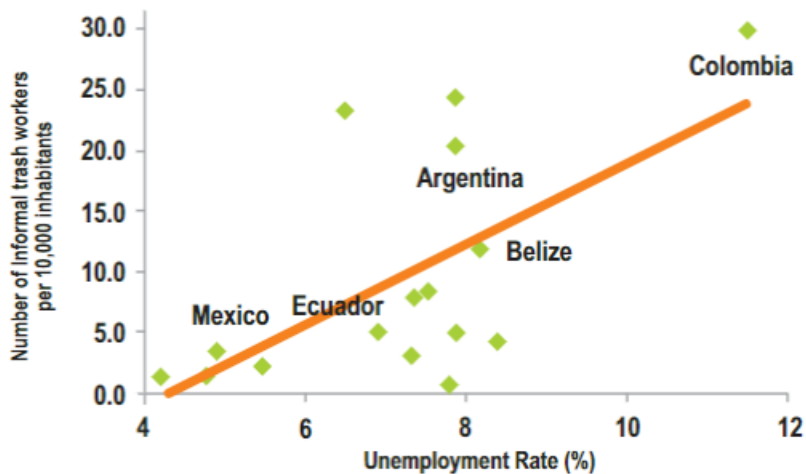
Figure 6: The Environmental Kuznets curve



Source: Agarwal, 2018

The income level does not only influence the quantity of waste that is generated but also other aspects of solid waste management such as the size of the informal sector. As a matter of fact, regions facing high levels of poverty and unemployment tend to have a higher number of informal waste pickers (Tello Espinoza et al. 2010). The Figure 7 below demonstrates the relationship between the unemployment rate and the number of waste pickers in Latin America and the Caribbean (LAC).

Figure 7: Relationship between the unemployment rate and the number of waste pickers in LAC



Source: Tello Espinoza et al. 2010

Finally, the price of disposing waste and the market price for recyclable material are also strong economic incentives for households, firms and government to put in place a recycling system in a region (Beede, Bloom, 1995). For a concrete and recent example of the fluctuating market of recyclable material we can refer to the recycling crisis of

2017 when China decided to stop importing used plastic and paper which consequently made the prices of those materials drop considerably and resulted in an important crisis for the municipalities and firms which were involved in this market (Roston, 2019). Indeed, the withdrawal of China which represented a large part of the world demand for recycled material resulted in a saturated market with excess supply which in turn made the prices drop. In the case of plastic, the low price of oil has also impacted the recycling market since it made virgin plastic cheaper than recycled one (Roston, 2019). Currently, some countries which are running out of space to store the materials to be recycled have started to send them to landfill or burn them. However, consumers nowadays put more and more pressure on governments and companies for recycled products or recycling systems which encourage them to pursue in this market even if the offer tends to exceed the demand (Roston, 2019). It is for example the case in Switzerland where the only revenue coming from all the different materials brought by the population to municipal recycling center comes from metal and oil². The municipalities however pay for the recycling of the other materials to reduce the amount of waste incinerated and reaching final disposal in order to reduce the environmental impact of the solid waste management.³

This second section studied the sector of solid waste management as a whole, looking at its functioning, its stakeholders and the challenges it faces. It has addressed the economic, environmental and societal dimensions to deal with when managing solid waste. Lastly, solid waste management in developing countries was discussed. This section highlights the important differences between the systems in place in developed and developing countries. One important lesson of the analysis is that each region needs a system tailored to its specific geographical and environmental, cultural and societal characteristics, and resources availability (Villalba, 2020). Few research have been made on solid waste management in Mexico and less on the system in place in the city of Querétaro which is why this report will focus on the solid waste management system of the city of Querétaro by taking into account the specific characteristics and challenges of this city and its region.

² Interview with Mr. Ruegg, Ingeneer at Direction générale de l'environnement, Canton de Vaud, 23 March 2020

³ Interview with Mr. Ruegg, Ingeneer at Direction générale de l'environnement, Canton de Vaud, 23 March 2020

3. Methodology

In order to fully understand the current solid waste management in place in Querétaro and to bring elements of response to the above mentioned question of study, qualitative data was collected through various interviews conducted in February and March 2020 in Querétaro. The interviews were conducted in Spanish and in rare cases in English with the different stakeholders involved in the current solid waste management system in this city. Those stakeholders were the municipality in charge of managing the overall good operations of the system, the private solid waste management providers to which the municipality subcontracts most of the actual operations, other private companies and associations or NGOs active in the sector, and finally the population who represents the waste generator and the users of the solid waste management system.

The interviews have been conducted in the form of semi-structured interviews. This method was selected because it is well adapted for delving into the respondents' issues and points of view and it is also well suited for asking clarifications if needed (Barriball, While, 1994). Additionally, it was well adapted for interviewing a sample group with different professional, educational and personal stories as it was the case for the stakeholders interviewed in Querétaro (Barriball, While, 1994).

The main objectives of the interviews conducted in Querétaro were to get a clear understanding of the current system, its stakeholders and its value chain, to identify the challenge of managing solid waste in the city and to grasp areas of improvement in order to adapt the system towards a more economically and environmentally sustainable one. In total thirteen people working or involved in the solid waste management sector in Querétaro were interviewed, most of them in person, two of them by phone, and one by email. Fifteen inhabitants of the city coming from various backgrounds were also interviewed in order to assess their satisfaction on the waste management service delivered in their city and to take into account the challenges that they face as service users. The inhabitants were randomly selected people of both gender and belonging to different age cohorts interviewed in the streets, in shops, in restaurants or in the private university campus of the *Tecnológico de Monterrey*. The random sampling method was chosen because it gives everyone the same chance of being selected and it eliminates selection bias (Salkind, 2010). The interviews of the people in charge of the sanitary landfill and the separation plant were followed by the visit of the infrastructures where some pictures present in this report were taken and where further specific questions were asked. The informal sector that also plays an

important role in the solid waste management system in Querétaro could not be directly interviewed for a constraint of time and circumstances. However other stakeholders in contact with this sector have been able to give important information about it and to discuss about their stake.

In a second phase, three interviews were also conducted over the phone in Switzerland later on in March and April 2020. The interviewees were all solid waste management professionals in Switzerland but were coming from different backgrounds. They have been interviewed through semi-structured interviews as well, the aim being to get some insights on Switzerland and Europe's best practices, and to get their opinion about the challenges identified in Querétaro in terms of solid waste management. It was also the occasion to discuss with them about the possible recommendations and initiative to move the system of waste management of the city of Querétaro towards a more economically and environmentally sustainable one.

As a preliminary research and an ongoing process, different documents available online and dealing with the solid waste management system in Querétaro such as articles of law, journal articles and municipal reports were analyzed. The goals were to get a full understanding of the current system as well as its evolution through time, to identify the stakeholders involved in the process and to get insights on potential challenges.

In a later stage all the interviews were transcribed. The data collected through the interviews and the documents analysis were reviewed in order to identify the different challenges in Querétaro regarding solid waste management and to think of ways to make the system economically and environmentally more sustainable by adopting more efficient and environment friendly practices.

4. Solid waste management in Querétaro

4.1 Overview of the city of Querétaro

The city of Querétaro officially called Santiago de Querétaro is located in the center of Mexico, around 200 km northwest from Mexico City. It is the capital of the state of Querétaro where more than 878'00 inhabitants live (INEGI, 2015).⁴

The state of Querétaro is one of the smallest state in Mexico covering an area of around 760 km², but it is an important historical place for the country since it is where Mexicans first declared their independence in 1810 (History, 2018). The city of Querétaro has also kept traces of its history since it is a well preserved Spanish colonial city. Its center has been designated a UNESCO World Heritage site in 1996 for its colonial architecture and its well preserved buildings from the 17th and 18th century (UNESCO World Heritage, no date).

Today Querétaro is also known for hosting many manufacturing companies that produce amongst other automobile parts, heavy machinery, oil-drilling equipment, food products, and consumer goods (Britannica, 2020). It is a city and a state that form an important economic center for the country and that have known a large increase in its population in the last decades due to a higher number of births than death and an increase in the national and international migration which has brought in new opportunities but also new challenges (Portal de Queretaro, no date). One of those challenges is the important increase in the waste generated by the population which has required and still requires today to adapt the solid waste management system of the city.

4.2 Stakeholders of the SWM system in Querétaro

Before diving into the value chain of the solid waste management system of Querétaro and the challenges that the city faces in this sector, this section will look at the different stakeholders involved in the solid waste management system. The purpose of this section is to set a clear picture of all the people and the institutions involved in the solid waste management system in the city of Querétaro in order to understand their level of implication and their interests which is essential to then analyze the initiatives suggested in the fifth section of this report.

