Applying the Integrated Solid Waste Management Framework to the Waste Collection System in Aguascalientes, AGS, Mexico

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The design of a waste collection system affects public health, the extent of participation in the system by residents, the recovery of resources from waste, and the cost of collection. Many developing countries use communal container collection [CCC] systems in which large containers are dispersed throughout neighbourhoods for the storage of waste until collection. These systems tend to have limited success as they often do not garner viable amounts of participation and containers are prone to being overfilled. The communal container waste collection system in the city of Aguascalientes, AGS, Mexico was assessed according to the Integrated Solid Waste Management [ISWM] principles of social acceptability, environmental effectiveness, economic affordability and effective management. Information was collected through seven interviews with waste-related managers, 282 residential questionnaires, and 12 informal collector questionnaires. The collection system has a high rate of use by residents (99%) attributed to: non-burdensome one-way distances from residences to containers (mean 114+/-71m); thorough, daily collection; and a culture of cleanliness. Factors of adherence to waste collection regulations were found to be public knowledge, social acceptability, convenience and perception of importance. The collection system was assessed by rational-intuitive consideration of all indicators and principles, to be mostly acceptable from an ISWM framework due to: a high collection rate (~100% daily) which is enabled by effective monitoring and efficient operation; a high rate of use of the system by residents; similarity of the resource recovery rate to that of other developing and developed countries; and long-term affordability. Areas for improvement in equality of service provision, collaboration with informal collectors, and communication were identified. Lessons learned about communal container collection are applicable to lower-middle and upper-middle income countries.

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Chapter 1
Introduction

Picture living in a place where garbage goes uncollected and piles up in the street outside of your home. That waste provides a breeding ground for disease-carrying rats and flies, blocks storm drains allowing for mass reproduction of malaria-carrying mosquitoes, and leaches toxins into your drinking water and garden soil (Tchobanoglous, Theisen, & Vigil, 1993; Flintoff, 1976; Korfmacher, 1997; Galishoff, 1988). This is the situation for many people in urban areas of developing countries around the world. This is not however the situation in Aguascalientes, a city in central Mexico that provides waste collection via large, dumpster-like, communal containers, and has streets as litter-free as those of Canadian cities.

In most developing countries only 25-80% of waste is collected and disposed in a controlled manner, while the rest builds up in streets and open spaces (Oluwande, 1984 (<25%); Cointreau, 1984 (30-80%); Medina, 2005 (70%)). Developing cities often cannot provide sufficient waste collection due to: lack of financial resources; lack of governance capacity to design, administer and operate collection; and lack of participation by residents in required waste collection activities (Oluwande, 1984; Boadi & Kuitunen, 2005; Buenrostro & Bocco, 2003; Korfmacher, 1997). The problems of collection in developing countries have been compounded in recent decades by a dramatic increase in waste generation due to industrialization, increase consumerism, and rapid urbanization (Arlosoroff, 1991; Bartone, Bernstein, Leitmann, & Eigen, 1994; Owaga, 1989). Industrialization also increases the toxicity of waste. The problems of waste in developing countries necessitate affordable waste collection solutions that are suited to the needs, climates and built forms of developing countries.

House-to-house, heavily-mechanized, weekly waste collection common in developed countries is not suited to the financial limitations, warm climates, dense urban form, low waste generation rates, and narrow streets of developing cities (Holmes, 1984; Cointreau, 1984; Bhide & Sundaresan, 1984). Alternatively, many developing urban areas have designated collection points that may or may not have storage facilities, at which waste generators can drop-off waste for later collection (Korfmacher, 1997; Flintoff, 1976; Ogawa 1989). Such systems, with containers for storage of waste, are referred to in the literature and in this thesis as communal container collection [CCC] systems. Unfortunately these systems often fail because waste is usually left uncollected, and collection points are often further from many residents than they are willing to travel to dispose of waste (Flintoff, 1976; Blight & Mbande, 1996).

However, in the visibly clean city of Aguascalientes, AGS, Mexico, a CCC system appears to be successful. Questions arise: Is this system really successful? If so, what aspects contribute to its success?

A framework from which to evaluate success is necessary. Integrated Solid Waste Management [ISWM] is widely accepted and utilized as the current waste management paradigm. While the traditional model of waste management views waste as a nuisance to be controlled through technology, ISWM recognizes the need for waste management systems to be tailored to the communities they serve, and gives consideration to social and environmental aspects (van de Klundert & Anschutz, 1999; Kollikkathara, Feng, & Stern, 2009). In determining the optimal waste management system for a particular community, ISWM considers: stakeholder needs, community context (including characteristics of waste and distances to resources recovery markets); and the various available methods of waste prevention, resource recovery and disposal (Tchobanoglous et al., 1993; van de Klundert & Anschutz, 1999; Kollikkathara et al., 2009). ISWM aims to find a balance between three key principles: environmental effectiveness, social acceptability, and economic affordability (McDougall, White, Franke & Hindle, 2001) through effective management techniques.

The principles of ISWM encompass all of the aspects that waste management influences and is influenced by. The principle of environmental effectiveness suggests that waste management ought to reduce the negative impact of waste on the environment. This can be done through the promotion of reducing, reusing and recycling waste, and by minimizing the environmental cost of transporting waste. The principle of social acceptability recognizes that the way waste is managed has social impacts and negative impacts ought to be minimized. Social impacts of waste management include human health effects, the burden of participation in waste collection, and disparities between groups of people (for example by class or gender, expressed in differences in service provision or burden of participation). The principle of economic affordability suggests that a waste management system should not cost beyond the financial means of the population the system serves. Effective management, although not a principle explicitly stated by authors of ISWM, is the means by which the other principles are achieved. Management encompasses: methods and technologies used for waste collection; the policies that legislate the operation and use of the system; reporting and monitoring; and communication with the public.

This thesis uses ISWM as a tool to assess an existing waste collection system, which is not the conceptual model's intended purpose. The original purpose of ISWM was to help decision makers select an optimum waste management system to meet specific waste management objectives (Tchobanoglous et al., 1993). No study was found which assessed an existing waste collection system according to ISWM. Indicators of each aspect of ISWM have been drafted by van de Klundert and Anschutz (1999), but those

authors have not used them in an assessment. This thesis may be one of the first studies to use ISWM as an assessment tool and perhaps the very first to do so with well-defined principles and indicators.

This thesis assesses the communal container system of Aguascalientes from an ISWM framework to determine the extent to which the system meets the principles of ISWM of environmental effectiveness, social acceptability, economic affordability, and effective management, and to identify attributes of the system that contribute to meeting these principles. If these attributes can be applied to other developing urban areas, collection rates in them could be improved, significantly improving human and environmental health.

1.1 Purpose

The purpose of this thesis is to assess communal container waste collection from an ISWM framework. Waste collection in the municipality of Aguascalientes, AGS, Mexico was examined as a case study.

The objectives of this thesis are:

- To describe the waste collection system of Aguascalientes in detail
- To assess the waste collection system of Aguascalientes according to the principles of ISWM
- To determine characteristics and/or standards of CCC systems that may be generally applied to other developing areas to improve their waste collection
- To increase the body of knowledge of CCC systems
- To provide insight into the use of ISWM as an assessment tool

1.2 Research Questions

The research question for this thesis is: *How well do communal container collection systems function in developing countries according to an ISWM framework?* The collection system of Aguascalientes, AGS, Mexico is examined as a case study. This question will be answered through the following sub-questions:

1. What are the characteristics and processes of CCC in Aguascalientes and in developing countries in general?
2. What aspects of the collection system in Aguascalientes garner participation?
3. How well does the waste collection system in Aguascalientes meet the principles of ISWM where the principles are: social acceptability, environmental effectiveness, and economic affordability?
4. What aspects of the management of the collection system in Aguascalientes contribute to the adherence (or breach) of the ISWM principles outlined above?

5. Based on responses from stakeholders and the principles of ISWM, are there ways in which the waste collection system of Aguascalientes could be improved?
6. What characteristics of, or lessons learned about, CCC systems, can be applied to waste collection in other developing urban areas?
7. How well does the concept of ISWM work as an assessment tool for existing waste collection systems?
    i. What indicators can be used to measure adherence to the principles of ISWM, and how well do they function?

1.3 Report Structure

This thesis is divided into seven chapters. The second chapter provides a review of the literature on: the problems posed by waste; traditional waste management and ISWM; waste management in developing countries and barriers posed; waste collection systems used in developing countries including a thorough description of types of CCC systems; and the social, environmental, economic and management aspects of waste collection. A brief description of the municipality of Aguascalientes is included. The third chapter outlines the methodology of this study including the interview phase, the questionnaire phase and methods of analysis. The fourth presents the results of the interviews in the form of a detailed description of the waste management system in Aguascalientes. The results of the residential questionnaires including descriptive statistics and significance findings are presented in the fifth chapter. Informal collector survey results and findings from encounters with businesses that buy and sell recyclable material are also included in the fifth chapter. The sixth chapter, the discussion, answers the research questions of this thesis by: exploring factors of participation, proper use, and resource recovery; discussing the relevant results by each aspect of ISWM of social, environmental, economic and management; assessing the collection system according to ISWM; and reviewing the use of ISWM as an assessment tool. The seventh chapter concludes this thesis by: summarizing the results; highlighting key findings; offering specific recommendations to the municipality of Aguascalientes and general recommendations for the application of CCC in other developing areas; reviewing the answers to the research questions; and suggesting areas for further research.

Chapter 2
Literature Review

2.1 Introduction

A review of the literature pertaining to waste management in general, and waste collection in developing countries in particular, provides context for the case study and inspires relevant questions. In the discussion, points from this literature review are used to show how the findings of this thesis tie into and extend the body of knowledge of waste management. This literature review: lays the foundation of why effective waste management is important; provides an overview of Integrated Solid Waste Management, the tool by which the case study is assessed; and briefly describes waste collection systems commonly used in developing countries. More specifically, the topics covered are: the definition of waste; the problems posed by waste; the definition of waste management; the traditional model of waste management; the conceptual model of ISWM; waste management in developing countries including barriers and benefits posed; common waste collection systems with an in-depth look at CCC; the social, environmental, economic and management aspects of waste collection systems; and a brief description of the municipality of Aguascalientes.

2.2 Waste

Waste management authors generally define waste as items that are no longer wanted by the original owner or user and thus discarded or abandoned by them (Rimberg, 1975; Flintoff, 1984; Tchobanoglous et al., 1993; Bilitewski, Härdtle, Marek, Weissbach, & Boeddicker, 1996). Solid waste is often distinguished from liquid waste, a term which is used to refer to sewage and wastewater. For this thesis the use of the word waste is not meant to include sewage and wastewater, even without the specification "solid". Rimberg (1975) excludes discarded items for which recycling is cost effective from his definition of waste, saying that waste has "negative economic value" and "are not worth the cost ... involved in recycling and are cheaper to throw away than recover" (pg. 5). Other more recent publications highlight that many types of waste have value as resources (Tchobanoglous et al., 1993; Flintoff, 1984). As Tchobanoglous et al. (1993) state "Because of their intrinsic properties, discarded waste materials are often reusable and may be considered a resource in another setting." (p. xvii).

Waste can be divided into several categories based on origin. Waste can be generated "in household, commercial and industrial premises, institutions and on the streets" (Cointreau-Levine, 1982,

p. xi). Tchobanoglous, Kreith and Williams (2002) divide waste into the categories residential, commercial, institutional, construction and demolition, municipal services, treatment plant sites, industrial, and agricultural, but specify that municipal solid waste, for which municipalities tend to be responsible for collection, include all of the above except municipal services, water and wastewater treatment sites, industrial and agricultural. Franklin (2002) stated that municipal solid waste includes waste from residential, commercial, institutional and some industrial sources. According to Franklin: residential waste is from any type of human dwelling ranging from detached single family homes to apartments; commercial waste is from places of business including offices, shopping malls, warehouses, hotels, airports, and restaurants etc.; and institutional waste is from schools, medical facilities, and prisons. The industrial waste included in municipal solid waste is that produced in offices and restrooms but not arising from industrial processes.

For this thesis, waste is defined as discarded items resulting from human activities, some of which may have value as resources. These items may be from any of the above mentioned sources, but this thesis is primarily concerned with residential waste and some commercial waste (only that which is produced by small businesses).

