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A SUSTAINABILITY ASSESSMENT OF THE CURRENT MUNICIPAL WASTE MANAGEMENT SITUATION IN THE METROPOLITAN REGION OF SANTIAGO DE CHILE

1. Introduction

1.1. Background and Context. Rapid urbanization is a remarkable phenomenon of the last decades; according to estimates from the United Nations, the world population will be 51.3% urban by 2010. This rapid urbanization process takes place especially in the less developed regions, for example in Latin America the level of urbanization is even higher than in Europe, reaching 78% (UN 2008).

Megacities are characterized by complex, dynamic processes, which turn the urban habitat into a space of opportunities attracting people from rural areas, but which transform it as well into a space of risk, especially if it suffers from uncontrolled population growth, spatial expansion or rapid change of land use. It is important therefore, to obtain a better understanding of these megacities in order to attain a greater degree of sustainable development.

Changes in cities' population growth and development may have a considerable influence in the generation and composition of municipal solid waste (MSW). Proper management of solid waste is crucial for the health and well being of urban residents and therefore for the sustainability of the city.

Chile has experienced a rapid economical growth during the last decades (CIA 2007). As a consequence, the quantity and quality of MSW produced, has changed. This trend poses challenges to the different actors involved in MSW management; they must find appropriate solutions, including the work of the informal segregators. The informal waste sector is a remarkable characteristic of waste management in low and middle income countries, (Medina 2008). This group of people earns its livelihood by collecting, sorting, and trading valuable materials that are used as secondary raw materials by production industries.

Consequently, the question whether the integration of the informal sector into formal waste management systems is possible arises, and if such integration would improve the sustainable development of the Metropolitan Region of Santiago de Chile.

In order to answer this main **research question**, other ones need to be investigated as well; for example, which are the main features of MSW management in Santiago? Which is the role of the informal sector within system? How sustainable is the current MSW management situation? Moreover, which technical systems can be implemented in order to improve the sustainability of the MSW management? And finally, how to achieve a more efficient participation of the informal sector into the technical systems of MSW management?

1.2. Aim and scope. The general goal of this research is to propose a more sustainable waste management concept for the city of Santiago, understanding the impacts that changes in the current system might have on the environment and on the informal sector. This research is based on the hypothesis that in order to improve the sustainability of the waste management of Santiago two important aspects must be considered. On one side, the application of the waste hierarchy¹; on the other side, inclusion of informal workers into new service roles of separate collection and recycling, by supporting better market actions, diversification of activities, formation of cooperatives, etc. should take place. In order to prove this hypothesis several waste management strategies, including the informal workers, will be analysed, and evaluated by means of selected sustainability indicators.

2. Methodology

2.1 Literature review. It includes research on important concepts, such as *sustainable waste management, municipal solid waste management, informal waste sector and material flow analysis*.

2.2 System definition and material flow analysis

- Definition of research object.
- Definition of the system for the material flow analysis, including input and outputs; boundaries in time and space; waste management processes, and determination of mass conservation equations.

2.3 Data Collection

- Background research: identification of most relevant processes and stakeholders involved in the formal MSW management of Santiago.
- Field research: improvement of the quality of the data already gathered, especially regarding formal and informal fluxes. During this research *semi and unstructured* interviews were undertaken. Interviews were conducted to public authorities in municipalities where segregated collection takes place; institutions involved in waste management (National Commission of Environment and Health Ministry); national and international organizations (House of Peace, German Association for Technical Cooperation); private production companies. Additionally, *observation and unstructured interviews* were undertaken to informal collectors during their working activities.

2.4 Calculation of material flows. A global balance is necessary to determine the different flows within the MSW management system. The waste flows to be considered are:

- Waste arriving at the three landfills located in the Metropolitan Area. Source: Seremi Salud.
- Composition of the waste arriving at Loma Los Colorados landfill. Source: (interview with Arturo Arias, July 2008, Engineer Manager at Quilicura Transfer Station). With this information it is possible to estimate, through extrapolation, the waste composition at the other landfills.