⁴ Last numbers published by the *INEGI*, the official public entity responsible for regulating and coordinating the National Statistical and Geographical Information System in Mexico

The stakeholders involved in the solid waste management in Querétaro as of today are first of all the municipality and more precisely the public services department. Since a few years, the municipality has subcontracted the different steps of the solid waste management to four private companies, except for the collection of waste in the public institutions and special services to private organizations that is still being taken care of by the municipality itself.⁵ The companies currently working in this domain for the municipality are *SULO* that collects waste in the public bins, *Red Ambiental* which takes care of the waste recollection to households, *Veolia* that is managing the sanitary landfill, and *Broquers Ambiental* which manages the separation plant.⁶

The informal sector and the recyclable material traders are also an important part of the solid waste management system in the city of Querétaro since there are many companies that buy valuable material and businesses that recycle those materials.⁷ The providers of those companies and some small companies themselves are very often informal. Called “pepenadores” in Spanish, informal recyclers live out of the sale of the recyclable materials that they collect in the city.

Some NGOs and associations are also playing an important role in the solid waste management system of the city, mostly regarding recycling. Most of them are active in the environment sector, and some have even put in place complete recycling systems in specific areas of the city that they manage independently. More generally speaking, the goal of these organizations is to put pressure on the other actors such as the municipality to solve the different problems identified in the solid waste management system.⁸ Finally, the population has to be considered as part of the stakeholders since they are the waste generators, and the ones indirectly paying for the operations.

4.3 Value chain functioning of the SWM system in Querétaro

As previously mentioned, the municipality of Querétaro supervises the solid waste management system in the city but the operations are subcontracted to private companies. The municipality was historically taking care of the operations but three years ago the mayor of Querétaro Mr. Marcos Aguilar decided to change the system

⁵ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

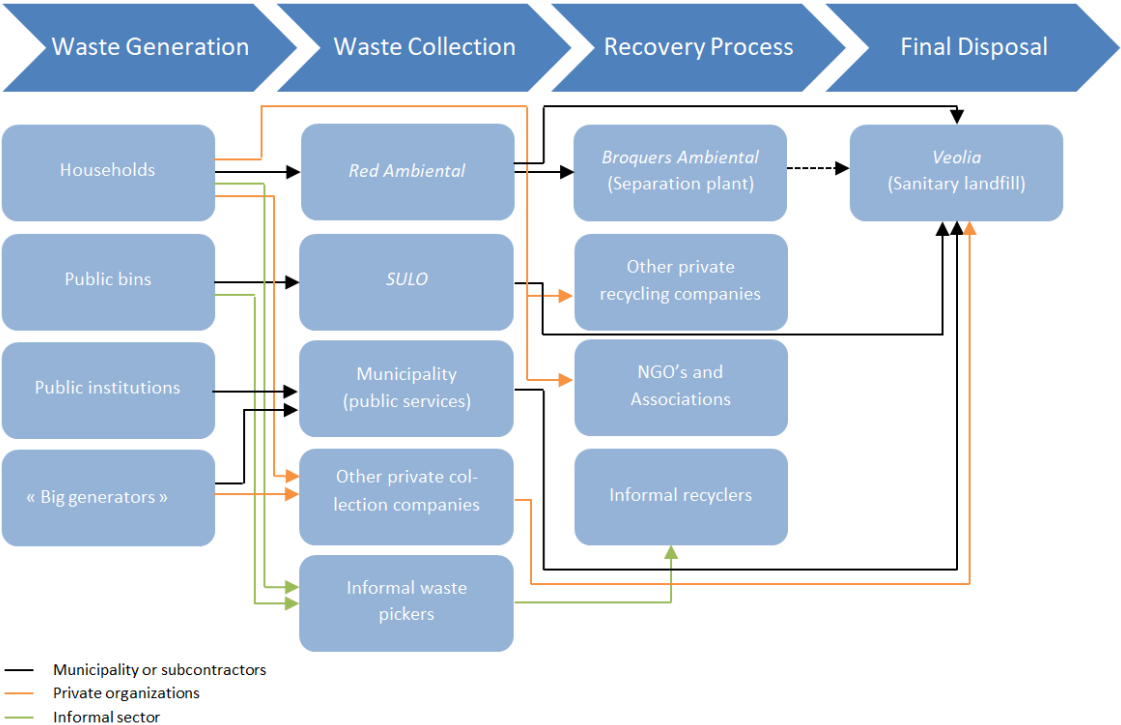
⁶ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

⁷ Interview with the Founder and member of *Promotores y Comunicadores Ambientales, A.C.*, Querétaro, 12 February 2020

⁸ Interview with the Founder and member of *Promotores y Comunicadores Ambientales, A.C.*, Querétaro, 12 February 2020

and to work with subcontractors.⁹ According to the Director of the public services of Querétaro, there were many reasons for that decision but some of them were that the vehicle park of the municipality was too old, and that the municipality was missing the necessary personnel for the operations.¹⁰ The graph in Figure 8 sets the main steps and actors of the value chain of the solid waste management system in Querétaro that will be detailed later in this section.

Figure 8: Value chain of the solid waste management system in Querétaro



Source: Author's visualization

The first step of the solid waste management that is the recollection is managed by the company *Red Ambiental* for the city's households. The recollection to households is done daily in the downtown main squares and every three days in the rest of the city. It is a general recollection system that collects all sorts of waste together.¹¹ However, it is important to mention that the municipal recollection does not yet cover the whole city; there are still zones in which the collection of waste is not regularized because the

⁹ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

¹⁰ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

¹¹ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

constructors have not yet delivered the necessary documents to the municipality.¹² In those cases, other private collection companies are directly contracted by the inhabitants or the constructors to collect waste.¹³ The municipality collects the waste generated by the public institutions of the city, and also provides special services to private organizations that generate big volume of waste that cannot be collected through the general collection service, such as restaurants for example.¹⁴ In this report those institutions have been called “big generators”. Finally, the company *SULO* is contracted by the municipality to collect waste in the 14'500 public bins available in the city.¹⁵ *SULO* also collects waste from 50 “monumental bins” which are underground bins of half a ton each where people can drop separately plastic, paper and carton, metal, and mixed waste.¹⁶

In January 2020 and according to an article published by the *Diario de Querétaro*, the daily generation of solid waste amounted to 900 tones which correspond to an average of 1kg per inhabitant (Ruiz, 2020). The waste in the state of Querétaro is composed of 18% of recyclable material, 62% of organic and 20% of other waste (CASAS, 2019).

Once collected, the waste is taken by trucks to the sanitary landfill of Mompaní (Figure 9) which is managed by the company *Veolia*, and to the separation plant that operates next to the sanitary landfill since March 2018 (Ruiz, 2020). *Veolia* is an international company that has been active in Mexico for 25 years and that employs 2'670 employees in the country (Veolia, no date). The company has a contract of 20 years with the municipality that started in 2006.¹⁷ The sanitary landfill of Querétaro was constructed on 20 hectares in 1996 but in 2014 the municipality increased its capacity to 40 hectares¹⁸. Today *Veolia* receives at the sanitary landfill between 800 and 1'000 tons of waste per day coming from *Red Ambiental*, *SULO*, the municipality, and other

¹² Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

¹³ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

¹⁴ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

¹⁵ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

¹⁶ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

¹⁷ Interview with the Operations manager, *Veolia*, Querétaro, 7 February 2020

¹⁸ Interview with the Operations manager, *Veolia*, Querétaro, 7 February 2020

private collecting companies.¹⁹ According to the Chief of services working at *Veolia*, there is an increase every month in the quantity of waste that arrives in the sanitary landfill of Querétaro.²⁰

The sanitary landfill is equipped with installations to extract biogas from the methane that is produced when the waste disintegrate. There are currently 42 pipes that collect methane and the total production of biogas in 2019 was of 5'130'009 Kwh. The energy produced is then used for public lightening and 9% of it is sold to third parties.²¹

Figure 9: Sanitary landfill of Querétaro



Source: Photo taken by the author in February 2020

The separation plant (Figure 10) has been constructed and is today managed by the company *Broquers Ambiental*. It was built in 2018, it employs 206 people who work in two shifts, and it has a 20 years contract with the city of Querétaro (Contreras, 2018). The plant separates and sells all the materials it receives except for the polyester that is not recycled in Mexico, and the carton that costs more to recycle than its market price.²² This plant is the result of a private investment of the company *Broquers*

¹⁹ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

²⁰ Interview with the Operations manager, *Veolia*, Querétaro, 7 February 2020

²¹ Interview with the Biogas manager, *Veolia*, Querétaro, 7 February 2020

²² Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

Ambiental worth 300 million of Mexican pesos (corresponding to around 13.4 million US dollars) (Contreras, 2018). It is today the biggest and most modern separation plant of this type in Latin America (Contreras, 2018), and has placed Querétaro as the city with the best solid waste management in Mexico (Vargas, 2018).