If poorly managed, waste can adversely impact human health. Waste, improperly stored, uncollected or placed in open dumps, encourages the multiplication of flies and rats that can be vectors of diseases (Tchobanoglous et al., 1993; Flintoff, 1976). Negative health impacts due to waste are amplified in developing countries due to warm climates, which accelerate disease vector reproduction, and poor collection (Holmes, 1984; Boadi & Kuitunen, 2005; Korfmacher, 1997). Infectious diseases that can be propagated by uncollected waste include dysentery, worms, enteritis, typhoid fever, hepatitis, and cholera, and the dust from waste can cause lung infection and unpleasant odours (Holmes, 1984). Storm drains blocked by uncollected waste may create pools of water where insects can breed, such as mosquitoes which may carry malaria (Holmes, 1984).[1] Water adjacent to or flowing through uncollected or improperly disposed waste will be contaminated, leading to further negative health impacts if used by humans (Korfmacher, 1997; Galishoff, 1988).

Negative environmental impacts from improperly disposed waste include soil, water and air pollution, and loss of resources. Decomposing organics release methane and other greenhouse gases which make up 3.6% of greenhouse gas emissions in the world (Kollikkathara et al., 2009). Toxic elements from waste in uncontrolled dumps can leach into and contaminate soil, surface water and ground

[1] For example, waste blocking drains has led to fly infestations in low income areas of Accra, Ghana (Boadi & Kuitunen, 2005).

water, negatively impacting biological cycles and, if consumed, causing adverse health effects (Tchobanoglous et al., 1993). If little effort is made to use waste as a resource, raw resources continue to be harvested for human use (Kollikkathara et al., 2009). A shift to, or increased, consumerism compounds the problems of waste as the waste generation rate and the use of toxic and persistent materials increase (Claggett, Hattie, & Watson, 1998).

2.3 Waste Management and the Traditional Approach

The possible negative health and environmental impacts of waste, as well as the potential use of waste as a resource, make effective waste management prudent. Waste management involves all the activities associated with the control and handling of waste from generation to disposal. Bilitewski et al. (1996) wrote that "waste management encompasses the collection, storage, treatment, recovery and disposal of waste." (pg.11). Tchobanoglous et al. (1993) agree that waste management is the "discipline associated with the control" (pg. 7) of the above aspects, but add generation as an aspect, such that waste management is also associated with the promotion and control of waste reduction and reuse. They note that waste management involves "administrative, financial, legal, planning and engineering functions" (p. 7).

The traditional model of solid waste management is limited in scope to the storage, collection and disposal of waste, with disposal usually being by combustion, dumping on land or dumping into bodies of water (Gotoh, 1989; Kollikkathara et al., 2009). Resource recovery and stakeholder participation are typically not considered. The traditional approach is to react to waste as a problem to be dealt with by disposal, rather than to be proactive and preventative to reduce the amount of waste being disposed (Buclet, 2002). Waste is viewed as an engineering problem to be addressed primarily by technology-heavy solutions (Tchobanoglous et al., 2002; Buclet, 2002) and the problem of waste is addressed in similar ways in different areas, regardless of local context. As environmental and social problems due to this model became apparent through time, this model was no longer considered to be adequate (Kollikkathara et al., 2009).

This traditional, technology-focused approach to waste management has met with limited success in developing countries (Arlosoroff 1991; van de Klundert & Anschutz, 1999; Holmes, 1984; Brunner & Fellner, 2007). Traditional methods have failed in developing countries due to: the use of expensive and inappropriate technology which cannot be locally maintained; lack of governance and economic capacity; and lack of consideration of social, physical, and climatic differences between countries (Arlosoroff 1991; van de Klundert & Anschutz, 1999; Holmes, 1984).

2.4 Conceptual Model: Integrated Solid Waste Management

One way to evaluate a waste collection system is to measure the system against a standard of success, such as a theoretical, optimal outcome. Integrated Solid Waste Management [ISWM] was chosen as the conceptual framework by which to assess this case study. ISWM was developed in response to the realization that there is no universally applicable method of waste management, but rather that each waste management system ought to be tailored to the community served (Kollikkathara et al., 2009; Korfmacher, 1997). For example, Korfmacher (1997), in a case study on waste collection in South Africa, found that "even within one country, solid waste collection systems are not automatically transferable from one community to another" (abstract). Cointreau (1984) supports this concept by identifying factors that influence waste management which differ by community such as labour costs, fuel costs, capital costs, urban form, waste quantity, waste composition and socio-cultural attitudes. Holmes (1984) also highlights the need to consider the characteristics of the community when creating waste management solutions, and the importance of producing local waste management tools and equipment.

ISWM considers all methods of waste prevention, waste collection, resource recovery and disposal and chooses the best combination of methods to achieve the specific waste management goals of a community (Kollikkathara et al., 2009; van de Klundert & Anschutz, 1999; Tchobanoglous et al., 1993). The scope of ISWM is from waste generation to disposal or resource recovery.

The aspects, principles, objectives and goals of ISWM range by author in detail, lexicon and focus (from technically to holistically focused), but major themes can be drawn out. Van de Klundert and Anschutz (1999) defined the aspects of ISWM as Technical/Operational, Environmental, Financial, Socio-Economic, Institutional/Administrative and Policy/Legal. Kollikkathara et al. (2009), when citing McDougall et al. (2001), wrote the objective of ISWM is "achieving environmental benefits, economic optimization and societal acceptability" (p. 983). For this thesis, the aspects of ISWM are defined as social, environmental, economic, and management. The four main principles of ISWM then become social acceptability, envirnomental sustainability, economic affordablity and effective management. Considering these principles in unison, the optimal waste management system for a community would be one which minimizes environmental and public health harm, that stakeholders are willing and able to participate in, and is economically affordable. The social, environmental, and economic aspects of the waste collection system in Aguascalientes, and the management techniques used to control them, are examined through this thesis to determine how well the system measures up to the theoretical optimal system of ISWM.

Waste management has social impacts on: human health, by mitigating the harmful health affects of waste; people's routines, by requiring action of the waste generators which may be either convienent or burdensome to them; and social justice, as differences in waste management provision by social group can deepen inequalities between groups. Therefore waste management decision-makers ought to consider the social impacts of their decisions, and include stakeholders in the decision-making process. Social aspects of waste management to be considered in determining a waste system are: religious and cultural customs; preceptions of waste; human health (Holmes, 1984); and stakehold participation (van de Klundert & Anschutz, 1999; Claggett et al., 1998). Beyond mere consideration of and conformity to social context, waste management planners may attempt to change social norms which stipulate how waste may be handled and by whom, and behaviours towards waste. Public education on hygenic waste handling and about the health and environmental impacts of waste may increase the public acceptance of and participation in proper waste management (Holmes, 1984).

The environmental impacts of waste management systems should be considered by the relevant desicion makers. In their section on the environmental principle of ISWM, van de Klundert and Anschutz (1999) suggest that waste management:

> technologies and systems should: be clean, i.e. minimise the negative impact on soil, air and water at local, regional and global level; promote closed cycle systems and avoid loss of raw materials, energy and nutrients; follow the 'waste management hierarchy', preferring options that promote waste prevention, source separation, re-use and recycling, above those merely aimed at collection and disposal; and encourage treatment and resource recovery as close to the source as possible. (p. 6)

A general principle common throughout ISWM literature is resource use ought to be maximized and the amount of materials disposed ought to be minimized. The Waste Hierarchy, frequently cited in early ISWM literature, arranges methods to mitigate waste in order of environmental effectiveness. The order of the Waste Hierarchy, from most effective and desirable waste management technique to least is: source reduction (reduce), recycling, waste transformation (i.e. composting or combustion to retrieve energy from waste), and land filling (Tchobanoglous et al., 1993). According to the Waste Hierarchy, each method should be exhausted before moving onto the next. However, in some circumstances recycling may require more energy and create more pollution than lower levels of the hierarchy such as transformation or landfilling (Kollikkathara et al., 2009). The environmental effectiveness, and therefore priority, of each method of waste mitigation depends on community context including distance to mitigation facilities.

ISWM suggests resource recovery at multiple stages be considered. Resource recovery has been observed in developing countries to occur within households, at storage sites, during collection and from disposal sites (Cointreau, 1984).

An economically affordable waste management system is one that does not cost more than the income received from user/beneficiary payments and other consistent sources of funding. Waste management fees have to be affordable to the users in order to maintain both economic affordability and social acceptability. In detail, according to van de Klundert and Anschutz, (1999):

> Financial management of technologies and systems should: be based on the 'all beneficiaries contribute principle'...; be geared towards the most efficient overall system, leading to the lowest cost per ton to operate, taking into account the cost of other affected urban systems; ensure highest productivity of labour and capital in the local situation; lead to full cost analysis and full cost recovery... (p. 6)

However, according to the experience of Cointreau, the lowest cost system may not be the most appropriate for a developing country (1984). For example. labour intensive systems may not cost the least but may be favourable to meet employment objectives (Cointreau, 1984). Cointreau also points out however, that the most labour intensive methods of collection may have issues of worker health, safety and dignity and may not be socio-culturally acceptable.

Management was not seen in the literature as a specified aspect of ISWM (likely because management is included in the term and inherent in the concept of ISWM). Management has been included as an aspect in this thesis to cover those aspects of a waste collection system which can be controlled by the provider and by which the principles of social acceptability, environmental effectiveness, and economic affordability are, or are to an extent, achieved. This category encompasses the remaining aspects of ISWM defined by van de Klundert and Anschutz (1999) of technical/operational, institutional/administrative and policy/legal. Effective management is the design and control of aspects within the waste management provider's power (i.e. policies, processes, technologies) such that the above principles are satisfactorily achieved.

2.5 Waste and Waste Management in Developing Countries

The study site is in Mexico which is a developing country as defined by the World Bank (2010a). Waste management is important in developing countries: to prevent public health harm from waste, especially to the poor who generally experience greater exposure to uncontrolled waste (Arlosoroff, 1991; Bartone et al., 1994); to control and reduce the negative environmental impacts of waste; and to bolster economic development (Arlosoroff, 1991). To better understand the circumstances and issues surrounding

waste and waste management in developing countries, the literature about waste generation rates and composition, and typical barriers and opportunities to waste management in developing countries is reviewed here. Table 2.1 shows the World Bank country classifications by income, and the ranges of quantities of waste generated and costs of waste management for each category.

Table 2.1: Country classifications based on income as defined by the World Bank showing the ranges of waste generation and ranges of cost of waste management and collection for each income class. Sources: The World Bank, 2010a; Cointreau, 2006; Troschinetz & Mihelcic, 2009.

Classification	GNI per capita Range (USD)	Example Countries	Per capita daily waste generation range (kg)		Cost of WM as % of income[2]	Cost of waste collection as % of income[3]
Low income	≤$995	Haiti, Ethiopia, Afghanistan, Cambodia	0.35-0.75[3]		0.7-2.6%	0.5-1.6%
Lower-middle income	$996 - $3,945	India, Indonesia, Guatemala, Pakistan, Ukraine, Ghana	Middle income	0.45-1.1[4] 0.77[4]	0.5-1.3%	0.4-0.9%
Upper-middle income	$3,946 - $12,195	Mexico, Romania, South Africa, Malaysia				
High income	≥$12,196	Canada, Czech Republic, Japan, Oman,	0.65-2.2[4] 1.43-2.08[5]		0.2-0.5%	0.2-0.3%

Typical waste quantities and their trends in developing countries are presented here for later comparison to those of the case study. Flintoff found the worldwide range of waste generation to be 0.25-1.00 kg per capita per day (1984). Waste generation has increased since the time of Flintoff's study as seen by the waste generation data presented in Table 2.1. Cointreau (1984) reported the typical density of waste in middle income countries to be 170-330 kg/m^3, which falls into the worldwide density range reported by Flintoff (1984) of 100-600 kg/m^3. Combining Flintoff's generation and density ranges, the worldwide volume of waste generated daily would range from 0.5-10 L/person/day circa 1984. The waste generation rate in volume is of interest to this study because the amounts of waste generated by residents of Aguascalientes were estimated in volume. With increased income, the quantity of waste generated

[2] Source: Cointreau, 2006
[3] Source: Cointreau, 2006. Classifications are based on World Bank country classifications in 1994. Generation rates are for mixed urban waste including residential, commercial, industrial and institutional waste, as well as street sweepings and yard waste, but not construction/demolition debris.
[4] Average for 23 countries with GDP <10,000USD. Source: Troschinetz and Mihelcic, 2009.
[5] For countries with GDP >10,000. Source: Troschinetz and Mihelcic, 2009.

increases and density decreases as the composition becomes less organic (Cointreau, 1984; Flintoff, 1984; Blight & Mbande, 1996).

On average, waste in developing countries is 55% organic, but waste composition is highly variable by country, especially for organic content (Troschinetz & Mihelcic, 2009; Flintoff, 1984 (25-75% range of organic content)). Troschinetz and Mihelcic (2009) through an extensive review of waste composition literature found that waste in developing countries typically has higher organic content and lower paper and cardboard content than waste in developed countries, but similar glass and plastic content. The composition of waste impacts the type of equipment that can be used for waste collection and processing, and the potential resource recovery rate.