¹ The General approach to the waste hierarchy is: 1. Qualitative and quantitative prevention 2. Recovery (re-use, recycling or recovery operation) 3. Safe Disposal (ISWA 2006)

- Recyclable materials. *Segregated collection (formal)*: statistics of materials collected are given by the municipalities where segregated collection takes place.

Drop off containers (formal): information partly obtained during interviews and partly with calculations using amount and volume of containers, frequency of collection, as well as densities of materials collected.

Primary collectors (informal): the size of the sector and amount of materials collected is gathered by literature review and interviews (see 2.1 and 2.3).

The material flow analysis allows determining the mass flows, stocks, concentrations and transfer coefficients within the system. The material flows are calculated using Excel ® and STAN (Cencic), a program developed by the Institute of Water Quality, Resources and Waste Management of Vienna University of Technology.

2.5 Assessment of waste management scenarios

2.5.1 Selection of sustainability indicators. In order to carry out a goal orientated assessment it is necessary to select representative sustainability indicators for waste management, based on the Integrative Sustainability Concept (Kopfmüller 2001). Criteria to select indicators include their validity, i.e. indicators should properly reflect how the sustainability of the waste management (positive or negative impacts) is affected by changes in indicator values. Other criteria include data availability, possibilities to define quantitative goals, and indicators should be simple to understand, even by people or working groups not directly related with the field.

2.5.2 Selection of target values for sustainability indicators. The definition of target values for the selected indicators is based on a hierarchical approach: (1) to consider the national framework in Chile, including definition of objectives at the political, governmental, or non governmental level; (2) to consider the opinions of experts (at the national level) in the waste management field and (3) to analyze experiences and trends at the international level (focusing on Latin America, Europe, Germany) of waste management strategies.

2.5.3 Assessment of current MSW management in Santiago. The current situation of MSW management in Santiago is evaluated by using selected indicators. This evaluation allows determining which deficits should be improved in order to achieve sustainable development.

2.5.4 Development of alternative waste management strategies. Within the Risk Habitat Megacity Project, framework scenarios will be developed for Santiago. Proposed strategies of waste management will be based on the special characteristic of each scenario. In a first step, it will be analyzed which are the important parameters influencing (quantitatively and qualitatively) the MSW and which variations might occur. Thereafter, alternative waste management strategies will be proposed. This approach accounts for fulfilment of sustainability requirements (target values of sustainability indicators). MSW management strategies will include different technical

systems, based on waste hierarchy and considering the integration of the informal workers into technical process. These scenarios will be assessed in the same manner as the current MSW management system (2.5.3)

3. Results

3.1 General system definition for MSW management in Santiago de Chile. The research object of the present project is municipal solid waste, define as *domiciliary solid waste*, including yard and small quantities of hazardous waste and commercial waste similar to domiciliary, including food and packaging waste. The research area is the Metropolitan Region of Santiago, formed by 52 municipalities.

Figure 1 shows a general scheme with the most important processes of the MSW in Santiago.