Figure 10: Separation plant of Querétaro



Source: Photo taken by the author in February 2020

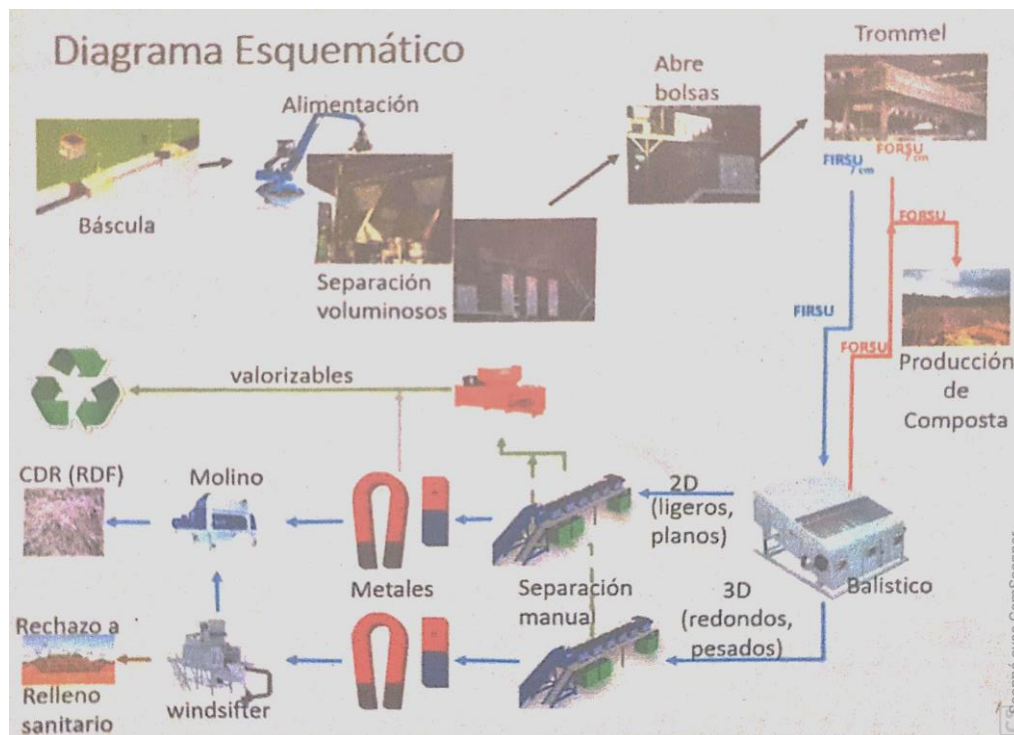
The goal of the separation plant is to separate 100% of the waste. However the quantity of waste that is currently being separated in order to be recycled only reaches 50% of the total generated waste according to the Director of the plant.²³ The proportion can vary if there are malfunctioning in the plant in which cases a bigger proportion of waste is directly sent to the sanitary landfill.²⁴ After the separation, 5% of the waste is valuable material that is recycled, 30% is transformed into combustible called Refuse Derived Fuel (RDF), 50% is organic material transformed into compost and given to the city for its green areas, and finally the last 15% that cannot be recovered are sent to the sanitary landfill.²⁵ The separation plant has two lines that work simultaneously and its functioning is described in the Figure hereunder (see Figure 11).

²³ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

²⁴ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

²⁵ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

Figure 11: Process of the separation plant of Querétaro



Source: presentation by *Broquers Ambiental*, February 2020

Except from the separation plant there is currently no official recycling system put in place by the municipality. Today some NGOs or association have installed independent recollection systems in some part of the city which is for example the case in the area called “El campanario” where the organization *Apis Inovación Sustentable* has put in place a system that collects the waste separately and brings it to recycling centers for 10 Mexican pesos (\$0.45 US) per week and per family.²⁶ The collection center of Jurica is also a place that receives the recyclable materials from the population before bringing them to recycling plants. This center was created in 1987 and around 60 others were created afterwards in the entire city but most of them stopped existing as the municipality stopped helping them because of changes in the politics.²⁷ Some people chose to bring their recyclable materials directly to private companies that recycle them which is why they are mentioned in the Figure 8 as stakeholders of the recovery process in Querétaro.

The informal sector also plays a role in the solid waste management in Querétaro since there are many people collecting the materials that can be recycled from the streets or

²⁶ Interview with the Founder of the NGO *Apis Inovación Sustentable A.C.*, Querétaro, 6 February 2020

²⁷ Interview with a member of the foundation committee of the collection center of Jurica, Querétaro, 14 February 2020

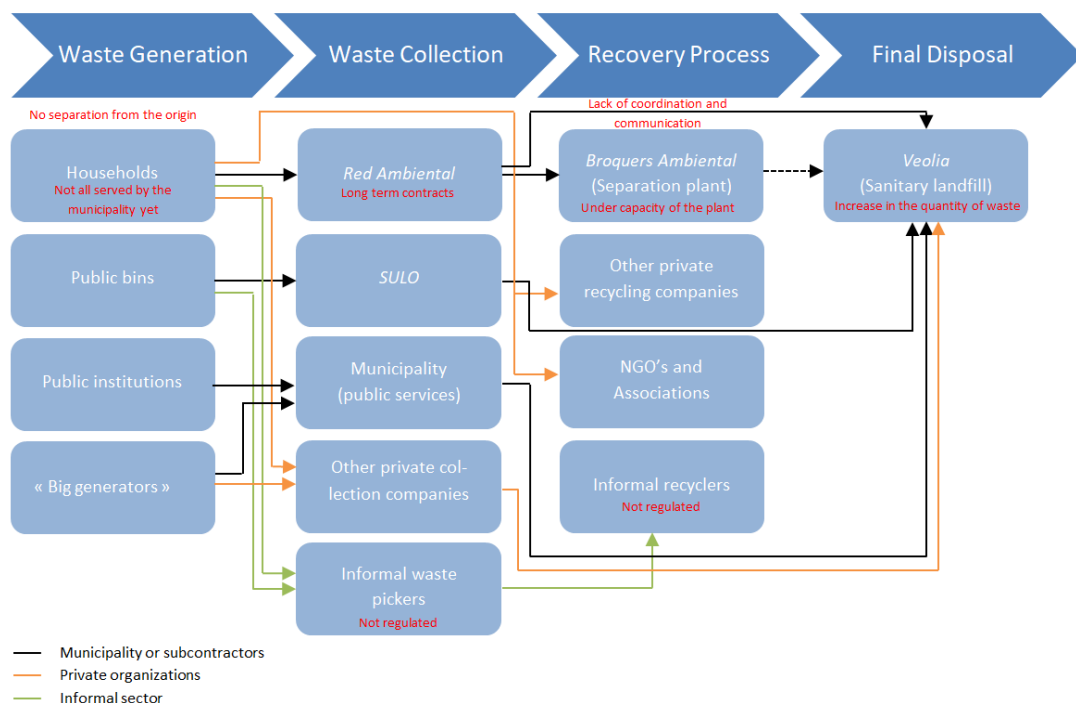
from the waste that households put in front of their doors. After collecting the materials, informal recyclers trade them to small or medium companies whose business is to sell the material to bigger reseller or directly to recycling companies.

Finally and concerning the collection of waste that end up in the street or what can be called littering, there is a cleaning system in the downtown of Querétaro that is put in place by the municipality in order to keep the streets clean. Since the center of Querétaro is part of the UNESCO list of World Heritage sites, the city has the obligation to keep its downtown streets clean which is why in this area municipal employees clean the streets from any waste that can be encountered twice a day.²⁸ However, it is only the case in the center of the city; there is no cleaning system in place in the rest of the city.

4.4 Challenges

After analyzing the current solid waste management system of the city of Querétaro and interviewing the main stakeholders, different challenges have been identified. The ones directly linked with a specific step of the value chain have been identified on Figure 12.

Figure 12: Challenges identified in the value chain of the solid waste management system in Querétaro



Source: Author's visualization

²⁸ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

The first challenge that has been identified is a lack of coordination and communication amongst the stakeholders mostly concerning the separation and recycling system. Indeed, as seen previously, *Broquers Ambiental*, the informal sector and NGOs or associations are working in the recycling sector in Querétaro, but they do not coordinate with each other in order to be more efficient. Also, most of the people interviewed in the population did not know the existence of the separation plant, and were confused or frustrated about the separation system. Some people are still separating their waste but see that the recollection system does not take it into consideration, using the same truck independently of the waste being separated or not which creates some confusion or frustration.