Factors of waste composition are of interest because they explain how composition varies by area. Troschinetz and Mihelcic (2009) identified the factors of waste composition in developing countries to be seasonal effects, income level, domestic fuel supply, geography, living standards, and climate. Flintoff (1984) also identified income as a factor of waste composition. He found that as income increases, the proportions of paper, glass and metal generated increase while the proportion of organics decreases.

The barriers and benefits to waste management encountered in developing countries are of interest to this thesis because they provide context by which to better understand the waste management circumstances of the case study. Also, understanding these barriers and benefits may provide insight into why certain collection systems do or do not work well in certain areas. Barriers include financial limitations, governance/institutional weakness, limited data on waste quantity and composition, lack of expertise, warm climates, dense and scattered urban form, and rapid urbanization. Financial limitations and governance/institutional weakness are the roots causes of limited data on waste characteristics and lack of expertise, which more directly impact waste management.

Lack of funding for waste management has been identified as a barrier by Oluwande, (1984), Buenrostro and Bocco, (2003), Boadi and Kuitunen, (2005), and Cointreau, (1984 & 2006). Limited funds available to governments often result in other important services, such as housing and water provision, being given higher priority than waste management (Oluwande, 1984). Wilson (2007) found that waste management increases in priority as living standards improve. Financial limitations are compounded through time if municipalities have to borrow money at high interest rates to fund waste

management activities or if the country experiences inflation which increases the cost of labour (Cointreau, 1984).[6]

Governance/Institutional weakness was found to be a barrier to waste management by Wilson, (2007), Oluwande, (1984) (specifically with respect to house to house collection), Troschinetz and Mihelcic, (2009), Lopez de Alba Gomez, (2010), Boadi and Kuitunen, (2005), Buenrostro and Bocco, (2003), and Korfmacher, (1997). For example, Boadi and Kuitunen, (2005) found through a study in Accra, Ghana that an inability to service the entire population with collection was due in part to weak institutional capacity. Weak governments and institutions have limited ability to create effective plans, and ineffective planning has been observed to contribute to unsatisfactory waste collection (Bhide & Sundaresan,1984; Buenrostro & Bocco, 2003). Buenrostro and Bocco (2003) also cite lack of administrative capacity, which led to too many responsibilities for municipal employees in small municipalities in Mexico, and corruption as barriers to waste management, both of which are related to weak governance. Weak governance and low institutional capacity can lead to insufficient enforcement of laws and regulations related to waste management (Lopez de Alba Gomez, 2010). Lopez de Alba Gomez also found inconsistency in the support for waste management plans between successive political administrations in Mexico City, which made the continuation of created policies difficult. Governance/institutional weakness is related to limited financial resources as municipalities may not be able to hire enough employees, or those with sufficient expertise, to plan and administer waste management.

Lack of expertise as a barrier to waste management is supported by Boadi and Kuitunen (2005) and Buenrostro and Bocco (2003). Policies created by non-experts are often not enforceable and not effective (Buenrostro & Bocco, 2003). Without waste management expertise, all of the possible methods of collecting waste, recovering resources, and disposal may not be considered in planning a waste management system. A lack of expertise may result in unplanned, ad-hoc waste management systems which are generally insufficient.

Lack of data on waste quantity and composition was identified as a barrier to waste management in developing countries by Buenrostro and Bocco (2003), and Flintoff (1984). Waste quantity and composition data is necessary in order to design and manage a suitable collection, resource recovery and disposal system. Lack of this data is caused by lack of finances, human resources and institutional capacity (Boadi & Kuitunen, 2005).

[6] Often in the development of waste management systems in developing countries more mechanized equipment is implemented (using loans) without reducing labour, which combines the negative impacts described above (Cointreau, 1984).

The warm climates of many developing countries accelerate decomposition and disease vector reproduction (Bartone et al., 1991; Flintoff, 1976; Holmes, 1984; Boadi & Kuitunen, 2005; Korfmacher, 1997). Areas with warm climates need more frequent collection than areas with cooler climates, but frequent collection is difficult in countries with limited financial resources.

Low income areas of cities in developing countries tend to have dense, disorganized urban form and narrow, dirt streets. These physical features limit the size of collection equipment that can be used, and the ability of trucks to manoeuvre, in those areas, which limit the method of collection (Korfmacher, 1997; Bhide & Sundaresan, 1984; Oluwande, 1984).

Many developing urban areas are currently experiencing rapid urbanization which increases urban density, increases waste generation, changes waste composition and further exasperates waste collection efforts (Arlosoroff, 1991; Bartone et al., 1994; Ogawa, 1989; Boadi & Kuitunen, 2005; Ekere Mugisha, & Drake, 2009; Buenrostro & Bocco, 2003; Sharholy, Ahmad, Vaishya, & Gupta, 2007). The institutional and economic capacities of developing countries are often insufficient to adapt waste management systems to these changes (Bartone et al., 1994; Ogawa, 1989).

Despite these barriers, developing countries offer unique opportunities to waste management which are not often discussed in the literature. Three such opportunities have been identified through this literature review. They are: the low cost of labour; the large general, unskilled labour force; and the low waste generation rate relative to developed countries. These opportunities are worth highlighting because they can and should be used to design different methods of waste management than those used in developed countries.

Labour in developing countries is roughly $1/10^{th}$ the cost of labour in developed countries (Cointreau, 1984). The low cost of labour combined with the large general labour force allow for labour intensive waste collection systems which contribute to employment and reduce the need for expensive mechanical equipment.[7] Labour intensive collection methods are common in low income countries. Per 10,000 residents, low income countries typically have 10-50 collection workers, middle income countries have 5-30, and cities in the U.S. only have about five (Cointreau, 1984).

[7] Cointreau (1984) explains that a financial principle of waste management in developed countries is to optimize labour output, for example through highly-mechanized technology that allows for one labourer per truck, since the cost of labour is high, while a financial principle of developing countries should be to optimize vehicle productivity, since equipment is expensive relative to labour.

2.6 Waste Collection in Developing Countries

The way waste is collected can either aggravate the above barriers, or work as effectively as possible within limitations while taking advantage of opportunities. In this section waste collection is defined and several collection methods used in developing countries are described. Examples of locations where each method is used and brief discussions of which aspects work well are included in the descriptions. Curbside collection, commonly used in developed countries, is also described, and reasons why this method is not appropriate in developing countries are presented. CCC, which is used by the case study, is described in great detail to give an in-depth understanding of this method and to show the range of types of container systems.

Tchobanoglous et al. (1993) distinguish between 'waste handling and separation' and 'waste collection'. They define waste handling and separation as "the activities associated with the management of wastes until they are placed in storage containers for collection" (p. 12) and waste collection as "the gathering of solid waste and recyclable materials… the transport of these materials… to the location where the collection vehicle is emptied" (p.12-13). However, the transport of waste from locations of generation to storage containers is affected by the type of collection system and may involve third parties. For this reason, the use of the term waste collection in this thesis encompasses both waste handing and separation and waste collection as defined by Tchobanoglous et al. (1993). Collection can either be of co-mingled or separated waste (where co-mingled waste is a mix of recyclables, organics and other waste) (Tchobanoglous et al., 1993). The collection systems are described as though for co-mingled waste, but some can and are used to collect separated waste.

Within a city there may be neighbourhoods of varying built forms suited to various methods of collection (Farsi & Hammouda, 1984). In Accra, Ghana, container systems are used in low income areas, but curbside collection is used in high income areas (Boadi & Kuitunen, 2005). However differences in collection method by income may be indicative of prejudices towards low income groups, a consideration which is discussed further in a review of the social implications of waste collection in the section entitled *ISWM Considerations for Waste Collection*.

"Non-collection" is the term Korfmacher (1997) used to describe systems in which residents are responsible for taking waste to the final disposal location. These systems are common in rural areas of developed countries. Incentives are sometimes used to motivate participation. In Curitiba, Brazil residents in squatter settlements can "sell" garbage for bus tickets or food. This "garbage purchase" system costs the same as private collection in those areas would and is subsidized by taxes on wealthier neighbourhoods.

Many authors use the terms house-to-house or curbside (in Britain kerbside) collection when discussing the method whereby waste generators place their waste on the curb outside of their home or business at a designated time for collection by truck. In this thesis, this method is referred to as curbside collection while a different method is referred to as house-to-house collection.

Curbside collection is not appropriate in developing countries due to low waste generation rates, compact urban form, limited financial resources and high-organic waste composition. Developing countries typically have low waste generation rates and compact urban form, so if curbside collection was used, trucks would have to make frequent stops to collect small amounts of waste. If the collection frequency is held constant, this method would be more expensive per mass unit of waste in developing countries than developed (Cointreau, 1984). In developed countries with curbside collection, the collection frequency is usually once per week. In the warm climates of many developing countries, more frequent waste collection is required, in which case curbside collection would be even less financially feasible. Small houses common in developing countries may not have adequate storage space for waste if collection were only once a week (Bhide & Sundaresan, 1984). Areas with narrow and/or poor roads, or no roads, make collection using the large trucks commonly used for curbside collection impossible (Holmes, 1984).

Curbside collection is used in many urban areas in Europe, but the narrow streets of old neighbourhoods pose a challenge to this method. The solutions may be relevant to developing cities that have areas of narrow streets. In various European cities, curbside collection along narrow streets either does not occur at all, or occurs via small trucks. Where curbside collection does not occur, residents have to take waste to transfer points, communal containers (1 for every 700 houses in Barcelona; Ajuntament de Barcelona, n.d.), or refuse storage rooms in apartment buildings (City of London, 2009). Low capacity waste collection vehicles of 3.5, 6.5 and 12 tonnes are used for collection from narrow and no-exit streets in Vallée de Chevreuse, France (Veolia Environmental Services, 2010). Many cities in Asia use motorized tricycles of $2m^3$ capacity to collect waste along narrow streets (UNEP, 2005). Creative solutions to the narrow street dilemma that are currently being tested include horse-drawn carts and robots. Horse drawn carts are used for collection along narrow streets in 60 towns in France (which previously had communal containers placed in locations accessible to collection trucks) (Karp, 2010). Small, on-demand waste collection robots of about $1m^3$ capacity were tested by 100 households in a dense, narrow-street area of Peccoli, Italy in the summer of 2010 (Sprey, 2010).

House-to-house collection, used in some developing cities, occurs when a waste collector enters households to collect waste (Flintoff, 1976). This method is very labour intensive and may not be socio-

culturally acceptable depending on attitudes and values surrounding security and privacy. Weak governance and corruption can reduce the effectiveness of house-to-house collection. In Ibadan, Nigeria, where this method is used, collection labourers would only serve households that gave tips, even though all residents were already required to pay a municipal fee for the service (Oluwande, 1984).

Block collection occurs when waste generators bring waste out to the collector(s) as he/she passes through their neighbourhood (Flintoff, 1976; Cointreau, 1984; Korfmacher, 1997). The collector(s) generally follows the same route and schedule, and may ring a bell to alert residents that he/she is nearby. This method is not convenient for users who are not usually home when the collector passes by. Block collection may be less expensive than CCC (described below) since the capital costs of containers are avoided and, if the collector gathers fees, costs can be more easily recovered.

Korfmacher (1997) compared two areas where block collection was used: Adjoufou, Abidjan, Ivory Coast and Alladjan, Ivory Coast. When first implemented in Adjoufou, block collection worked well and had a high participation rate because it was the free option of two, but after a while residents regressed to disposing waste in undesignated areas. Block collection consistently worked well in Alladjan where the success was attributed to the convenience of daily collection. The fee recovery rate is high in Alladjan since 80% of the salaries for collection workers came from fees, providing incentive to collect them.

Collection points or depots are places where waste from various sources (residences and businesses) is deposited to be later collected and transported to a secondary collection point or final disposal site. These points may or may not have a container for waste storage. There may be more than one level of collection points. For example, in Adjoufou II, a region of Abidjan in the Ivory Coast, residents deposit waste in communal drums placed less than 30m from each house which are later transported by wheelbarrow and emptied into large skips for the storage of waste until transport to final disposal site (Korfmacher, 1997).

Communal Container Collection

Communal containers are storage containers at waste collection points used by more than one household (Flintoff, 1976; Ogawa 1989). A wide range of containers, collection techniques and degrees of mechanization are used in communal container systems. The literature on the benefits and disadvantages of CCC, types of systems, and methods of transport of waste to collection points has been reviewed.