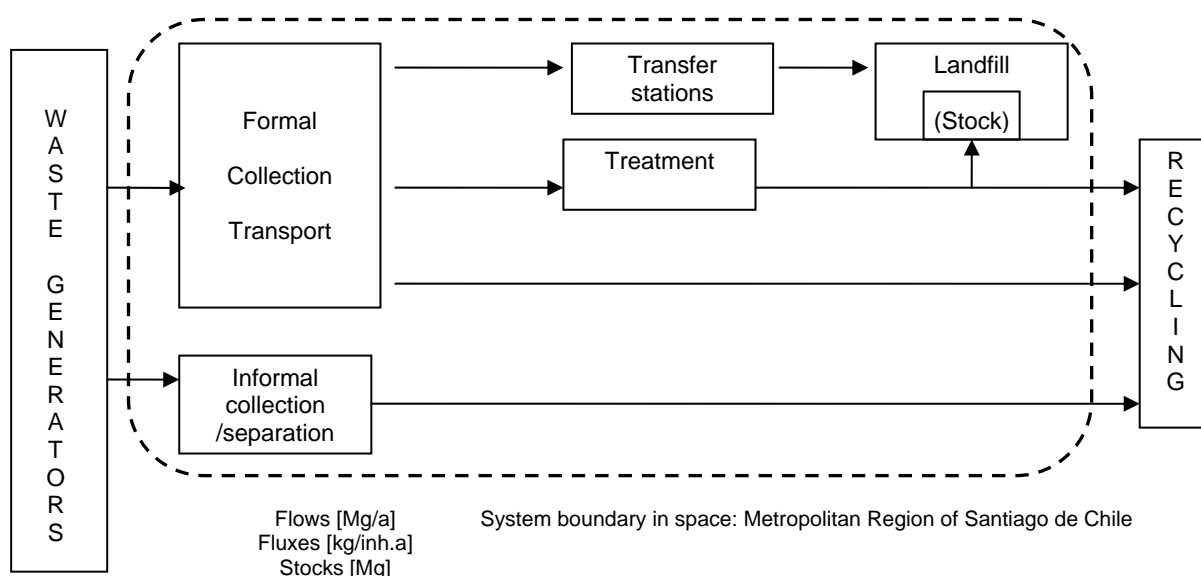


Figure 1. General System Definition of Waste Management in Santiago de Chile

Source: derived from Brunner and Fellner 2004

3.2 General characteristics of MSW in Santiago

3.2.1 Waste quality, quantity and costs. About half of the MSW generated in Santiago is organic, while paper accounts for about 17%, plastic for 10%, glass and metals have a fraction of 5% and 3.5% respectively. The remaining fraction includes textiles, diapers, ashes, and inert materials. Other important characteristics of the MSW management in Santiago are shown in Table 1.

Table 1. MSW management characteristics for Santiago de Chile, 2007

MSW generation ¹	[Mg]	2,903,346	
Specific MSW generation ¹	[kg/inh/day]	1997	0.9
		2007	1.3
MSW costs ²	[Mio US\$/a]	106	
MSW costs per tonne ^{2,a}	[US\$/Mg]	44	
MSW costs per capita ^{2,a}	[US\$/inh/a]	17	

Source: 1: Szantó 2006 and own calculations

2: SINIM, 2008

a: costs include collection, transport, transfer and landfilling of waste.

It is difficult to obtain a transparent figure of the MSW management costs for Santiago. Many municipalities have agreements with private companies which include collection, transport, transfer and landfilling of wastes. In 2007, the costs for these services was in the order of 44 US\$ per tonne of waste. From this total the highest values correspond to waste collection (varying from 9 US\$/Mg to 95 US\$/Mg, whereas landfilling costs are in the order of 5 to 15 US\$ per tonne. Waste fees paid by citizens' cover, on an average, only 40% of total costs; however, values show large variations between municipalities.

3.2.2 Waste collection. Waste collection of mixed waste covers the whole Metropolitan Region of Santiago, with a frequency that varies from a minimum of three days per week to daily in the commercial districts of the downtown (Szantó 2006). Formal collection includes *segregated collection* of wastes (recyclable materials and biowaste) which took place (at the moment of the field research) in five out of fifty-two municipalities in Santiago. The other formal recycling scheme consists on containers (*drop off systems*) located in public places, where people can voluntarily deposit materials such as paper and cardboard, glass and plastic bottles.

A different collection system is formed by the informal sector ("Cartoneros", "Cachureros"). There are between 8,000 to 15,000 people working in the informal sector (Alaniz 1998; BID 2005), parallel to the formal system in Santiago. Waste pickers collect especially paper, cardboard and scrap; materials that go through the recycling chain from middlemen to production companies.

3.2.3 Waste treatment. Treatment of municipal solid waste is limited mostly to final disposal on controlled landfill, but without previous biological or thermal treatment. There are three relatively new landfills operating in Santiago where approximately 90% of the MSW is deposited; landfills are equipped with a base seal and collection system for leachate; two of them also have collection and burning of landfill gas, but non energy recovery takes place.

3.2.4 Municipal solid waste mass flow. Figure 2 shows the waste mass flow for Santiago during 2007, this flow chart will serve as a basis for the development and analysis of future waste management scenarios.