Moreover, the work of separating waste from a mixed trash is challenging for the separation plant which has difficulties recuperating some valuable material such as organic waste paper. The current capacity of the separation plant has also been widely belied during the interviews. According to the chief of the public services of the municipality, around 20% of the total solid waste generated in the city was processed by the separation plant.²⁹ According to Dr. Casas it is 5% only (Casas, 2019). Both contradict the official number of 50% stated by the Director of the separation plant or the 44% announced by the secretary of the Municipal Public Services (Ruiz, 2020).³⁰ This wide difference shows that there is no clear or credible communication from the municipality nor the separation plant on the actual percentage of waste currently being processed in the city of Querétaro. In all cases, we can suppose that the plant is not yet able to treat the majority of the waste generated in the city.

The lack of a separation system from the origin has led not for profit organizations to put in place such systems themselves but the efforts are isolated in a domain where economies of scales can be considerable. Some individuals who are not part of those areas but still want their waste to be recycled take the initiative to bring them personally to companies or shops that will receive it but it is a lot of work to do independently and we can challenge the sustainability of such an exercise. Some of those organizations have tried to rally their effort with the municipality without success. One of the reasons for that are the long term contracts (up to 20 years) that the subcontractors have signed with the municipality. However, every year, the contracts are analyzed by the

²⁹ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

³⁰ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

municipality that has the legal authorization to end or modify them if needed.³¹ It is also important to mention that waste separation has been promoted by the municipality to households since 2006 but it only has an educational purpose and is not linked with a separate collection system.³²

Moreover, a problem that many people interviewed mentioned was the lack of institutional memory and systematic vision due to the short term mandates of the politics in charge of taking decisions concerning the solid waste management system. Indeed, the people in charge of the related decisions in the municipality change every 3 years and do not want to take decisions that will hurt their politic image. The budget allocation of the municipality has also been criticized in one interview; it seems that 40% of the total budget is attributed to communication, and other projects that are not under the responsibility of the municipality are financed by it, resulting in a very small proportion of the budget available for solid waste management.

Concerning the legal aspect, one of the interviewee confirmed that there was a legal framework but said that in reality it is not always enforced. Indeed, since 2004 there is a legislation called *Waste prevention and integral management of waste of the State of Querétaro* that sets rules to regulate the generation, the utilization and the management of urban solid waste and special waste (Casas, 2019). There is also a *Regulation of cleaning and public services for the municipality of Querétaro* modified last time in 2014 that regulates the cleaning service, recollection, transfer, treatment and final disposal of waste, and finally a *Legal framework to condominiums* that applies to large generators who generate over 10 tons of waste per year (Casas, 2019). However Mr. Medina from the College of Biologists of Mexico also stated in an article from the *Excelsior* that in Mexico "although there are some of the best environmental laws, their execution is a problem because they are not thought of in terms of the authority to execute them and of the citizens to abide by them" (Contreras, 2014).

According to one of the interviewee, corruption sometimes takes place in the municipality which makes it harder to change the system and enforce the laws. Corruption is an important socio-political issue known to be a serious national problem in Mexico which is ranked as the most corrupted country within the Organization for Economic Cooperation and Development (OECD) (Rodriguez, 2018). The state of Querétaro is not spared since it has one of the lowest level of transparency and highest

³¹ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

³² Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

level of corruption and impunity of the country (Rodriguez, 2018). Corruption typically affects the public sector in the form of embezzlement or misappropriation of public funds (Rodriguez, 2018).

Another point to be addressed when talking about the solid waste management system in Querétaro is the management of the informal sector that plays an important role in the recycling system. At the moment, the informal sector is not integrated in any public or private systems and operates in a totally independent way. It has some positive aspects since it allows for the recuperation of a lot of recyclable materials. According to an interviewee, it is probably also a factor that has played a role in decreasing the violence in Querétaro that is known to be one of the safest cities in Mexico. Indeed, due to the number of companies willing to buy those materials, there is a market for recyclable material which creates the opportunity for people who need money to sell those materials instead of having to proceed to illegal, dangerous or violent ways to earn money.³³ However, the informal sector in some Mexican big cities has become so big that it is today referred to as a mafia. In Mexico City for example, some heads of the mafia named the “Garbage Kings” control the dump sites by charging the scavengers or “pepenadores” a monthly fee for the access to the dump and by forcing them to sell the material they find to them rather than outside (Baverstock, 2016). Those practices raise important social concerns since it is a form of exploitation.

Finally, even if a lot of stakeholders are aware of the environmental issues we are today confronted to and convinced of the importance of a good and sustainable solid waste management system, a lack of education and culture on the topic has regularly been mentioned in the various interviews that have been conducted. It can be linked with the increase in the total quantity of waste which is also an important challenge to be addressed since there is a larger volume of waste arriving in the sanitary landfill each month. Looking at the last decade, there were 628 tons generated per day in the city of Querétaro in 2010 (Casas, 2019) against 900 tons in 2020 (Ruiz, 2020). The average solid waste generation per capita in Querétaro amounts to 0.906 kg per day which makes it one of the ten states in Mexico with the highest waste generation rate (Almanza, 2018). This increase could be partly due the impressive and rapid increase of population in the state of Querétaro which represents according to an article from *El Financiero* 40 families moving in the state every day (Almanza, 2018). However, it can also be explained by the consumption patterns of the population and the lack of education on the subject which has been mentioned many times during the interviews.

³³ Interview with the Founder and member of *Promotores y Comunicadores Ambientales, A.C.*, Querétaro, 12 February 2020

5. Recommendations

This section studies some initiatives that the city of Querétaro could take in order to adapt its solid waste management towards a more sustainable one from an economical and environmental point of view. These initiatives come from the challenges identified during the evidence collection carried out in the city with the different stakeholders involved in the process, and are adapted to the local conditions. The areas for improvement include economic, environmental and sometimes social dimensions, and are backed up with literature showing the benefits of such initiatives and examples of successful enforcement.

5.1 Separate waste collection system

The first suggestion would be to move from a mixed collection system to a separate collection system with three different fractions of waste collected separately. The three fractions would be 1) the organic waste meaning all the biodegradable refuses, 2) the recyclable materials such as paper, plastic, metal, glass or textile, and 3) the other waste mostly referring to sanitary waste.

This proposition is motivated by different challenges identified in the solid waste management system in Querétaro. First, it is driven by the incapacity of the separation plant to process as much waste as it is planned for. Indeed the goal for this plant is to process 100% of the total waste but it currently processes a lot less than that (the exact percentage varied widely between the information sources; from 3 to 50% were mentioned, but in any cases the 100% is not yet achieved).³⁴ Another element that moots this proposition is the observation that a lot of citizens of Querétaro feel frustrated or confused about separating their waste when they see that the truck puts them all back together during the waste collection. Indeed, as previously mentioned, many citizens already do the effort to separate their waste either for their environmental conscience or for the informal waste pickers who pass in the street in search of valuable material to sell. However, people feel that their efforts are useless when they see that the municipality collects all waste in the same way independently of it being previously separated or not.

A separate collection system is already in place in many countries such as France, Italy or Canada, and this system already exists in Mexico showing that it could be feasible in

³⁴ Interview with the Chief of public services, Municipality of Querétaro, Querétaro, 12 February 2020

Querétaro as well.³⁵ Indeed, since July 2017, and according to the environmental norm NADF-024, the population in Mexico City has to sort their waste in organic, recyclable, voluminous and other waste (see Figure 13), and every three days a different type of waste is collected (SEDEMA, no date). Thanks to this norm, in one year the Mexican capital has been able to collect 120 tons of organic waste transformed in compost and used to fertilize the parks and green areas of the city (SEDEMA, no date).

Figure 13: Plan for the separation of waste in Mexico City



Source: Union Guanajuato, 2017

The city of Querétaro does not currently collect waste separately because it has signed a contract of 15 years with the company *Red Ambiental* to which it subcontracts the municipal collection of waste. This outsourcing partnership apparently makes changes in the collection process more complicated even though, according to the Director of the public services, the contract is reviewed every year and can be changed or stopped before the end.³⁶ Lack of political will or interest groups might also be the reason why the municipality has not yet adopted a separate collection system in spite of the economic and environmental benefits that can come with it. However, such a collection system would not represent a drastic change from the actual system since the collection already takes place three times a week in most parts of the city. Instead of collecting mixed waste three times a week, *Red Ambiental* would collect a different fraction of waste every time. The organic and recyclable fractions would go to the separation plant while the other waste would go to the sanitary landfill.

³⁵ Interview with the Communication Manager, *Helvetia Environnement*, Geneva, 26 March 2020

³⁶ Interview with the Director of public services, Municipality of Querétaro, Querétaro, 20 March 2020

In order to incentivize the population to adopt this new separate collection system, the collection would only take place if the waste is properly sorted. In this scenario, the human factor is very important since citizens would play an active role as a processor of materials at source (Kumar, Bharti, 2012). It is the reason why educational programs would be needed in order to explain to the citizens how to separate their waste properly and to raise awareness among the population about the importance and the social, economic and environmental benefits of separating waste.