CCC has the benefits of being less expensive than many other methods of collection and being well suited to settlements with little or no road access. CCC yields shorter routes and faster collection

than the methods listed above (excluding non-collection) and therefore can have lower operating costs. Curbside collection was found to be 2.27 times more expensive than a CCC system proposed for a city in the Middle East (Holmes, 1984). Compared to collection point systems without containers, containerization allows for higher worker productivity as collectors spend less time sweeping and shovelling (Cointreau, 1984). Communal containers are well suited to market places and other commercial centres (Oluwande, 1984), and neighbourhoods with poor or no road access such as squatter settlements (Blight & Mbande, 1996) because they can be placed adjacent to these areas on roads that collection vehicles can travel.

The main disadvantage of CCC is that a high burden of participation is placed on the waste generator. The distance from household to container and container height affect the burden of participation (Flintoff, 1976; Ogawa, 1989; Parrot, Sotamenou & Dia, 2008; Blight & Mbande, 1996). Many CCC systems have failed because the burden of participation was greater than the waste generators' "willingness to co-operate" (Flintoff, 1976, p. 60). Oluwande suggests that containers be located close to roads and be easily accessible to decrease the burden of participation and discourage dumping in other areas (1984). Distance to collection point and other factors of participation are discussed in greater depth in the *ISWM Considerations for Waste Collection* section of this literature review.

There are several other disadvantages to CCC. Containers are prone to being full and overflowing (Oluwande, 1984; Blight & Mbande, 1996). However, correct capacity and regular emptying can help prevent overflowing. Blight and Mbande (1996) found that despite frequent collection, containers may be set on fire, and in very low income areas may be stolen and used for other purposes, including shelter.

Containers may be stationary or portable (Cointreau, 1984; Vijay, Gupta, Kalamdhad, & Devotta, 2005). Stationary containers are not lifted or moved during collection and are often permanent structures. They may be made of cement/concrete or masonry (Vijay et al., 2005; Holmes, 1984). They may be three sided, or four sided with a door or low walls, and may or may not have a roof (Oluwande, 1984). Stationary containers are used in the Bandung Region of Java, Indonesia (Owens & Macklin, 1984) and some communities in India (Vijay et al., 2005).

No discussion of which aspects of stationary container systems work well was found in the literature, but points against these systems were made. Cointreau (1984) does not recommend stationary containers because: some waste is always left in them which facilitates disease vector reproduction; waste is often strewn about by scavenging animals; people often avoid them because of the smell and mess; and waste removal requires a high amount of manual labour and time. Up to 75% of collection time is spent loading waste into vehicles when stationary containers are used (Oluwande, 1984). Hand-loading waste

can be hazardous to collectors' health (Owens & Macklin, 1984). Coad (1984) does not dismiss stationary containers but rather offers recommendations for their improvement. He suggests they be paved for easy shovelling and cleaning, and have a raised platform so waste can be easily pushed into trucks (with ramps up to the platform for waste carts).

Portable containers may be hauled to a transfer point or final disposal site and either returned or replaced with a clean one, or mechanically lifted onsite to empty waste into a truck. Hauled containers may be on wheels and have a towing mechanism or be lifted onto a truck bed (Oluwande, 1984). Hauled containers are often found in India and are typically metal (Vijay et al., 2005; Sharholy et al., 2007). Cointreau (1984) finds portable containers to be suited to large buildings and densely populated areas, and remarks that collection time is not wasted waiting for users (compared to block collection), or collection activities such as shovelling waste.

Holmes (1984) suggests that containers 1-2m^3 are "most sensible method for giving the almost obligatory daily collection service [in developing countries]" (p. 10). Containers of that size are successfully used in Lagos, Nigeria and Colombo, Sri Lanka. In India, heavy concrete rings, 1m in diameter, are often used (Bhide & Sundaresan, 1984). They are not stolen because they are very heavy and not worth much. Galvanized iron bins, 1m^3, are also common but tend to get stolen.

Transport of wastes from generation sites (i.e. households) to collection points (or small dumps) can be done by the waste generator, the waste collection provider, or a third party. Transport by a third party, such as independent or commissioned individuals or organizations, was the method most frequently mentioned in the literature. Transport by anyone other than the waste generator must involve either house-to-house or block collection. Collection workers or third parties may transport waste with a yoke and baskets, or in a small vehicle such as a wheelbarrow, handcart, bikecart, donkey and cart or horse and cart (Coad, 1984; Owens and Macklin, 1984; Tabasaran, 1984; Vijay et al., 2005; Patrick, 1984; Korfmacher, 1997; Boadi & Kuitunen, 2005). Often collectors will sort waste and recover items of value. In the Bandung Region of Java, Indonesia waste is transported by 1m^3 handcart that can weigh 700 kg fully loaded (Owens and Macklin, 1984). Non-generator transport provides a high level of service and employment (in Iran, Coad, 1984), but has low labour productivity, which may be a concern if the collection workers are publically employed. Transport by the waste generator was rarely mentioned in the literature. Generator-transport occurs in some cities in India (Bhide & Sundaresan, 1984) and in Aguascalientes, Mexico.

2.7 ISWM Considerations for Waste Collection Systems

The literature findings about the characteristics and functions of waste collection systems in developing countries were divided into the ISWM aspects of social, environmental, economic, and management. Examining these aspects yields insight into the design characteristics of effective waste management systems. The subsections within each ISWM aspect below provide the framework for the indicators that were used to assess the collection system in Aguascalientes. Most of the discussion of management pertains specifically to CCC systems but the other three categories are more general in scope.

SOCIAL

The design of a waste collection system has social impacts on public health, the burden of participation on the waste generators, inequalities between groups, and the working conditions of collectors. The literature was reviewed pertaining to: participation in waste collection systems; waste collection service inequity; and waste collectors, formal and informal.

Participation

Waste collection programs cannot function without a satisfactory level of user participation (Ojeda-Benítez & Beraud-Lozano, 2003; Pickford, 1984; Oluwande, 1984). For example, Bhide & Sundaresan (1984) found that in several municipalities in India, waste collection was not satisfactory due in part to lack of co-operation by residents. Factors of participation in waste collection in developing countries identified in the literature were reviewed for later comparison to the factors identified through the case study of this thesis. Factors identified in the literature were: convenience; regular and thorough collection; cultural and religious beliefs surrounding cleanliness; public awareness and education about waste related issues; fines and financial incentives; and the extent of public involvement in waste related decisions.

Waste generators will often not use a collection system that they find inconvenient (Bhide & Sundaresan, 1984), especially if they do not have an appreciation for the health and environmental benefits of proper waste management, (which can be influenced by public education and awareness). In designing a system that requires a lot of citizen participation “an understanding of the people living in each neighbourhood being served” is required (Cointreau, 1984, p. 156) in order to make the system more convenient for them.

If waste generators are responsible for transporting waste to a collection point, the distance from location of waste generation (i.e. household) to waste collection point influences convenience for the user

and therefore public participation in the collection system (Flintoff, 1976; Ogawa, 1989; Parrot et al., 2008; Bhide & Sundaresan, 1984). Collection points at close intervals tend to garner more participation than those further apart. In India, when collection points are far apart, waste generators were observed to dump waste in more convenient places (Bhide & Sundaresan, 1984). India has a national guideline that the maximum distance from household to collection point be 250m (500m between points) (Vijay et al., 2005). This distance seems short, especially considering that waste tends to be transported from house to collection point by third parties with carts in India. The rationale for this particular distance was not given. Owens and Macklin, in a study on the waste collection system in the Bandung Region of Java, Indonesia, suggested limiting the distance from households to collection points (transfer locations) to 1km for handcart collectors (1984).

Regular collection encourages participation (Cointreau, 1984; Korfmacher, 1997). Collection must also serve all collection points to achieve public satisfaction (Sharholy et al., 2007). If collection is not regular and thorough, waste will build up at collection points and overflow from containers making those sites unpleasant and hazardous to health, which discourage their use.

Cultural attitudes, customs, religious beliefs and perceptions regarding cleanliness are thought to affect participation in waste collection (Holmes, 1984). Some cultural attitudes and customs influence how waste is handled and by whom (which may contribute to social injustice). Perceptions of the sanitation of collection points affect their use as demonstrated in Cointreau's (1984) finding that people often don't want to walk into or near stationary containers because of the smell and mess.

Public education about and awareness of the health and environmental problems caused by uncontrolled waste influence participation in waste collection. In Jeddah, Saudi Arabia, one aspect of their successful strategy to cope with increasing waste generation was an extensive public education and awareness campaign in schools and through mass media (Farsi & Hammouda, 1984). Bhide and Sundaresan wrote that public participation in newly implemented collection methods will only occur if citizens "become aware of ill-effects of existing systems and the advantages" of alternative methods (1984, p. 148). Hasan (2004) found that education, especially at a young age, is important to participation in waste management, and that rules and regulations alone, without education, are not successful in motivating participation. Parizeau (2006) found that educating people about waste problems increased their willingness to participate in and pay for community based waste management.

Money is a great motivator for participation, whether by the risk of loss through fines, or potential gain through incentives. The aforementioned system in Curitiba, Brazil where residents in squatter settlements "sell" garbage for bus tickets or food is an example of a successful incentive program

(Korfmacher, 1997). Fullerton and Kinnaman (1995) found that in areas where unauthorized dumping and/or burning is not possible, municipalities can charge for curbside collection, while in areas where dumping and/or burning can and does occur, a deposit/refund system is more effective.

Public involvement in the planning of waste management can contribute to participation by: allowing the public to clearly communicate in which systems they would be willing to participate; facilitating public education on the importance of good waste management; and garnering a sense of local and public ownership of the system. The United Nations Centre for Human Settlements, in a list of five attitudinal changes among solid waste management professionals in developing countries, included "recognition that district or neighbourhood-level garbage collection schemes devised and managed in cooperation with the residents are often the cheapest and most effective solution" (Korfmacher, 1997, p. 481). Top-down approaches to waste management imposed by outside parties are often unsuccessful due to lack of public involvement. Pickford (1984), in examining successful environmental upgrades to slums, found public co-operation is not aroused by paternalistic attitudes of outsiders coming to "improve" them and wrote "...telling people what they *ought* to do is seldom effective" (original emphasis, p. 35).

Waste Collection Inequity

Inequalities in waste collection service by income status have been observed in developing countries. These inequalities can be manifested by different proportions of waste collected, or different methods of collection. In Accra, Ghana, container systems are used in low and middle income areas, often with too small and too few containers, while curbside collection is used in high income areas (Boadi & Kuitunen, 2005). Containers are emptied less frequently in poor areas in Accra than in medium income areas. As a result, the containers in poor areas overflow and residents dump waste elsewhere. Fobil, May & Kraemer (2010) found the proportion of waste collected to be significantly related to socio-economic [SE] status ($p<0.001$) and strongly associated with education level in Accra. In Mexico, low income areas tend to receive sporadic, or no collection (Medina, 2005). The higher collection rate in high income areas of Mexico is attributed to the lobbying efforts of the wealthy, while people in low income neighbourhoods lack the resources and political connections to lobby successfully.

Some residents of low income areas, including most or all in illegal squatter settlements, do not pay taxes (Medina, 2005; Mungai, 1998; Pickford, 1984). Waste collection providers may justify a providing a low level of waste collection service to low income areas by arguing that people should not receive a service for which they do not pay. This rationale is more common when collection is privately provided. In a study on four municipalities in Mexico, collection was more thorough in low income areas when the service was publically rather than privately provided (Ojeda-Benítez & Beraud-Lozano, 2003).

In many developing countries, women carry more responsibility for waste management than men (Ekere, Mugisha & Drake, 2009; Beall, 1997). In a study on resource recovery in the Lake Victoria region of Uganda, Ekere et al. (2009) found that waste utilization as a resource was higher among men than women, while waste separation was 10% higher among women. The higher separation behaviour was attributed to the women carrying more responsibility for waste management and being more environmentally friendly. In a study on waste-related gender inequalities in Bangalore, India and Faisalabad, Pakistan, Beall (1997) found women to be more responsible than men for the separation of waste within households in accordance with traditional roles. She also found waste separation by women was motivated to a small extent by financial incentives, but by not environmental concern.

Collectors

Collectors of waste and recoverable materials are subject to frequent close contact with waste. Consideration ought to be given by waste management planners to how collector's activities impact their health and general wellbeing. Collectors may be formally employed by the waste collection provider, or operate informally and independently by recovering items of value to sell.