MSW generation in 2007 accounted to almost 3 million tonnes. From this, 2.87 million tonnes of mixed wastes were deposited in bins or bags, for further collection either by formal services or informal collectors. Roughly 87% of the waste generated in the city is deposited in landfills. The landfill Loma Los Colorados received approximately 1.48 Mio. tonnes; Santa Marta landfill received about 733,000 tonnes and Santiago Poniente 313,000 tonnes of waste. Informal workers collected and separated approximately 347,000 tonnes of recyclable materials from containers and bags of private residences, small offices and business. These materials were sold to middlemen and further processed in different production companies, together with the materials collected with formal systems. Formal recycling collection

systems consist of *drop off systems* (19,000 tonnes); *segregated collection* of inorganic (4,200 tonnes) and biowaste (11,000 tonnes) for composting.

The total recycling rate in Santiago is about 13%. The largest contribution to this value is given by the informal sector, which contributes with 94%. Formal collection only adds to 6%, of which drop off systems correspond to 5% and segregated collection only to 1%.

3.3 Selected sustainability indicators and target values in waste management for Santiago. In order to carry out a goal orientated assessment, indicators that refer to the guidelines of sustainable MSW management in Santiago (Seidl 2008) have been selected (Table 2). Current values of indicators and preliminary target values, which still need to be discussed with the Chilean partners in the waste management field, are shown.