The goal of this change in the waste collection system in Querétaro is to increase the efficiency of the separation by bringing to the plant organic and recyclable materials separately. This would allow the separation plant to process a bigger percentage of the total waste that is generated every day in the city. If the new system is successfully put in place it would generate economic benefits for *Broquers Ambiental*, and for the municipality. Indeed, in an interview from *Querétaro 24-7* dated from 2018, the Mayor of Querétaro Mr. Marcos Aguilar affirmed that the cost of processing a ton of waste in the separation plant was lower than the cost of disposing a ton of waste in the sanitary landfill which means that if the capacity of the separation plant increases, it would reduce the costs of disposing waste for the municipality (Vargas, 2018). If the capacity of the plant is increased, new jobs could also be created the same way the construction of the plant initially generated more than 200 jobs (Vargas, 2018). According to an article from the Swiss Federal Institute of Aquatic Science and Technology, the creation of employment is the main economic benefit of resource recovery in developing countries (Zurbrugg, 2003).

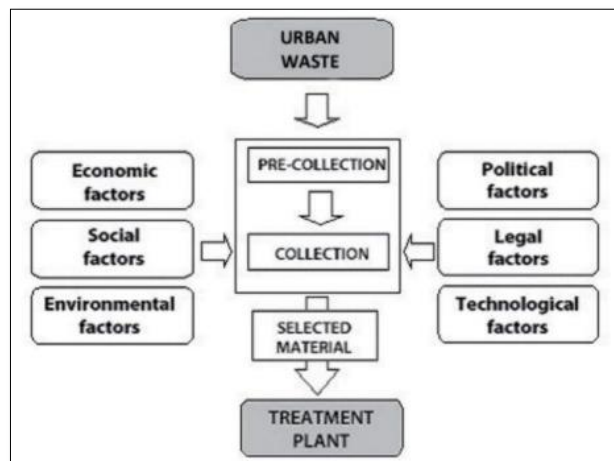
Besides, most solid waste generated in developing countries are decomposable or recyclable which provides high opportunities for the socio-economic development of the region (Khatib, 2011). In 2002, a program of organic waste recycling and waste reduction was put in place in the Yucatan Peninsula in the South of Mexico and showed that the amount of waste sent to final disposal could be reduced by two third and that it could become profitable in the long term (Maldonado, 2006). The cost of producing quality compost for agriculture would also importantly decrease if households would separate their compostable and non-compostable waste (Beede, Bloom, 1995). Studies conducted in Canada have shown that, separate collection having a different economy of scale than mixed waste collection, it is possible through separate collection to have longer collection routes that can serve up to three time the number of households per route and per day than a mixed collection system demonstrating once again how economic and environmental benefits could come out of a separate collection system (UN-Habitat, 2010).

The proposition would also move the current system towards a more environmentally sustainable one since, if a bigger fraction of the waste can be processed by the separation plant, a smaller quantity of waste will be disposed in the sanitary landfill and a bigger quantity of waste will be recycled therefore decreasing the need for extracting natural resources. To give some examples, recycling one ton of paper saves 17 trees and 50% of water, and recycling one ton of aluminum prevents the emission of two tons of carbon dioxide (UN-Environment, 2017; Mahajan, Vakharia, 2016). Furthermore, the organic fraction in Querétaro is important since it is considered to constitute 62% of the total waste (Casas, 2019). Putting in place a separate collection at the origin of the process would drastically increase the quality of the compost made out of the organic fraction. The organic waste currently extracted from the process of the separation plant is given to the city for fertilizing its green areas.³⁷ However since it comes from mixed waste, it has a low quality and contains traces of contaminants in the form of other materials that could not be separated such as small plastics. Collecting the organic fraction separately would avoid contamination of other waste components (UN-Habitat, 2010). This proposition makes sense since organic waste has a really good recovery potential and reusing it as compost for example, reduces the costs of disposal infrastructure, and extends the life of such infrastructures while reducing their environmental impact (Zurbrugg, 2003). More generally speaking both the quality and the quantity of the recyclable materials can be maximized thanks to a separate collection system (Calabrò, 2009).

The collection system is influenced by many different factors that need to be taken into account when analyzing a new collection system which are the economic, social, environmental, political, legal and technological factors (Kumar, Bharti, 2012). Those factors are illustrated in the separate collection diagram below (Figure 14).

³⁷ Interview with the Director of the separation plant, *Broquers Ambiental*, Querétaro, 7 February 2020

Figure 14: Separate collection diagram



Source: Kumar, Bharti, 2012

After the implementation of the new collection system and in order to verify the efficiency of the system it will be important to calculate the separation rate which is the ratio between the weight of raw material sorted and the total amount of solid waste (Kumar, Bharti, 2012). The quality rate will also be an important indicator and will be obtained by computing the ratio between the waste collected correctly in each fraction and the total amount of waste collected for each fraction (Kumar, Bharti, 2012).

5.2 Integration of the informal sector

The second proposition is to integrate the informal sector in the official solid waste management system of Querétaro. Indeed, as it has been mentioned before, the informal sector is part of the solid waste management system in Querétaro and in Mexico in general but it is not recognized. The observation that has initiated this proposition is the problematic turn that has taken the informal sector in other Mexican cities such as Mexico City as it has been explained earlier. Moreover, great advantages that will be outlined in this section can come from integrating the informal sector into a city's solid waste management system not only for the informal sector itself but also for other stakeholders.

As a short reminder, the informal sector usually regroups poor or marginalized people who work as trash pickers, sorters, traders and re-processors, collecting valuable materials from the municipal waste and preparing them for reuse, but whose work is not recorded nor recognized (UN-Habitat, 2010). As stated by the International Labour Organization (ILO), they are "individuals or small enterprises that intervene in waste management without being registered and without being formally charged with

providing waste management services” (Gupta, 2012, p.12). According to the *Regional Evaluation on Urban Solid Waste Management in Latin America and the Caribbean*, 3.3 people per 10'000 inhabitants are waste pickers in Mexico (Tello Espinoza et al. 2010). The *National Institute of Waste Pickers* affirms that there are 200'000 companies involved in the collection or recycling of waste in the country amongst which 98% operate informally (Gómez, no date). Those numbers provide evidence that the informal sector in Mexico is an important stakeholder to take into account when considering the solid waste management of this country.

In many parts of the world, informal workers play a role in waste management, mostly in places where there is no formal or well-functioning system for recyclable materials. It is even more common when it is hard to find formal jobs due to economic instabilities or when imported raw materials are expensive due to inflation of currency depreciation (Wilson, 2015). In 2009, according to the *New York Times*, specialists estimated 15 million people to be informal recyclers around the world dealing in some regions with up to 20% of all waste, which makes it an important activity at the global level (Chaturvedi, 2009).

The informal sector provides livelihoods to many poor people living in cities and can be seen as a way to fight poverty and consequently as a way to contribute to the UN development Goals (UN-Habitat, 2010). Environmentally speaking the informal sector contributes to a sustainable resource management since it has an important role in resource recovery (Gupta, 2012). Economically speaking it benefits cities since informal recyclers remove materials from the official waste management system resulting in lower costs of collection, transport and disposal for the municipalities (Gupta, 2012). The informal sector is usually more efficient in recovering value from the waste than the formal sector and they reach high recycling rates since they only work with the materials that are profitable and that have high market value (Gupta, 2012). According to Velis et al. (2013), since the informal sector is entirely market-driven, it can achieve really high recycling rates and can save local authorities up to 20% of their waste management budget which in some cities represents millions of dollars per year. As an example, it has been estimated that waste pickers reduced the quantity of waste by 30% in Jakarta which importantly reduced the waste management costs of the city (Medina, 2008).

However, informal waste recovery sometimes comes with downsides too. Due to a lack of capital, education and recognition, informal recyclers usually work in unsafe and unhealthy conditions with low income perspectives and cases of child labour and

human exploitation have also been observed (Wilson, 2015). Since the industry requires collecting large volumes of materials, informal recyclers usually sell to middlemen who pay them too little to escape poverty (Medina, 2008). The activity of the informal sector can also create tensions with 1) the formal sector that can see it as unfair competition, 2) the municipality since informal work is untaxed, and 3) with the population that can feel aversion or suspicion towards waste pickers even though most of the time the public feels a social connection with informal recyclers (Wilson, 2015). From the interviews conducted in Querétaro, this seemed to be mostly the case. Everyone that was interviewed was aware that informal workers picked up waste in the streets for which they sometimes purposefully prepared the material separated outside their door. In some cases, they even personally got acquainted with recyclers from seeing them doing their job since many years.