Formal waste collectors are those employed publically or privately to collect waste. The nature of their duties, work environment, compensation, etc. (insurance, sick days, overtime pay) affect their health, dignity and quality of life. Collection workers have a greater risk of acquiring infection or injury than other people. Bhide and Sundaresan (1984) reported a greater proportion of collection workers had parasitic infections[8], respiratory diseases and skin diseases than a control group. Cointreau (2006) cited the following risks of injuries for collection workers relative to other workers. Danish waste collection workers had a 5.6 times greater risk of injury than other workers between 1989 and 1992. In 1998 the U.S. Department of Labour reported that waste collection workers had a 10 times greater risk of death than other workers. Brazil reported 700 accidents per 1000 collection workers per year. Compared to the probability of injury for all workers in Brazil, which averaged to be 0.016 for 2009 and 2010 (ILO, 2010b), the collection workers have a 43 times higher probability of acquiring injury than other workers. Cointreau (2006) found accident rates to be higher among collection workers in developing countries than developed due to poor working conditions and lack of protective gear.

Informal waste collectors are unregulated individuals, families, groups or small enterprises who recover items to reuse or sell from households, waste collection points or disposal sites (Cointreau, 1982; Del Pilar Moreno-Sanchez & Maldonado, 2006; Blight & Mbande 1996; Korfmacher, 1997). Informal

[8] 98% of participating collectors had parasitic infections while only 32.9% of the control group had them.

collectors are found in many developing communities regardless of whether or not those communities have formal waste collection systems (Korfmacher, 1997). In some places, they collect waste directly from households to sort out recoverable materials and dispose the rest. They may collect waste from houses for free, or may be required to pay the municipality a fee for the privilege to do so, especially in wealthy areas (Cointreau, 1984).

Informal collectors face health, social and economic challenges. Health problems include stomach illnesses, skin diseases, deficiency diseases and risk of injury/harm from machinery when collecting in dumps or landfills (Blight & Mbande, 1996). Socially, their work may be perceived by others as degrading (Furedy, 1989). In some cultures, certain classes are perceived to "have a natural affinity with dirt, disorder and waste work" (Buell, 1997, p. 88), an attitude which acts to encourage those groups to participate in informal collection and then justify social discrimination against them. Informal collectors are often paid a low percentage of the actual value of the resources they collect since there are several levels of recovery markets and they work at the primary level (Vogler, 1984). For example, in Mexico, primary collectors receive less than one quarter of the final buyer price (Holmes, 1984) while the middle men profit the most (Buenrostro & Bocco, 2003). Despite economic justice issues, informal collecting can be profitable. In three municipalities studied in Mexico, informal collectors who collect waste from low income areas that receive insufficient municipal collection make 3-5 times minimum wage (Medina, 2005). They are still perceived as poor though.

Many studies focus on the poor living and working conditions of informal collectors that surely do need improvement, while few, but an increasing number, focus on the positive benefits of the informal waste sector (Nas & Jaffe, 2003; Del Pilar Moreno-Sanchez & Maldonado, 2006; Masocha, 2006). The benefits of the informal waste sector include saved energy, reduced waste, increased recovery of resources, reduced use and import of raw materials, reduced cost of municipal solid waste management programs, and increased income for the poor (Del Pilar Moreno-Sanchez & Maldonado, 2006; Blight & Mbande, 1996). The impact of informal collectors on the recovery rate is not marginal. A study on informal collection in border towns of Mexico and the United States showed that scavenging efforts (within households, at dumpsites and from streets) led to a 75% recovery of aluminum cans (Medina, 1998).

Municipalities ought to work with and support informal collectors rather than disadvantage them (Cointreau, 1982; Furedy 1992; Buenrostro & Bocco, 2003; Blight & Mbande, 1996; Korfmacher, 1997; Beall, 1997). The municipal policies regarding informal collectors identified by Medina (2005) in a study on Mexico, in increasing order of co-operation, were repression, ignorance/neglect, collusion

(exploitation, mutual profit/assistance), and stimulation (supportive policies). When new waste collection systems are put into place, those systems should "not increase the vulnerability of waste pickers by displacing them without providing viable and sustainable livelihood alternatives" (Beall, 1997, p. 88). To prevent this, informal collectors ought to be included in the waste management decision-making process (Buenrostro & Bocco, 2003). Municipalities should consider the resource recovery rates of the informal collector sector when making waste management decisions (Cointreau, 1982; Furedy, 1989). Unfortunately areas with weak governance may not have the capacity to co-ordinate co-operation with informal collectors (Korfmacher, 1997).

There are several examples of collection systems that involve co-operation with informal collectors. In Cairo, Egypt after a collection system that was implemented by a developed country failed, the city decided to work with the community of informal collectors resulting in contracting them to perform waste collection (Korfmacher, 1997). This system improved collection and maintained the informal collectors' livelihoods and recovery rates. In the same article, Korfmacher wrote about Harare, Zimbabwe where the co-operation between buyers of recycled material, the municipality and informal collectors who were allowed to operate at city's dump sites, facilitated the creation of an extensive recycling industry. Policies that are supportive of informal collectors in Mexico range from the legalization of informal collector activities, the encouragement the formation of informal collector cooperatives, and "the awarding of concessions in particular sections of cities" (Medina, 2005, p. 395).

ENVIRONMENTAL

The method of waste collection impacts the environment by affecting the extent of resource recovery and the amount of fuel used to transport waste. The following section presents the literature on: the state of resource recovery in developing countries; factors of resource recovery; and factors influencing fuel usage for waste transport.

In this thesis resource recovery rate is defined as the amount of waste diverted from final disposal as a portion of the amount of waste generated. The resource recovery and recycling rate statistics cited below used this definition.

The resource recovery rates of developing countries vary greatly by country, with some having comparable or greater recovery rates than developed countries. The resource recovery rates of the developing countries studied by Troschinetz and Mihelcic (2009) ranged from 0-41%. These authors reported that developed countries typically fall into this range with the E.U. having a recovery rate of

18% and the U.S. 30%. In Canada, the national residential recycling rate between 2004 and 2006 was 22% by mass, and provincial recycling rates ranged from 6.9-40.7% (Statistics Canada, 2008).

Barriers to recycling encountered in developing countries were researched. Troschinetz and Mihelcic (2009) found the education levels of waste management labourers and professionals, the method of waste collection and segregation, and government finances to be the top three greatest barriers to recycling in developing countries. Distance to reclamation markets can also be a barrier. Vogler (1984) noted that more recycling occurs in Latin America and industrialized parts of Asia, than in the Caribbean and Africa. He attributed higher recycling rates to closer proximity to reclamation facilities (which process recovered items into bulk material for remanufacturing) and markets for reclaimed materials. Transportation costs are added to the price of reclaimed materials, and if the price is very high, reclaimed materials may not be able to compete with raw resources. Furthermore, the use of fossil fuels to transport recyclables reduces the environmental benefits of recycling. In some places the environmental costs of transporting recyclables are so great that disposal is more environmentally effective than recycling (Larsen, Merrild, Møller, & Christensen, 2010).

Literature was reviewed on the factors of resource recovery behaviour in individuals in developing countries. Method of collection, economic incentives, knowledge of recycling collection systems, and social pressure were all found to be factors of resource recovery behaviour in developing countries (Troschinetz & Mihelcic, 2009; Kuo, 2006; Korfmacher, 1997; Ekere et al, 2009). Income level was not found to be related to recycling in developing countries (Beall, 1997; Troschinetz & Mihelcic, 2009). Factors from studies on recycling in developing and developed countries are summarized in Table 2.2. Studies on recycling behaviour in developed countries tend to focus on underlying indirect factors of behaviour while the studies on developing countries focused more on direct, practical factors (Troschinetz & Mihelcic, 2009).

The recovery rate is influenced by the waste collection and segregation system (Troschinetz & Mihelcic, 2009). Unfortunately, no studies that compare recovery rates by collection system in developing countries were found, so the following information is from studies performed in developed countries, the lessons learned from which may be somewhat transferrable. Curbside collection of recyclables yields higher recovery rates than programs in which residents must drop-off recyclable materials in recycling containers or centres (in Denmark: Larsen et al., 2010; in Sweden: Dahlen, Vukicevic, Meijer & Lagerkvist, 2007). More dispersed and less convenient recycling containers or centres had lower recovery rates (Larsen et al., 2010).

Table 2.2: Factors affecting recycling behaviour identified in the literature.

Category of Factors	Factor Affecting Recycling Behaviour	Relationship to recycling: Yes, No or Results are ambiguous
Demographics	Education	**Yes:** Hasan, 2004; Parizeau, 2006; Derksen & Gartrell, 1993, (weak)
		Ambiguous: Guerin, Crete & Mercier, 2001; Sidique, Lupi & Joshi, 2010
	Income	**No:** Derksen & Gartrell, 1993, Beall, 1997; Troschinetz & Mihelcic, 2009
		Ambiguous: Sidique et al., 2010
	Age	**Yes:** Bartelings & Sterner, 1999, (not linear – types recycled vary by age); Derksen & Gartrell, 1993, (weak, positive)
		No: Sidique et al., 2010
	Gender	**Yes:** Ekere, et al., 2009, (separation higher among females)
		No: Gamba & Oskamp, 1994
		Ambiguous: Sidique et al., 2010
Attitudes and Perceptions	Environmental concern	**Yes:** Gamba & Oskamp, 1994; Derksen & Gartrell, 1993, (low correlation, but combined with access to recycling the effect is stronger)
		Ambiguous: Sidique et al., 2010
	Perception of Effectiveness	**Yes:** Matsui, Tanaka & Ohsako, 2007
	Belief government is trying to protect environment	**Yes:** Guerin et al., 2001
Knowledge	Knowledge (About recycling programs, About types of recyclable materials)	**Yes:** Matsui et al., 2007 (strong effect); Gamba & Oskamp, 1994; Sidique et al., 2010; Troschinetz & Mihelcic, 2009; Perrin & Barton, 2001, (types of recyclables)
Design/Perception	Level of change to existing behaviour	**Yes:** Perrin & Barton, 2001
	Inconvenience/Difficulty of use (Includes sorting effort, storage requirements, distance to recycling facilities)	**Yes:** Matsui et al., 2007 Bartelings & Sterner, 1999; Gamba & Oskamp, 1994 Sidique et al., 2010 (drop off facilities in area of Michigan distance, sorting time); Perrin & Barton 2001, (strong); Ekere, et al., 2009, (time)
Design	Access to recycling program/facilities	**Yes:** Derksen & Gartrell, 1993, (strong)
External Pressure/Encouragement	Feedback (about individual recycling amounts)	**Yes:** Msengi, 2010, (strong effect); Perrin & Barton, 2001
	Social pressure	**Yes:** Gamba and Oskamp, 1994; Sidique et al., 2010 (mostly from family); Ekere, et al., 2009
	Community group encouragement (social pressure)	**Yes:** Msengi, 2010, (slight effect); Ekere, et al., 2009, (belonging to an environmental organization)
	Media	**Yes:** Nonami, Sugiura, Ohnuma, Yamakawa, & Hirose, 1997
Policy	Mandatory recycling	**Yes:** Sinclair, 1987; Kuo,2006
National Level	National awareness of a national environmental problem	**Yes:** Guerin et al., 2001

Resource recovery behaviour can also be influenced by fees and financial incentives. In Taiwan and Japan higher fees for non-recyclable collection had the effect of increasing the recycling rate (Kuo, 2006). Korfmacher (1997) found economic incentives, such as refunds for recovered materials, to be positive factors of resource recovery. In many developing countries, the value of recyclable materials provides financial motivation to separate and sell those items (Cointreau, 1984).

The success of recycling collection programs depends on the level of public knowledge about their existence and how to use them. Corral-Verdugo (1997), in a study in Mexico, found that recycling behaviours are more dependent on competencies and knowledge than beliefs about the positive benefits of recycling (as cited by Troschinetz & Mihelcic, 2009).

Social pressure from peers and family was found to have a positive effect on recycling behaviour in the Lake Victoria region of Uganda by Ekere et al. (2009). They also found that membership in an environmental organization was positively related to recycling behaviour. The decision to join an environmental organization may be either socially or environmentally motivated.

In the literature specific to developing countries, income was not found to be correlated to recycling (Beall, 1997; Troschinetz & Mihelcic, 2009). An increase in income could be hypothesized to decrease recycling behaviour that was financially motivated. Beall (1997) found this was not true at the household level in Bangalore, India and Faisalabad, Pakistan because as families gain income they tend to hire domestic workers who usually separate waste and sell recovered materials. Troschinetz and Mihelcic (2009), in study of recycling at the national level in 19 developing countries, found household economics to be one of smallest barriers to recycling in developing countries. In studies on recycling in developed countries, there is conflicting evidence as to whether or not there is a relationship between recycling and income (Sidique et al., 2010).