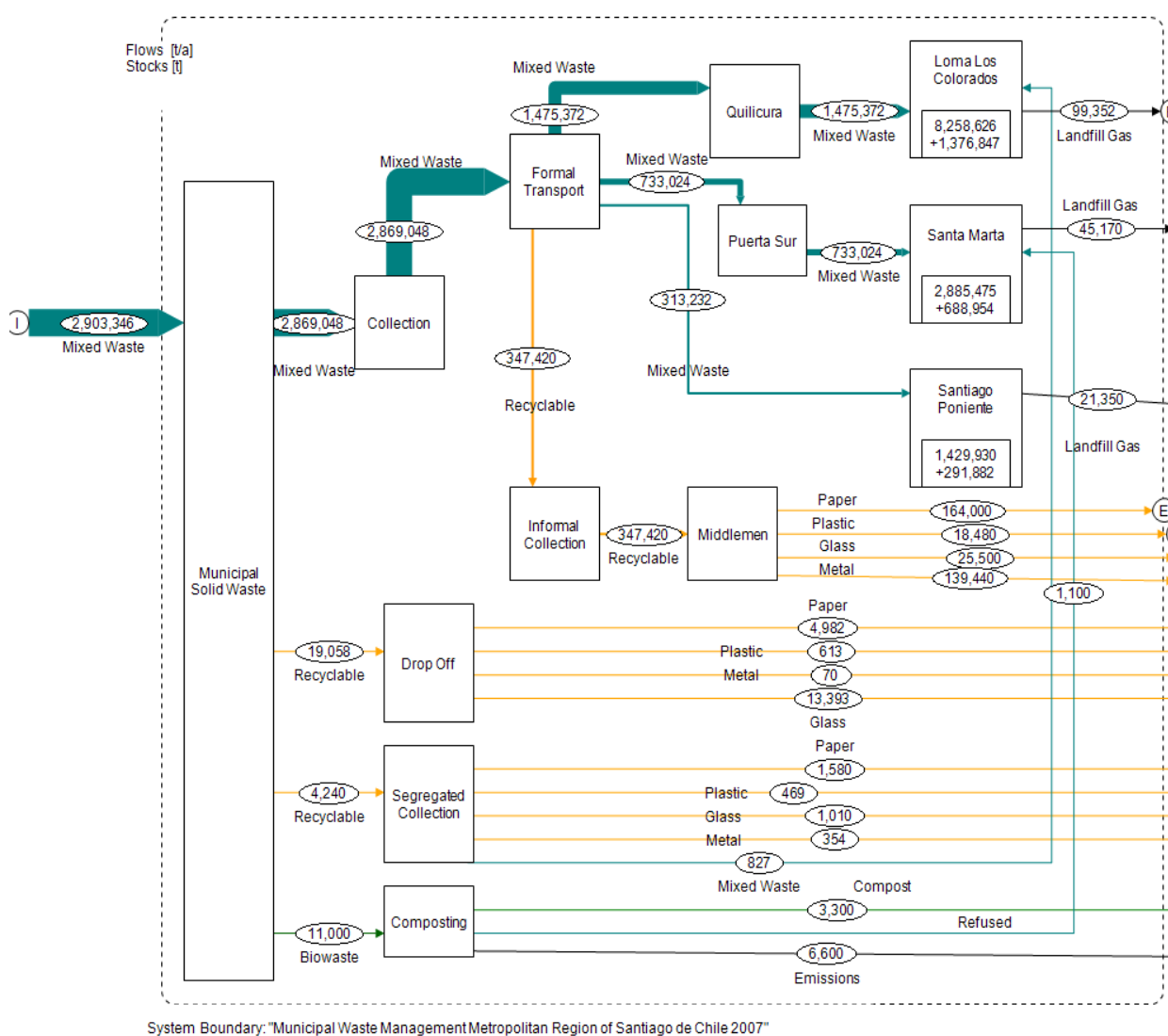


Figure 2. Waste Mass Flow for the Metropolitan Region of Santiago de Chile, 2007
Source: own elaboration

3.3.1 Specific waste arising. The specific waste production of Santiago de Chile has increased by more than 45% in ten years. This increase is associated with the rapid economic development of the country in the last years, changing consumption patterns and increasing the use of

resources. The national legal framework is deficient in political measures on waste prevention or minimization strategies. Therefore in order to propose a reasonable target value for this indicator, international trends have to be analyzed. For example, in the European Union (EU), it is an aim to decouple use of resources and waste generation from economic growth (Eurostat 2008). The goal therefore would be to minimise waste generation, even with economical development.

3.3.2 Amount of pre-treated waste that is sent to adequate landfills in relation to total waste arising. Currently, there is no pre-treatment of waste sent to landfills, this alternative has been designed to reduce the volume of wastes that are deposited in landfills and the adverse effects of the emissions generated during this process. As before, there are not political targets for this indicator at the national level in Chile. In the EU on the contrary, according to the landfill-guideline 1993/31/EG EU member states have to reduce the organic fraction of MSW, which is brought to landfills, gradually. The target value of this indicator for Santiago should be greater than 0, increasing over time to reach the ideal value of 100%.

Table 2. Selected indicators of sustainability in waste management in Santiago de Chile

Waste management guideline	Indicator	Current value	Preliminary target value
Maintaining the regeneration capacity of natural systems	Specific waste arising [kg/person/day]	1.3	<1.5
	Amount of pre-treated waste that is sent to adequate landfills in relation to total waste arising [%]	0	ideally 100
	Greenhouse gases emitted during waste management [kg. CO _{2eq} /person/year]	249	Within the Chilean National Action Plan of Climate Change, one of the targets is to apply mitigation measures for GHG
Sparing use of non renewable resources	Waste fraction recovered as material or energy [kg. of waste recovered/total waste arising] [%]	Materials: 13 Energy: 0	Recycling: 20 in 10 years, as proposed in the recycling strategy of CONAMA Energy Recovery: -
Guaranty of safe disposal	Remaining life time of adequate waste treatment and disposal facilities [years]	Loma Los Colorados: 39 Santiago Poniente: 17 Santa Marta: 15	Adequate to receive the total amount of waste produce in future years
Organization of the waste management system to justifiable overall economic costs for a fairer development	Fraction of Gross Domestic Product spent in municipal solid waste management [%]	0.37	0.2 – 0.5
Guaranty of the possibility of independent existence, which fulfils the basic needs and creates opportunities for development	Income level of informal workers in relation with minimum wage [%]	30 – 150	100

Source: based on Seidl 2008 and own elaboration

3.3.3 Greenhouse gases (GHG) emitted during waste management. The current Global Warming Potential (GWP) in the MSW sector, calculated during this research is 249 kg CO_{2 eq.} per person and year, the largest contribution to this value is given by emissions from landfills. Processes of waste management generate emissions of several GHG, which contribute to global climate change. Currently the Chilean Government is taking actions within the National Action

Plan of Climate Change in order to reduce GHG (CONAMA 2008). Specific reduction targets needed to be still defined.