Integrating the informal sector in the official solid waste management system would help the city of Querétaro to use waste as a revenue stream rather than only consider it as a cost structure. We could imagine putting in place a solid waste management system that offers good working conditions and a decent income to its workers, and that lowers the general costs of managing waste by taking advantage of the existing resources (UN-Habitat, 2010). Experts have agreed that the informal sector cannot be ignored when trying to improve the waste management system of a region in developing countries (Velis et al. 2013). Moreover, it has been demonstrated that the “the role of the informal sector is particularly important to address when a city is establishing a formal separate collection scheme” which would be the case if the change in the waste collection system proposed in point 5.1 is implemented in Querétaro (Wilson, 2015, p.178).

The fact that the informal sector is not yet integrated in the city of Querétaro is probably due to a lack of political interest since it does not pose important problem for the city yet. However, integrating the informal sector could prevent future problems due to uncontrolled activities to occur in addition to bringing more value to the city’s waste management system. If the formal and the informal sector worked together, it would not only increase the quantity and the quality of the materials collected, but it would also reduce the sector’s negative aspects by supporting entrepreneurship, flexibility and productivity that are typical of the informal sector (Wilson, 2015). In addition to that, the informal recycling sector could improve the industrial competitiveness of the region by offering a cheaper option to industries than buying virgin materials (Medina, 2008). Indeed, recycling demands less energy than obtaining virgin material which lowers operating costs for the companies (Medina, 2008).

Finally, if the informal recyclers were integrated to a formal system with insurances and reliable wages, they would have better work conditions and they would be less vulnerable to economic slowdowns (Chaturvedi, 2009). However, depending on the economy, the informal recyclers might have a better situation if they stay informal since in some region they earn more than the minimum wage. This is the reason why it is important to first understand the goals and interests of the different parties involved in order to create partnerships benefiting the whole community (Wilson, 2015; Gupta, 2012). The World Bank in its document *The informal recycling sector in developing countries* recommends starting with a consultation process including the waste pickers and the other key stakeholders to design a system that is “socially desirable, economically viable, and environmentally sound” (Medina, 2008, p.2).

Different ways exist in order to integrate the informal sector into the formal waste management system and many examples of initiatives that do so exist in different countries. The first step would be to legally give to the informal sector the right over the recyclables of the city of Querétaro and a regular access to waste, thus recognizing it officially (Gupta, 2012). To mention an example, in 2009 the Colombian Constitutional Court officially gave waste pickers the right to access and sort recyclable waste in the country (Global Alliance of Waste Pickers, 2014). In the city of Querétaro, the municipality could start with recognizing officially the informal sector which could also lead the way and encourage other cities, states and eventually even the Mexican government to follow the path. That would increase the informal workers’ rights and provide them with decent working conditions as well as offer them new opportunities and empower them (Medina, 2008).

Then, the informal sector should organize itself as cooperatives or other legal or semi-legal structures with which the municipality or businesses active in the sector could establish contractual relations (Gupta, 2012). In Brazil associations and cooperatives regrouping waste pickers have been created already from the 1990s in order to have a better bargaining power and to avoid exploitation resulting in much higher environmental and economic benefits from the material recovery activity (Wilson, 2015). In the last decades there has been an important growth in the number of cooperatives of waste pickers mostly in South America (Medina, 2008). In 2008 the first World Conference and Third Latin American Conference of Waste-Pickers took place in Colombia showing that the waste pickers around the world have started organizing themselves into local and national structures (UN-Habitat, 2010). The second step for the city of Querétaro would therefore be to encourage the creation of cooperatives that regroup and register the waste pickers of the city. The city could provide them with

identity cards and insurance plans as well as keep record on the number of informal recyclers in the city. The advantage of doing so is that the municipality or companies active in the solid waste management sector in Querétaro could contact those cooperatives when they need to hire new workers in order to integrate little by little those skilled people in the formal sector which is the step 3.

In Tandil, a city located 350km south from Buenos Aires, a complementary social salary (CSS) was put in place in 2016 allocating the equivalent of half of the minimal wage to the informal recyclers working in the city.³⁸ This system has improved the integration of the informal recycling sector and has encouraged the informal recyclers to take part in the local cooperatives.³⁹ To mention an example of a successful collaboration between the formal and the informal sector we can also refer to the city of Bangalore in India where businesses hire waste-pickers to manage their waste and do basic cleaning in return of a modest salary and allow them to keep the materials collected (UN-Habitat, 2010). In some countries waste pickers have adopted a semi-formal role by working under contract while still being involved in informal recycling (Gupta, 2012). Other interesting initiatives including the informal sector have been launched such as franchising depots to informal operators, licensing itinerant waste buyers, etc (UN-Habitat, 2010).

In summary, three models can be used to integrate waste pickers in Querétaro's waste management system which are microenterprises, cooperatives or public-private partnerships (Medina, 2008). If the proposition 5.1 of modifying the collection system is put in place and that the capacity of the separation plant of Querétaro is increased to process the 100% of the recyclable waste that is collected through the new collection system, the plant will probably need to increase its human capital which would be the opportunity to integrate people from the informal system.

These initiatives have three main goals; they aim at 1) increasing the recyclable recovery rate, 2) decreasing the solid waste management costs by diminishing the costs of transportation and disposal, and 3) supporting the waste pickers (Gupta, 2012). The idea is to put in place win-win solutions that improve the situation of both the formal and informal sectors. These propositions also aims at avoiding the informal sector to take uncontrollable proportions and exploitation to take place as it has for example happened in Mexico City like previously explained in section 4.4. Thereby, the

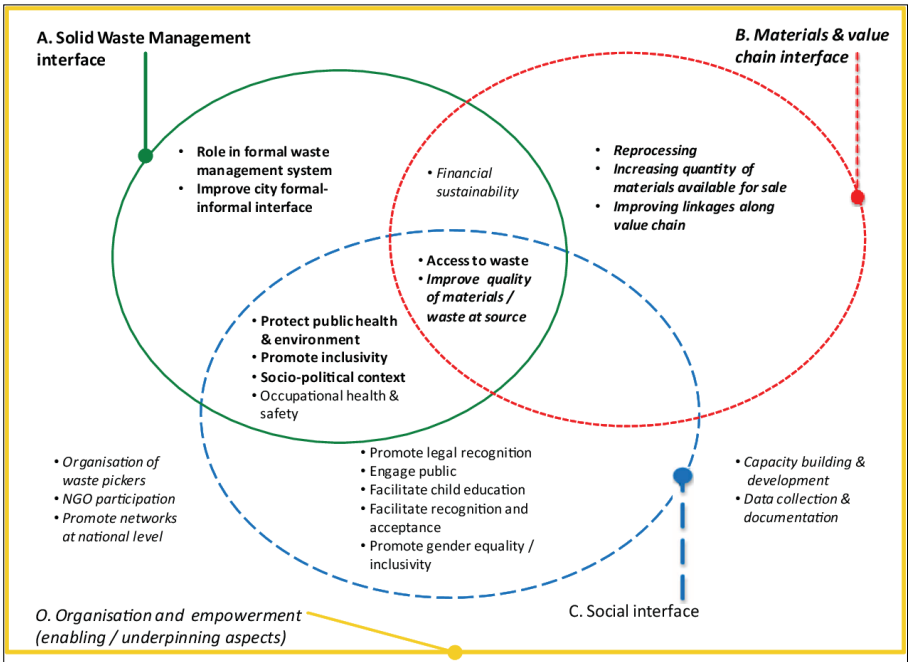
³⁸ Interview with a PhD candidate at University of Lausanne working on solid waste management in Tandil in Argentina, Lausanne, 26 March 2020

³⁹ Interview with a PhD candidate at University of Lausanne working on solid waste management in Tandil in Argentina, Lausanne, 26 March 2020

desired result would be to transform the solid waste management system of the city of Querétaro into a more economically and environmentally sustainable one as well as into a more socially inclusive one.

In order to understand better which are the alternatives that the municipality of Querétaro has to integrate the informal sector, an analytical framework for the integration of the informal sector in the solid waste management system in developing countries is illustrated in Figure 15. This framework provides a methodology to classify and analyze initiatives to integrate the informal sector into a region’s solid waste management system (Velis et al. 2013). It comprehends four aspects of possible areas of intervention in which many initiatives can be identified and which are: (A) the formal solid waste management system in which the informal sector operates, (B) the materials and the value chain providing the informal sector a revenue stream, (C) the society and its acceptance of the informal sector’s activities, and finally (O) the organization and empowerment of the informal recyclers (Velis et al. 2013).