Fossil fuel usage by collection trucks impacts the environment through the production of air pollution and greenhouse gases. Larsen, Vrgoc, Christensen, and Lieberknecht (2009) in a study on curbside collection in Denmark, found that fuel consumption was impacted by urban form and increased with distance to waste treatment facilities. Curbside collection of waste from large apartment buildings that had 0.600m^3 waste containers required fewer litres of diesel per tonne of waste (1.6 L/tonne) than collection from single-family homes which had smaller amounts of waste (0.190–0.240 m^3) at more closely-spaced intervals (3.3 L/tonne). Collection of small amounts of waste at short intervals consumes more fuel per tonne of waste than collection of greater amounts of waste at further spaced intervals because frequent stops increase the amount of idling, acceleration and braking.

ECONOMIC

High proportions of municipal budgets in developing countries are consumed by waste management. Of municipal budgets in low income countries, the proportion allocated to waste management ranges from 10-60% (10-40%, Cointreau, 1984; 20-50%, Arlosoroff, 1991; 55-60% in small towns in India, Bhide & Sundaresan, 1984). The cost of waste management decreases with increased national income from 0.7-2.6% of the gross national product [GNP] per capita in low income countries to 0.2-0.5% in high income countries (Cointreau, 2006). Very high proportions of waste management budgets are spent on collection (~90% of the waste management budget is allocated to collection when final disposal is into a non-engineered dump, Cointreau, 1984; Boadi & Kuitunen, 2005). This proportion is also high in developed countries, which typically spend 70% of their waste management budget on collection (Oluwande, 1984).

The operating and maintenance costs of collection are affected by the number of collection stops, the amount of waste collected, and the local cost of labour (Tchobanoglous et al., 2002). In areas with good roads, collection vehicles with mechanical loaders and tippers are more efficient and yield lower operating costs than manual loading and unloading (Cointreau, 2005), but have higher capital costs and may have higher maintenance costs if parts and repair service are not locally available. Placing more responsibility for waste management activities on users can reduce costs (Figueroa, 1998). For example, increasing the distances between collection points places more responsibility on users and can decrease both capital costs (fewer containers) and operating costs (less fuel used).

MANAGEMENT

The use of the term management here refers to all aspects of a waste management system which the provider can control. Controllable aspects may be physical, operational or regulatory. Physical aspects include type of collection equipment used, transfer stations and distance between collection points. Operational aspects include collection frequency and time of collection. Regulatory aspects include policies governing use of the collection system, report creation and monitoring. The following is a review of the literature on management techniques including how well they work (or do not work) in practice, and relevant recommendations made by waste management authors.

Several authors warn against the use of large trucks and/or compaction trucks for waste collection in developing countries. Vehicles used to collect waste from collection points in developing countries include tractors, rear or side loader trucks, tippers (dump trucks) or shovels (tractors with a scoop) (Holmes, 1984). Collection using large trucks is very difficult and often impossible on narrow roads

and/or rough, dirt roads (Holmes, 1984; Korfmacher, 1997; Bhide & Sundaresan , 1984). Cointreau (1984) found collection trucks that mechanically lift containers and compact their contents to be the most capital intensive and therefore not generally suited for developing countries. The high organic content of waste in developing countries makes compaction difficult and can cause frequent equipment failure to compaction trucks at high cost (Korfmacher, 1997; Cointreau, 1984). Arlosoroff (1991) similarly found compaction trucks to be used in too many cities where they are not needed and cannot be maintained, and suggested that "developing a preventative maintenance mentality is crucial, as is selecting trucks which require the minimum of maintenance, the ability to manufacture locally, and the availability of trained mechanics, spare parts and workshop facilities" (pg. 493).

Transfer stations are locations where waste from collection vehicles is compacted and loaded into larger vehicles for transport to a secondary transfer station or final disposal site. Waste may also be sorted at these locations and recoverable materials taken to recycling markets. Cointreau (1984) stated that each type of collection equipment has an economically viable radius of transport. In 2006 she reported that "an economic haul time for a small truck carrying 2 to 6 tonnes commonly is within 30 minutes one-way from the collection area to the unloading point" (pg. 8) which typically would be 15-30 km one-way in distance.

The frequency of removal of waste from collection points ought to be determined by climate and the amount of storage space in homes (Cointreau, 1984). Hot, humid climates require frequent collection to minimize foul odours and disease-vector reproduction (Cointreau, 1984; Holmes, 1984; Bhide & Sundaresan, 1984). Frequent collection is needed in densely populated areas where storage space in homes is limited. Collection occurs once a day in cities, and at least twice a week in rural areas in India (Bhide & Sundaresan, 1984), and every three days in Los Mochis, Sinaloa, Mexico (Ojeda-Benítez & Beraud-Lozano, 2003).

The time of day that wastes are collected affects traffic and the spread of odour from waste. Oluwande (1984) suggests that collection of wastes from collection points ought to occur at night when traffic is less congested. Boadi & Kuitunen (2003) found daytime traffic in Accra, Ghana to be unpleasant with the presence of open, smelly waste collection trucks.

Effective, enforceable policies and consistent reporting, monitoring and evaluation have been found to be important to the success of waste management plans. This was evident when changes were made to the waste management system in Jeddah, Saudi Arabia so the system could accommodate an increase in waste generation due to rapid urbanization and industrialization (Farsi & Hammouda, 1984). At one point during this adjustment, the municipality of Jeddah contracted British consultants to create a

one year waste management plan. This plan included regulations regarding waste collection, street sweeping, monitoring open dumps and the organization of spare parts for vehicles. These regulations were found to be effective. The consultants also implemented a reporting system that measured resources, efficiency, effectiveness and productivity. The reporting system was found to be a key component in the ability of the system to adapt to rapid changes. Jeddah, Saudi Arabia, was economically improving at this time, and was able to afford this system. Other developing countries may not be able to afford a similar system.

Policies may stipulate how waste generators use a collection system, for example at what time of day they may dispose waste. Cointreau (1984), in her discussion of container collection, mentions that a benefit of containers is that they are available for waste disposal 24 hours a day. In Aguascalientes waste generators may only dispose waste in the night. No reasons supporting night-time-only disposal were found in the literature.

2.8 Assessing Waste Management Systems According to the Principles of ISWM

Assessment models and methods commonly used by waste managers were reviewed for later comparison to the use of ISWM as an assessment tool. Assessment methods range from mathematical formulas to qualitative descriptions. Often the framework or goals against which the success of a system is measured are not explicitly stated in waste management assessments. Rather the goals are left to the discretion of the decision makers' or, in most developed and some developing countries, outlined by national or regional environmental legislation.

In a review of the literature on waste management analyses used in European countries, Pires, Martinho and Chang (2011) discussed systems engineering models and systems assessment tools, and their use in tandem. Examples of systems engineering models are cost-benefit analyses and forecasting models, and examples of systems assessment tools are material flow analyses, lifecycle assessments, risk assessments and environmental impact assessments. Pires et al. (2011) found that analyses of waste management systems are best preformed using a combination of systems engineering and system assessment methods, and provided a few combinations that have demonstrated efficacy. They did however point out that without set practices and guidelines, these analyses tend to value environmental and cost effectiveness above other principles, and suggest that more human factors be included. The goals or values of waste management were not explicitly stated in this paper, and their use in assessments was not discussed.

A model for value-based assessments was outlined in an article by Chambal, Shoviak and Thal (2003), and tested via a case study. This model involves breaking down objectives provided by waste management decision makers into measurable factors, each of which is assigned a value-based weight. Possible waste management alternatives are then ranked according to their ability to meet the objectives through a mathematical formula which sums the products of the factors' measurements and weights. The article did not mention what the objectives of waste management commonly are or ought to be. This model can be used to compare two or more possible systems but not to assess a single system.

Two assessments of waste management systems in developing countries were reviewed, one on the systems of 3 cities in Jordan (Abu Qdais, 2007) and one on industrial solid waste management in Tanzania (Mbuligwe & Kaseva, 2006). The study on Jordan was preformed ad hoc, first describing different functions and aspects of each system then providing recommendations for improvement. The study on Tanzania first described the state of industrial WM, focusing on resource recovery statistics, and then preformed a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) for each of storage, collection, transportation, processing/treatment and legislation. Neither study presented waste management goals or a framework of success against which the systems were assessed, but the recommendations imply that environmental and cost effectiveness were valued.

None of the above assessment methods were based on a framework of set waste management goals or principles, but rather were tailored to decision makers' goals and values. The lack of set principles has led to assessments focusing on and valuing environmental and cost effectiveness more than social acceptability. An assessment method based on the principles of ISWM would give equal consideration to social acceptability, environmental effectiveness and economic affordability.

Theoretically, existing waste management systems can be assessed according to the principles of ISWM. Van de Klundert and Anschutz (1999) created a list of qualitative and quantitative indicators that could be used to assess a waste management system according to ISWM (shown in Table 2.3). While they suggest that the higher values of these indicators a waste management system has, the more successful the system is at meeting the goals of ISWM, they also note that the indictors may be of varying importance and some may be contradictory. More work needs to be done to refine the indictors and determine an "appropriate weighting mechanism" (p. 15) "to weigh these different indicators against each other" (p. 10).

Table 2.3: Indicators for each aspect of waste management as determined by van de Klundert and Anschutz (1999, p. 10)

Aspect	Indicators
Technical	- amount of waste collected by area of the city - durability of equipment - existence of a separate hazardous waste management system - existence of preventive maintenance procedures
Environmental	- amount and % of waste recycled - extent of pollution of air, soil and water - amount of energy and natural resources saved through recycling
Financial	- degree of cost recovery - overall cost of waste management services provided - labour productivity (amount of waste collected per worker)
Socio-economic	- service coverage (% of citizens receiving minimum required waste collection service, e.g. twice a week) - working conditions (number and duration of sick leaves, health complaints) - user satisfaction with the service by area of the city
Institutional	- degree of formalization of informal sector (number of licensed community based organizations, co-operatives, micro-and small-scale enterprises) - existence of feedback mechanisms for citizens (complaint desks, etc.)
Policy/Legal	- degree of decentralization of authority and funds - height of budget earmarked for waste management

While most of the indicators suggested by van de Klundert and Anschutz (1999) seem reasonable, the indicators "degree of formalization of informal sector" and "degree of decentralization of authority and funds" assume that formalization and decentralization are more favourable than informal work and centralization. These assumptions may seem to be valid based on observed problems of the informal sector and centralization, but there are potential problems associated with formalization and decentralization as well. These assumptions contradict the principle of ISWM that waste management be tailored to the community.

2.9 Mexico: Classification as a Developing Country and Waste Characteristics

Mexico is classified as an upper-middle income country and had a gross national income [GNI] per capita of $8,340 USD in 2008 (The World Bank, 2010a; 2010b). It ranked 61st out of 182 countries by GDP per capita according to estimates by the International Monetary Fund (International Monetary Fund [IMF], 2010).

Waste composition, typical collection rates, resource recovery rates at the national level, and the average wage for a waste collection employee in Mexico are presented here to provide context and comparison to the case study. The composition of waste in Mexico in 1984 was reported to be 55%

organic, 15% paper, 6% metal, 4% glass, 6% textiles, 4% plastics, and 10% miscellaneous (Flintoff, 1984)[9]. The national collection rate has increased over time. The rate was about 70-77% circa 1997/8 (70% in 1998 reported by Medina, 2005; 77% reported in 1997 by Ojeda-Benítez & Beraud-Lozano. 2003) and increased to 90.1% by 2008 (*Secretaría del Medio Ambiente y Recursos Naturales* [SEMARNAT], 2009). Mexico has reported a national rate of recovery of resources from waste of 0.68% (Troschinetz & Mihelcic, 2009). The national average salary for waste collectors was reported to be 2,820 Mexican Pesos [MXN] ($238 CAD)[10] per month in 2004, which could be estimated to be 3,662 MXN ($309 CAD) per month in 2008 based on the increase in all wages in Mexico during that time period (International Labour Organization [ILO], 2010a; ILO, 2010).

2.10 Aguascalientes

Aguascalientes is a small state located in the centre of Mexico (Figure 2.1). The state had a population of 1,184, 996 in 2010 (*Instituto Nacional de Estadística y Geografía*, which translated is National Institute of Statistics and Geography [INEGI], 2010a). The largest municipality in the state is the municipality of Aguascalientes which largely consists of the capital city of the state, also called Aguascalientes. The municipality is 1,870 meters above sea level (*Consejo Estatal de Poblacion* [Coespo], 2006). The climate is arid overall, but has a rainy season from May to September with an annual average precipitation of 511 mm.

The population of the municipality 2010 was 797, 010 (INEGI, 2010a). No data on the population of the city in 2010 was found, but the populations of the municipality and city in 2005 were 723,043 and 663,671 respectively (INEGI, 2005). From 1990 to 2006, the municipality grew in population by an average of 2.6% per annum, and the city by an average of 4.1% per annum (Coespo, 2006). The city occupies a space of just over 10,000 hectares and had an average density of 66 persons per hectare in 2005.