3.3.4 Waste fraction, in relation with total waste arising that is recovered as material or energy. Recycling in Santiago is well positioned if compared with other Latin American countries, with a recycling rate of 13%; however, not all the recycling potential is being used. Moreover, this rate is only achieved thanks to the participation of the informal sector, since formal recycling is less than 1%. Composting is used to treat less than 0.5% of the total waste generated, and MSW is not used for energy recovery. At the national level a recycling strategy for Santiago was developed by CONAMA, the goal of the strategy was to achieve a recycling rate of 20%, a reasonable target value, if a long-term approach is considered. The recycling strategy does not establish any goal for composting or energy recovery. As already mention, in the European Union, according to the Directive on Landfills the organic fraction of MSW to landfills should be progressively reduced. Composting or energy recovery are alternative options to divert this waste fraction from landfills. It is important to mention, however that the determination of these target values should be analyzed regarding technologic, social and economical aspects within the Chilean framework.

3.3.5 Remaining life time of adequate waste treatment and disposal facilities. Approximately 90% of total MSW produced is sent to landfills. With current waste fluxes their average remaining life expectancy is 25 years. In order to secure sufficient and suitable sites for final disposal, this indicator must be regularly checked. Construction of new disposal sites should be planed ahead in time, in order to guaranty proper collection and transport of the MSW produced, and to avoid associated problems to human health and the environment.

3.3.6 Fraction of GDP spent in municipal solid waste management. This indicator reflects which fraction of a budget a region is able to spend in waste management. Currently, Santiago spent 0.4% of its GDP (17 US\$ per person and year) in waste management. Therefore, measures suggested as well as economical resources to be allocated in a sustainable waste management, should take this limiting factor into consideration. If the GDP of a region increases, then the relative costs (MSW costs/GDP) will decrease. But, in general, if there is an increase in GDP, more wastes will be produced. Therefore, more expenditure should be allocated to waste management in order to treat properly the new waste generated. An increase in absolute costs of waste management (MSW costs) should occur along with a minimum decrease or with a constant value of the relative costs (MSW costs/GDP), in order to be sustainable.

3.3.7 Income level of informal workers in relation with minimum wage. The recovery of valuable materials from waste is a survival strategy used by many population groups within the developing world. Several publications analyse experiences on formation of scavengers' cooperatives, which improve their living conditions and permit to obtain a better income.

These earnings vary largely with the quality and quantity of materials collected. This indicator should give the possibility of assessing how the efficiency of the work develop by the sector improve through organization and community cooperation. The incorporation of scavengers into formal systems can save cities' money and offer, at the same time, steady income to their members.

3.4 Preliminary assessment of current situation of waste management. The preliminary evaluation allows identifying the problem priorities of the waste management situation in Santiago. It is observed that the regenerating capacity of natural systems is under pressure, with high waste production, wastes being deposited in landfills without previous treatment and associated pollutant emissions, especially those contributing to global warming. Furthermore, the use of natural resources is not sustainable, as shown by the increase in waste production in the last years and low recycling rate. The contribution of the informal sector to recycling is large, but the services offer by the sector are not completely understood or acknowledged.

It is clear that there are several sustainability deficits in the current MSW management situation; the next question is which alternatives of waste management will permit the achievement of a sustainable development of the city of Santiago.

4. Perspectives and Outlook

Further steps include discussion and debates with Chilean experts and stakeholders to totally define target values of sustainability indicators. Then, waste management strategies to overcome these deficits, and thus to decrease the risk of not achieving a sustainable development, will be evaluated within the three framework scenarios for Santiago de Chile (Business as Usual, Collective Responsibility and Marked Individualism), currently being developed within the Risk Habitat Megacity Project.

5. Open Questions

Sustainability assessment: are there a reasonable minimum number of indicators to be used?

Scenarios: how to justify in a scientific way the several assumptions and their implications for the future development of waste management, in the different scenarios?

Risks: would it be pertinent to include an analysis and identification of risks to achieve sustainability under the risk concept of "Distance to Target" of the Risk Habitat Megacity Project?

General: organization of the informal sector, and hence, increase of recycling rates, would be an attractive option to apply clean development mechanisms projects?

Future: possibilities of adaptation and/or transfer of the methodology and results of the study to other Megacities in Latin America.

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