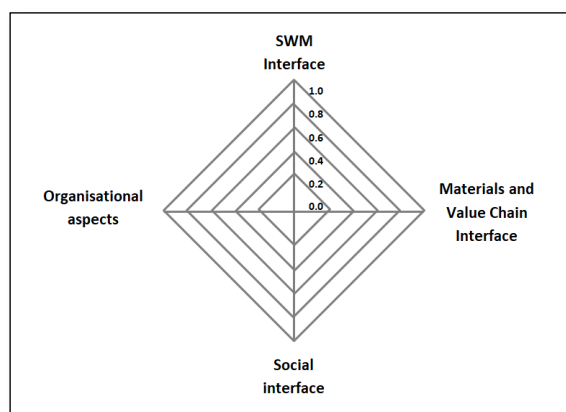
Figure 15: Framework for the integration of the informal sector in the SWM system



Source: Velis et al. 2013

The same authors have also created a radar diagram called *InteRa* (see Figure 16) that visualizes the planned or existing interventions to integrate the informal sector into the waste management system of a city and evaluates their relative importance in each category of the analytical framework (Velis et al. 2013).

Figure 16: InteRa rapid evaluation metric and visualisation tool



Source: adapted from Velis et al. 2013

5.3 Reduction of waste generation

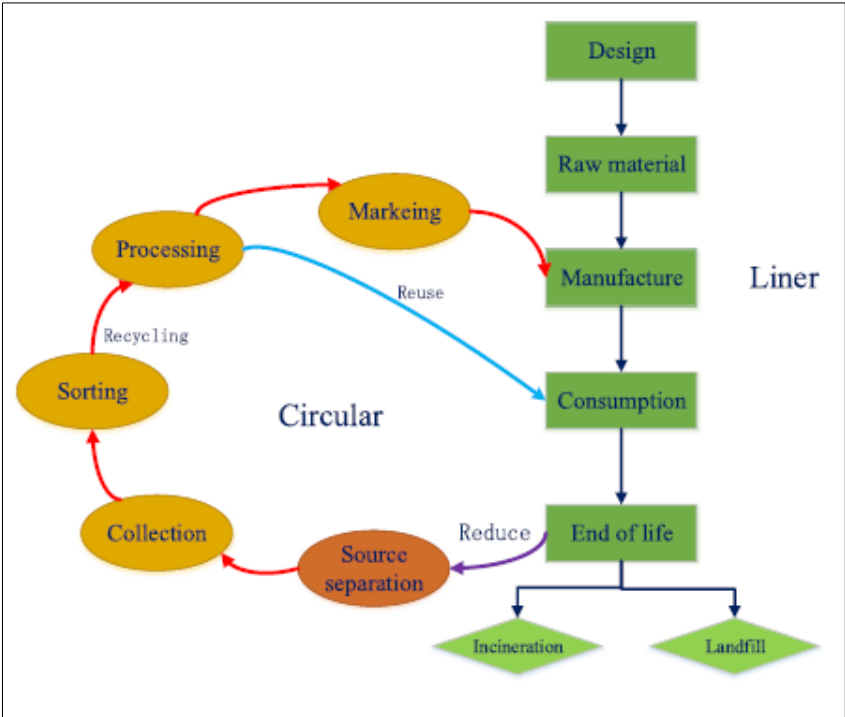
The third initiative to make the solid waste management system of Querétaro more sustainable from an economical and environmental point of view would be to reduce the amount of waste that is generated in the city. The rationale behind this proposition is that, as stated before, the quantity of waste reaching the sanitary landfill of Querétaro increases every month which poses an important challenge concerning the limited capacity and lifetime of the final waste disposal infrastructures of the city. As the quantity of waste increases, so do the costs of disposing waste which in turns increases the total costs of managing waste in the city.

The increase in waste does not only concern the city of Querétaro, it is a global issue to which every region is confronted already since many years. Indeed, between 1980 and 1997, the quantity of waste generated in the OECD countries, of which Mexico is part, had increased by around 40% and was expected to increase by another 40% by 2020 (King et al. 2006). For the next decades, the rhythm is not expected to slow down according to the World Bank that was expecting a rise from 2.01 billion tons of waste generated per year globally in 2016 to 3.40 billion tons by 2050 which makes it a very important concern to tackle globally considering all the potential problems associated to waste (Kaza et al. 2018). This impressive increase in the quantity of waste generated in Querétaro and in most regions of the world is linked with the economic development of the city, the rapid population growth and urbanization of the region (Kaza et al. 2018). It is also due to the population's consumption habits, the consumerism trend, and the rise in the community's living standard (Song, Li, Zeng, 2015).

The first option we can think about to reduce the generation of solid waste in the city of Querétaro is through a producer responsibility scheme which requires for the

manufacturers to be responsible for the environmental impact of their products throughout their life-cycle (King et al. 2006). It is a policy approach that gives producers the financial or physical responsibility for the treatment or disposal of the products they are putting on the market in order to give them incentives to reduce waste at the source or to support the recycling of their products (OECD, no date). Concretely it can be achieved for example through a take-back program allowing customers to return used materials to the distributors, or a deposit refund system (Kaza et al. 2018). Other initiatives to reduce waste through producer responsibility consist in encouraging them to repair, recondition, remanufacture or recycle (King et al. 2006). This concept is linked to the “3R rule” referring to “reducing, reusing and recycling” and which aims at saving materials and energy therefore benefitting the environment (Song, Li, Zeng, 2015). The “zero waste” approach is also a mean to prevent the generation of waste by designing a circular material flow (see Figure 17) to reach an optimum level of consumption (Song, Li, Zeng, 2015).

Figure 17: Linear vs circular resource flow



Source: Song, Li, Seng, 2015

In addition to the previously mentioned initiatives, an educational campaign should be launched to raise awareness throughout the population on the importance of waste reduction and to give them alternatives to reduce their waste generation. Another version of this programme should also be adapted for children as well and presented in the city’s public and private schools since good habits are easier to foster with children.

In Switzerland, where waste reduction is also a big challenge, such programs have been presented to children in schools since 1995 involving animations and projects around waste prevention.⁴⁰ Today the campaigns are made by the organization *Responsables.ch* which gives alternatives to the Swiss population in order to avoid, repair, reuse or recycle waste.⁴¹

For a waste reduction and prevention programme to be efficient it needs to be backed up by robust public policies that the municipality should put in place (King et al. 2006). It also asks for strong public-private partnerships between the businesses, the municipality and the population, by educational programs and financial incentives achieved for example through deposit refund systems (King et al. 2006). The city of Querétaro has already started to encourage the reduction of waste by banning single use plastic bags, straws and styrofoam in 2019 in all its shops which shows its willingness to decrease its global municipal waste generation (Contreras, 2019). However, due to the impressive increase in the quantity of waste generated the efforts should be strengthened and should engage all the stakeholders involved in the waste generation process from the companies to the population.

By reducing its quantity of waste generated, the city of Querétaro would be able to make economic benefits by reducing the costs of collection, transport and disposal of waste. Thanks to a waste prevention and recycling programme, the state of Yucatan in Mexico was able to reduce the quantity of waste sent to its final disposal site by two third which is non negligible (Maldonado, 2006). Reducing the generation of waste at source would also benefit businesses that could save important amount of money through no-cost or low-cost improvement resulting in continued growth and prosperity for the private sector in addition to the public one (Wilson, 2015).