The population of the municipality was 51.5% female in 2010 (INEGI, 2010a). Thirty percent (30%) of the population was under 14 years old, 65% was between the ages of 15 and 64, and 5% was 65 years old or older in 2010.

Based on indicators of education and access to public services, the state of Aguascalientes is the 5th least marginalized in Mexico (out of 31 states and one Federal District, *Consejo Nacional de Población* [CONAPO], 2005). The access to public services in Aguascalientes is high compared to other

[9] For more recent composition data see Addendum A.
[10] This, and all following monetary conversions, are based on the average exchange rate in 2009 of 11.837 MXN = 1 CAD reported by the Canada Revenue Agency.

states in Mexico with only 1.79%, 0.85% and 1.68% of the population in this state living in houses that lack piped water, electricity and drainage or sanitation services respectively in 2005 compared to 10.14%, 2.49%, 5.34% of the national population lacking those services respectively. The access to public services is even greater in the municipality with only 1.54%, 0.54% and 0.77% of the population lacking the aforementioned services respectively (*Gobierno del Estado de Aguascalientes*, 2006).

Figure 2.1: Map of Mexico showing the location of the state of Aguascalientes. Source: Google Earth, 2009.

The state of Aguascalientes had a GDP of 92,176 million MXN ($7,787 million CAD) in 2005 (INEGI, 2010b). This state had the 8th highest income per capita in Mexico in 2005 (assimilation of INEGI, 2010b and INEGI, 2005).

In the municipality, 33.1% of the employed population work in manufacturing and industry, and 61.8% work in commerce and service (Coespo, 2006). Women make up 36% of the work force. In 2005, the unemployment rate was 1.24% (INEGI, 2005). Minimum wage in Aguascalientes in 2005 was 44.05 MXN per day ($3.72 CAD) (*Servicio de Administración Tributaria* [SAT], 2010a). Figure 2.2 shows the wage distribution of the city of Aguascalientes.

The literacy rate of the population ages 15 years old and older of the municipality was 97% in 2000 (INEGI, 2000). The average grade of school complete by the same age category was 8.87.

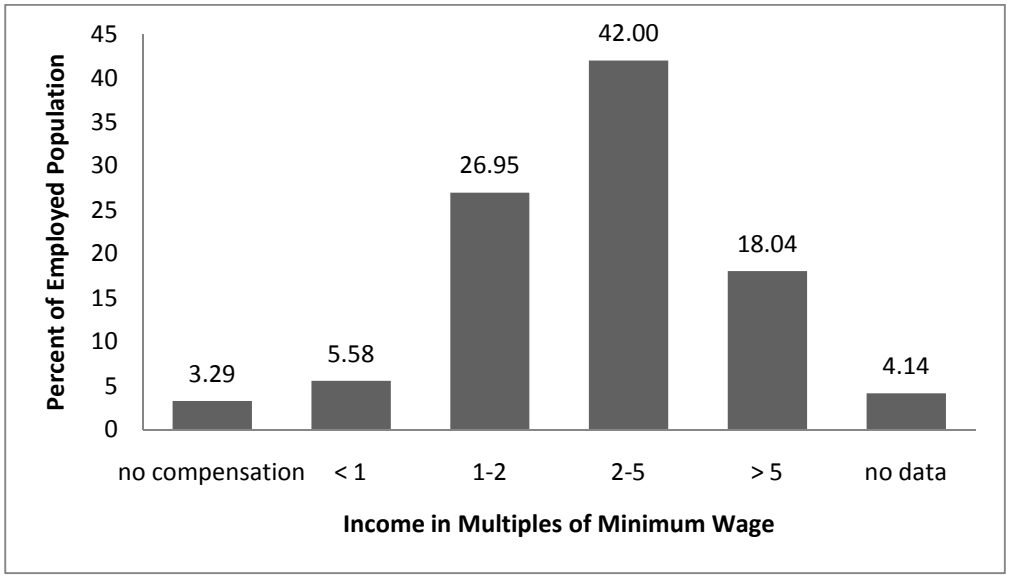

Figure 2.2: The wage distribution of the employed population in the city of Aguascalientes. Source INEGI, 2000.

The waste disposal system of the municipality of Aguascalientes has a positive reputation. Waste is disposed in an engineered landfill with an off-gas collection system that in the future will be used to power a portion of a car factory located in the municipality. This landfill received ISO 14001 certification based on the demonstration of the facility to meet the environmental policies of Mexico and other environmental and health standards set by the International Organization for Standardization [ISO][11] (*Secretaría de Servicios Públicos y Ecología*, 2007). This was the first landfill in Latin America, and the second in North America, to receive this certificate.

The municipality of Aguascalientes uses a CCC system to collect co-mingled waste. Approximately 4,600 containers are dispersed throughout the city and villages in the municipality (*Instituto del Medio Ambiente del Estado de Aguascalientes*, 2007).

[11] The ISO does not carry out certification for ISO 14001. Certification is performed by a third party. However the ISO does develop standards and guidelines for the assessment of conformity to ISO standards (ISO, 2011).

Chapter 3
Methodology

3.1 Introduction

This thesis used both qualitative and quantitative research methods. Three simultaneous phases of research were conducted in the months of September to December 2009. Phase One was the conduction of qualitative interviews with persons knowledgeable about different aspects of the waste management system in Aguascalientes. Phase Two was a quantitative questionnaire of households and businesses. Phase Three was a questionnaire of a small sample of informal waste collectors. While conducting the questionnaires, small buy/sell recycling businesses were encountered and asked questions regarding their activities. Since each phase involved humans, ethics approval was obtained. The consent forms, scripts and translator confidentiality agreement can be found in Appendix A.

The scope of this thesis was the city of Aguascalientes, not the entire municipality. The municipal waste collection department serves the entire municipality, but transportation and time constraints limited the field research to the urban area. The rural collection service differs from the urban service in that rural collection is once per week while urban collection is daily.

3.2 Phase One: Interviews with Persons Knowledgeable about Waste Management in Aguascalientes

Individuals who were knowledgeable about the various aspects of the waste management system were sought for interviews. The public relations officer of the *Secretaria de Servicios Públicos y Ecología* (the municipal secretary responsible for waste management) set up appointments for interviews and arranged a tour of the facilities. Interviewees included: managers or supervisors of each of waste collection, collection monitoring, recycling, the transfer and compaction station and the landfill; a landfill recyclables collector; a representative of a private energy-from-waste company; and a historian from the municipal archives. The researcher requested interviews with collection labourers but was granted none.

To capture the characteristics and processes of the waste collection system, interviews were conducted with both closed and open-ended questions designed to elicit information, and opinions. Table 3.1 shows the types of questions asked and their relations to different aspects of waste management. The interviews were conducted orally in Spanish through a translator and were audio recorded. Photos of the facilities were taken to enhance the description of the system. Interview information was supplemented

with information from municipal, state and federal websites. Economic information was gathered primarily from these sites. Spanish documents accessed online were translated using Google Translate: translate.google.com/*original website*.

Table 3.1: The framework for questions for Phase 1 interviews.

		Main Questions
Characteristics/ Processes		What are the characteristics and processes of the waste collection system?
Social Acceptability	Health	How does the collection system encourage/discourage the spread of disease and safe waste management handling?
	Stakeholder Involvement	Were/are stakeholders involved in planning the system? To what extent? Give interviewees the opportunity to voice their satisfaction, concerns and suggestions regarding the collection system.
	Education	Is waste education material available to the public? If yes, what information does it contain?
Environmental Effectiveness		How does the collection system mitigate environmental harm? What is the resource recovery rate?
Economic Affordability		Is the collection system financially self-sufficient?

To analyze the data, the researcher listened to the audio recordings and took notes from the translated English portions. Portions of the initial on-site translation of the spoken Spanish were verified by a second individual fluent in Spanish and English when there was doubt about the accuracy of translation.

3.3 Phase Two: Household/Business Questionnaire

The neighbourhoods of Aguascalientes were divided into three groups based on socio-economic indicators. Partitioning the neighbourhoods into these groups allowed for examination of the social equality of the collection system and analysis of whether or not socio-economic status is a factor of waste-related behaviours such as participation in waste collection activities. Education and income indicators from the year 2000 INEGI census were used to organize the neighbourhoods of the city of Aguascalientes into five socio-economic groups through k-means clustering on Predictive Analytics Software [PASW] (formerly known as SPSS). A k-means cluster analysis partitions data points into a specified number (k) of clusters with minimal variability within clusters and maximum variability between clusters (StatSoft, Inc., 2011).

Education and income variables that were missing data for more than three neighbourhoods with populations greater than 200 were not used in the k-means cluster analysis. Variables that were not

necessarily indicators of socio-economic status were also not included. For example, data about the number of hours worked existed but were not included because people who worked a small number of hours would include those who couldn't find more hours and were desperate for work (low income), and those who didn't need more hours and were not desperate for work (high income). The indicators used are shown in Table 3.2.

Table 3.2: The education and income indicators used to divide the neighbourhoods into socio-economic groups.

Education Indicators	**Income Indicators**
Population 6-14 years old that attend school	Employed population that receives less than minimum wage
Population 15 years old and up that are behind in school	Employed population that receives between one and two times minimum wage
Population 15 years old and up that have completed elementary school	Employed population that receives between two and five times minimum wage
Population 15 years old and up with junior high school or technical or commercial studies and have completed elementary school	Employed population that receives more than five times minimum wage
Population 15 years old and up with high school or university studies	
Population 18 years old and up with high school studies	
Population 18 years old and up with university studies	

Originally the k-means cluster tool was used to create three groups. However, of the first three neighbourhoods surveyed, one from each socio-economic cluster, little difference between their built forms was apparent, while a great amount of difference was observed between them and two commonly perceived socio-economically low and high neighbourhoods (Los Pericos and La Herradura respectively) which had also been surveyed. The long, flat sections of the curves of many of the socio-economic indicators seen in Figures 3.1 and 3.2 demonstrate that there are many neighbourhoods with mid-range values while only a few with high and low values for these indicators. The k-means alorgithm tends to create groups of similar size (MacKay, 2003). The number of nieghbourhoods in each group when the cluster analysis was used to create three groups were 63, 93 and 80, so the visibly large middle group was not grouped as such by the k-means cluster analysis. To ensure that the neighbourhoods surveyed represented the range of socio-economic statuses in Aguascalientes, another k-means cluster was preformed to create five clusters, the middle three of which were grouped together to create the middle socio-economic group. The resulting three groups are referred to in this thesis as SE Low, SE Medium, and SE High, based on their socio-economic [SE] status.