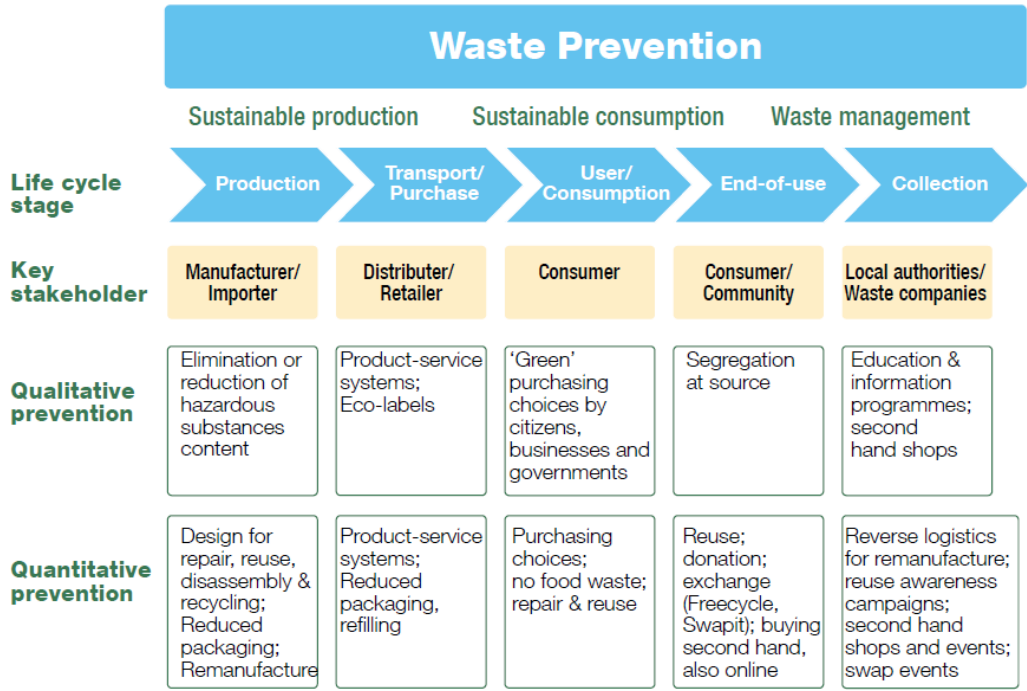
Environmentally speaking, reducing the generation of waste would have obvious and direct positive impacts for the city. It would reduce the demand for material and energy resources, it would reduce the quantity of waste in the sanitary landfill thus increasing its lifetime, and finally it would reduce the air, water and land pollution induced by disposing waste in landfills (King et al. 2006). As illustrated in Figure 18, waste prevention can avoid carbon emission not only in the waste management but throughout many sectors of the economy whether it is in the production or distribution process (Wilson, 2015). There are two ways of reducing waste; quantitative prevention

⁴⁰ Interview with an engineer at the territory and environment department of the Canton de Vaud, Lausanne, 23 March 2020

⁴¹ Interview with an engineer at the territory and environment department of the Canton de Vaud, Lausanne, 23 March 2020

measures that aim at reducing the quantities of material that become waste, and qualitative prevention measures that seek to reduce the use of hazardous substance in waste (Wilson, 2015).

Figure 18: Waste prevention at different stages in product life cycle



Source: Wilson, 2015

The life-cycle approach refers to waste as a resource and suggests tackling the problem at the source by adopting sustainable consumption and production practices which refers amongst other to reducing waste (Wilson, 2015). Using a lifecycle approach could reduce a region’s greenhouse emissions by 10-15% with an increase to 15-20% with the introduction of waste prevention (Wilson, 2015). The United Nations Environment Programme in its book *Global waste management outlook* encourages “treatment options that deliver the best overall environmental outcome, taking into account life-cycle thinking”, and ranks waste prevention as a priority which also refers to the waste management hierarchy illustrated in Figure 6 (Wilson, 2015, p.31).

This point is also linked with the UN sustainable development goal number 12 which seeks to ensure sustainable consumption and production patterns since sustainable production is linked with waste management (Wilson, 2015). By selecting their materials, producers determine the recycling potential of their product which subsequently influences the waste management (Wilson, 2015). They have a very important role in facilitating and promoting sustainable consumption (Wilson, 2015).

5.4 Collection of Data

The last area of initiative of this project for the city of Querétaro concerns the data collection around solid waste management. One of the observations that has been made during the data collection process was the important discrepancies on numbers or rates related to waste management which pose a problem when analyzing the current situation or potential changes. The quantity of waste produced by the population daily or the percentage of waste processed by the separation plant are some examples as they were many times contradicted showing a lack of clear and actualized data in this sector. It is due to a lack of coordination between the different stakeholders involved in the solid waste management system of the city and maybe also to a lack of financial resources.

Without clear numbers and indicators it is really difficult to evaluate waste management alternatives and to check the efficiency of any new system.⁴² A good data collection is essential for a modern waste management system (UN-Habitat, 2010). If the city does not put in place proper data collection, it will not be able to be transparent and accountable on its activities nor to establish new strategies and related budgets thus missing on opportunities to make positive changes (UN-Habitat, 2010). Quality of waste data is even sometimes viewed as a measure for the quality of the whole management system of a city, its degree of commitment and its governance system (UN-Habitat, 2010). Data is also very important to create policies, to design suitable systems of waste management, to choose strategic partners and to make future plans (Kaza et al. 2018). According to the *Global waste management* outlook, “without high-quality data providing the right information on the right things at the right time, designing, monitoring and evaluating effective policies becomes almost impossible” (Wilson, 2015, p.291).

The typical indicators that the city of Querétaro could start with keeping track of are the quantity of waste generated per person, the proportion of waste managed by the different methods, the percentage of households with regular collection services, and the percentage of recyclable waste that is actually recycled (Wilson, 2015). Putting in place a proper data collection system for waste in the city of Querétaro would help the planning, the evaluation and the monitoring of the overall waste management as well as all the previously mentioned initiatives aiming for a more economically and environmentally sustainable solid waste management system in the city.

⁴² Interview with a PhD candidate at University of Lausanne working on solid waste management in Tandil in Argentina, Lausanne, 26 March 2020

5.5 Action Plan

Building on the four initiatives previously exposed, an action plan has been summarized on the Table 1 below. Each initiative has been broken down into the main steps to be undertaken in order to reach the desired result of a more economically and environmentally sustainable solid waste management system in the city of Querétaro. The entity/ies in charge of undertaking each step is/are also indicated. Finally, the relative cost, expected benefits and level of complexity and risk of each step have been assessed through a red light system in order to get a complete picture of the implications of each initiative presented in this report.

Table 1: Action plan for the suggested initiatives

Steps and sequency	Entity in charge	Costs	Expected benefits	Complexity and risks
SEPARATE COLLECTION SYSTEM				
1. Approve the decision at the municipality level	Municipality	●	●	●
2. Reorganize the work of the collection company	<i>Red Ambiental</i>	●	●	●
3. Communicate the change to the population	Municipality (leader) and <i>Red Ambiental</i>	●	●	●
INTEGRATION OF THE INFORMAL SECTOR				
1. Legally give to the informal sector the right over the recyclables of the city	Municipality	●	●	●
2. Create informal recyclers' cooperatives	NGOs and associations (leaders) and informal sector	●	●	●
3. Contract the cooperatives	Municipality and private companies	●	●	●
WASTE REDUCTION				
1. Put in place a producer responsibility scheme through public policies	Municipality	●	●	●
2. Launch an educational campaign	Municipality	●	●	●
DATA COLLECTION				
1. Put in place a data collection system	Municipality	●	●	●
2. Keep track and publish the updated data regularly	Municipality	●	●	●

● Bad ● Medium ● Good

Source: Author's conceptualization

Conclusion

Querétaro's solid waste management system is considered as a modern one for Latin American with a controlled sanitary landfill and a separation plant. However, it is also widely criticized by some stakeholders, and many challenges have been identified during the analysis of the system in terms of sustainability, coordination, information and inclusion. By adopting an integrated approach to solid waste management, the city could move towards a more economically and environmentally sustainable system, as well as to a more socially inclusive one, which ultimately would benefit all the stakeholders and decrease the environmental impact of solid waste in the city.

Following the insights from the data collection, and the hierarchy of waste management, four initiatives can be taken to move the solid waste management system of the city of Querétaro towards a more economically and environmentally sustainable one. First, the collection system could be redesigned for a more effective system allowing the municipality to collect waste already separated through the implementation of a separation at the origin programme. A second initiative that also aims at increasing the efficiency of the system is to integrate the informal sector into the formal solid waste management system. As for the third initiative, this project wants to encourage the prevention of waste in order to reduce the cost and the environmental impact of managing waste. Lastly, and in order to support and monitor the potential implementation of the previously mentioned initiatives, this project suggests implementing better and more systematic data collection on the city's waste generation and management.

Those initiatives are based on the data collected in Querétaro and are specifically tailored to this city, but can be appropriate with slight changes to other regions with similar socio-economic and cultural status. Indeed many cities, mostly in developing countries, still lack inclusive and sustainable solid waste management systems, affecting the environment and their economic development. This report gives an example of how, by being innovative and adapting to the local conditions and specific challenges, those regions can move towards more sustainable systems of waste management while creating economic benefits and new opportunities.

As a way to further develop this study in Querétaro, a detailed execution plan could be elaborated in partnership with the stakeholders involved for each initiative. Pilot programmes could then be put in place and monitored in order to test the initiatives in real life, and adjust them if needed. Finally if the initiatives are put in place they need to be closely monitored in order to evaluate their success in transforming Querétaro's

solid waste management system into a more economically and environmentally sustainable one, and to serve as concrete example for other regions to follow the same path.

More generally speaking, it is crucial to adopt better and more sustainable practices in terms of solid waste management in every country in order to face climate change and to reduce our global CO₂ emissions. If the waste crisis is not attended by all regions in the near future, the impacts of generating increasing quantities of waste and not managing it properly will have very serious consequences on the people, the climate, and the economy.

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