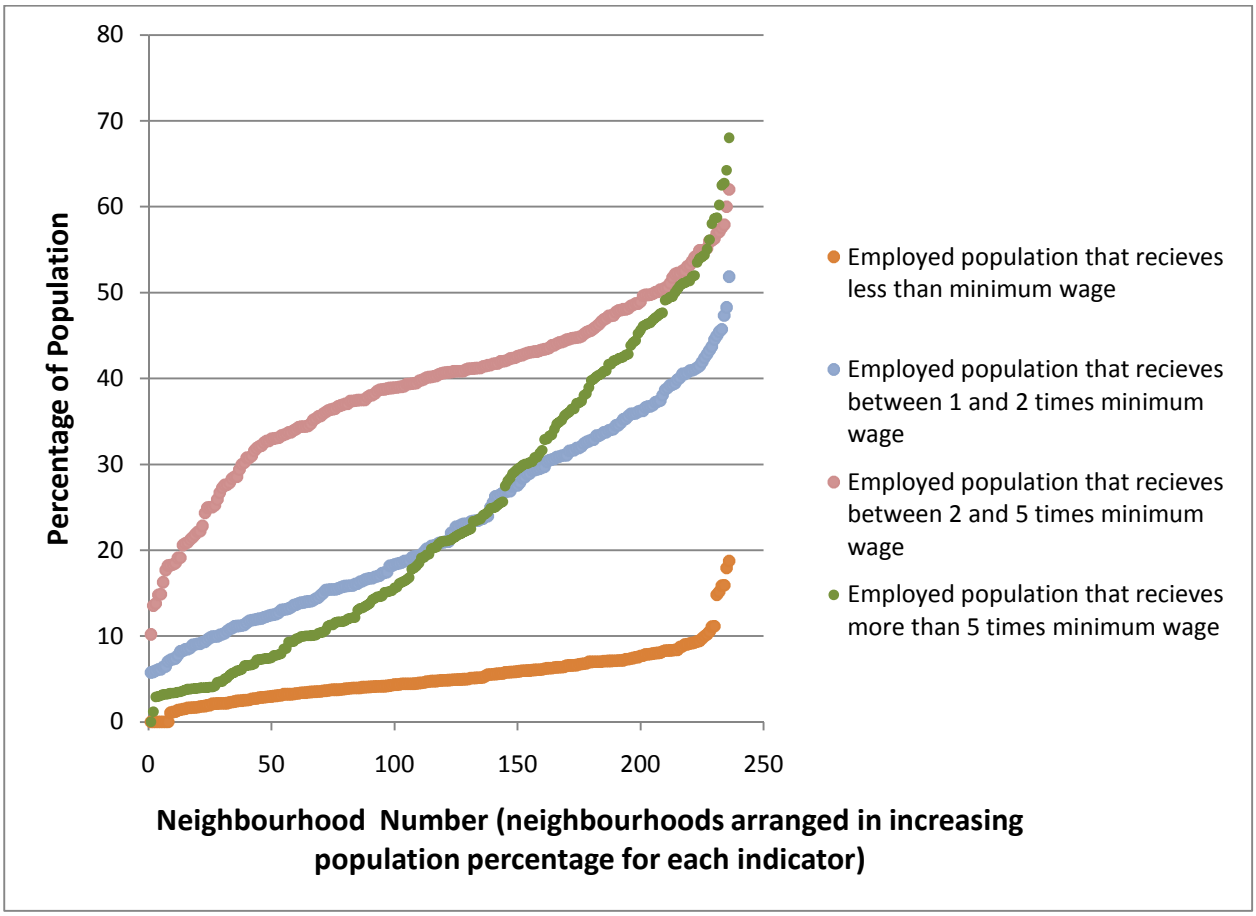

Figure 3.1: Income indicators as percentages of population versus neighbourhoods arranged in increasing order for each indicator.* Note the long middle sections of the lines that have small slopes relative to the low and high ends which have steeper slopes. This demonstrates that the group of middle income neighbourhoods is much larger than the low and high income groups. (*The indicators cannot be compared through this graph as the neighbourhoods are arranged in different orders for each indicator).

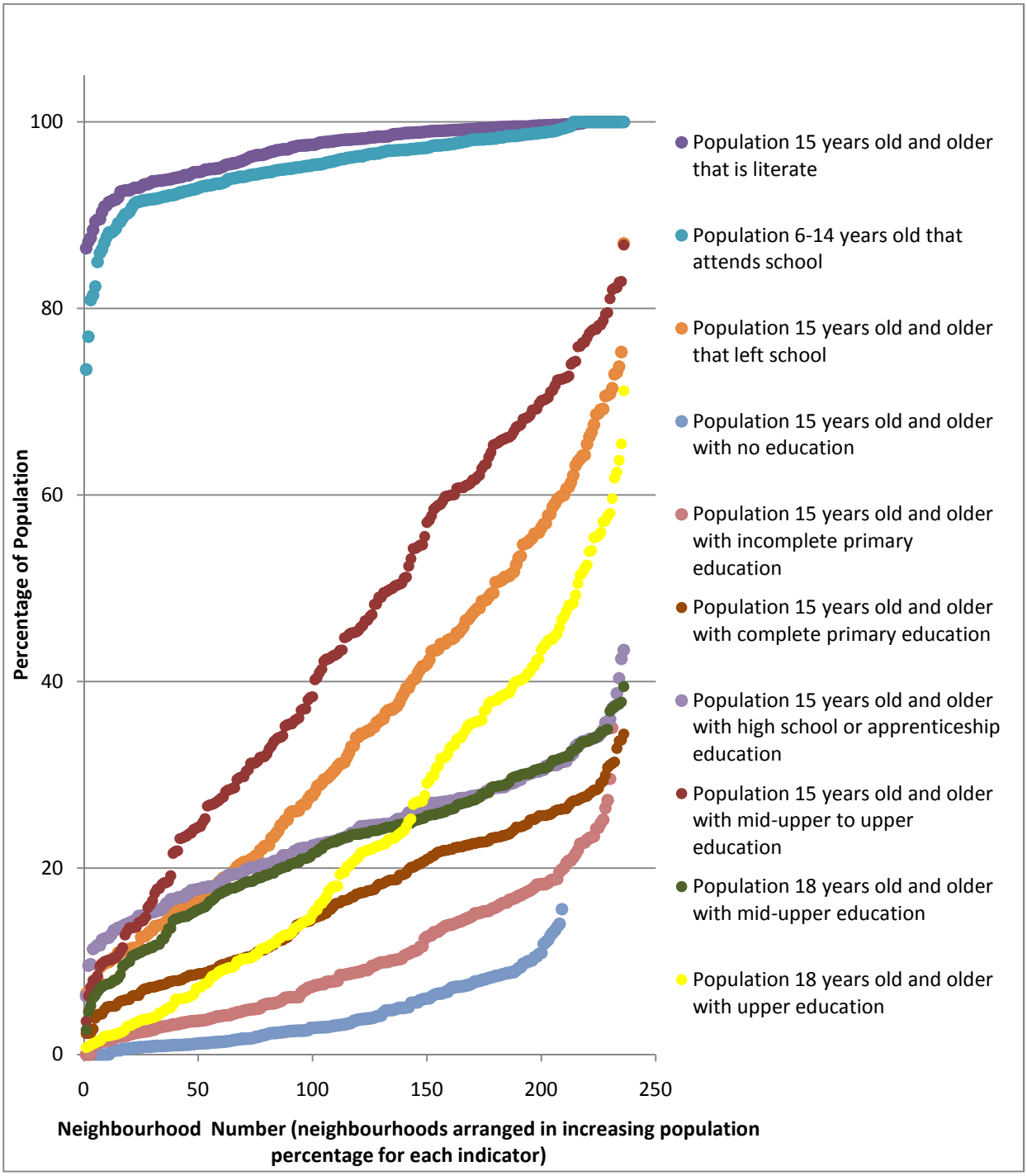

Figure 3.2: Education indicators as percentages of population versus neighbourhoods arranged in increasing order for each indicator.* Note the long middle sections of most of the lines that have small slopes relative to the low and high ends which have larger slopes. This demonstrates that the middle education group of neighbourhoods is larger than the low and high groups. (*The indicators cannot be compared through this graph because the neighbourhoods are arranged in different orders for each indicator).

Neighbourhood Selection

Three neighbourhoods from each socio-economic group were selected to be surveyed. One neighbourhood from each of the SE Low and SE High groups were suggested by an inhabitant of Aguascalientes and subsequently surveyed. Those neighbourhoods were Los Pericos (SE Low) and La Herradura (SE High). The remaining neighbourhoods were randomly selected according to the probability proportional to size [PPS] sampling method described by McGinn (2004) using the number of households in a neighbourhood as the size of that neighbourhood (rather than the number of residents, because the household, not the individual, was the sample unit). How to perform PPS sampling is explained in Appendix E. PPS sampling gave each household within a SE group equal probability of being selected at this stage of sampling, which increased the likelihood that the sample would be representative of the group (relative to sampling neighbourhoods with no consideration given to size). Random sampling avoids selection biases and allows sample results to be generalized to the population from which the sample was drawn. The website *Random.org* was used to generate a random number for this method of selection. The neighbourhoods surveyed are shown in Table 3.3.

Table 3.3**:** The neighbourhoods surveyed.

SE Low	**SE Medium**	**SE High**
Los Pericos Asentamiento Irregular	Del Trabajo	La Herradura
Vicente Guerrero	Casa Blanca	Bosques Del Prado Norte
Benito Palomino Dena	Libertad	Jardines De La Concepcion II

Many families in Aguascalientes, especially in SE Low and SE Medium neighbourhoods, operate small businesses out of their houses. For this reason, and because households and small businesses both use the containers, the questionnaire was designed for households and small businesses in residential areas. While selecting buildings to survey, households were not distinguished from small businesses with the intention of giving proportional representation to each building use in order to improve the accuracy of the understanding of the use of the containers.

Thirty buildings were surveyed in each neighbourhood. The sampling interval (*si*) for each neighbourhood was determined by dividing the number of households in each neighbourhood (as reported in the INEGI 2000 census) by the sample number of 30. (The number of households rather than the number of buildings was used because only these data were available.)

$$si = \#\text{ of households (from INEGI 2000 Census)}/30$$

A maximum survey interval of 20 was set for efficiency to save the time and energy of the researcher and translator. For $si < 20$, every $si/2$ building was sampled along one side of a street. For

si>20 every tenth building was selected along one side of a street. Surveying would commence at major entrance to the neighbourhood for convenience. A random number between one and *si*/2 (or one and ten if *si*>20) was chosen each time a new neighbourhood was surveyed to determine the first building from the entrance to sample. If there was no response at a selected building, or the resident/employee chose not to participate, then the adjacent building was selected and so on until a participant was found.

The household/small business questionnaire is provided in Appendix B. Questionnaires were conducted orally, face-to-face through a translator. Face-to-face surveying was chosen over mailed surveys to increase the response rate and remove the barrier of illiteracy to participation. Data was collected from any resident or employee present in each sampled residential unit as long as they were at least 16 years old and had knowledge of the waste activities in that household or business. The questions required either a numerical response or one or more of multiple response options. Multiple response options were not read aloud to avoid influencing the results by suggestion. Responses were briefly summarized if they did not fall into one of the multiple response options. Some of the questions pertained to the entire household or business, such as the waste quantity and composition questions, while others, such as the opinion questions, pertained to the individual. Table 3.4 shows the types of questions asked sorted by aspect of waste collection system.

Descriptive statistics were compiled and tests for significance were performed on the survey results. For the numerical results, including distance to container and amount of waste generated, means and standard deviations for all responses and each SE group were calculated and one-way analysis of variance [ANOVA] tests were performed to compare the means by SE group. Both the distance and waste generation data had to be transformed to meet the ANOVA assumptions of homogeneous variance and normal distribution. For the remainder of the questions which had nominal responses, the percentage of respondents that gave each response is presented for all respondents and each SE group. For questions that had several response options of which the respondent could only chose one, (such as "Do you know that there is a number on the containers to call in case of complaints?") Pearson's chi-squared tests were performed to determine the probability that differences in response frequencies by SE group were due to chance. For questions that had multiple response options, such as "What do you like about the waste collection system?", where respondents could have more than one "like", Pearson's chi-squared tests were performed on each individual response (i.e. for each "like") to test for a relationship to SE status. If more than 20% of observed results in a chi-squared table were less than 5, the test results were not considered to be valid in accordance with generally accepted convention.

Table 3.4: Base questions used to design the household/small business survey arranged by aspect of waste collection

Aspect of Waste Management			Questions	Results
Characteristics/Processes			How much and what types of waste are generated? What is the distance between the household/business and the nearest container?	- Mean amount of waste generated per capita - Mean, max/min distances to containers
Principles of ISWM	**Environmental Effectiveness**		What is the pre-collection resource recovery rate? Are efforts made to reduce/reuse/recycle/compost? What types of materials are reused/recycled/composted? How many residents are concerned about environmental health? What is the willingness to participate in more extensive source separation?	- Pre-collection resource recovery rate - % of households/businesses that reduce/reuse /recycle and/or compost - Types of materials diverted - % of respondents who are concerned about environmental health - % who are willing to participate in more extensive source separation
	Economic Affordability		Do the fees hinder the abilities of residents to feed, shelter, or clothe their family?	- % of respondents that feel fees affect ability to meet basic needs
	Social Acceptability	**Participation**	What is the participation rate? Are the containers properly used? How many people are knowledgeable about proper container use?	- % who use containers - % who adhere to each container regulation - % who know each aspect of container use (i.e. disposal schedule)
		Social Justice	Who manages waste within the household/business?	- Age and gender proportions of persons responsible for in-house/business waste management
		Benefits, Challenges, Suggestions	What are the positive and negative aspects of the collection system from the user's perspective? What are the user's suggestions for improvement?	- % who said each positive and negative aspect, and suggestion

3.4 Phase 3: Informal Waste Collector Questionnaire

According to convenience sampling described by Neuman (2007), informal collectors were approached when they were observed collecting waste from communal containers and asked if they would participate in a questionnaire. The sample size was small (n=12). Participants were asked questions regarding: demographics (age, gender); amounts and types of materials collected; collection practices

(times, locations, safety equipment used, to whom recyclables are sold); frequency of illness and/or injury; and opinions about the waste collection system. The informal collector survey is provided in Appendix B.

3.5 Data Collection from Buy/Sell Businesses

While conducting the household/ business questionnaire, small buy/sell recycling businesses were encountered. To ensure information from this sector of waste management stakeholders was included in this study, the business owners were asked if they would participate in a short survey. The questions asked pertained to the types and amounts of recyclables bought and sold, and prices at which recyclables were bought and sold. These businesses were not included in the household/ business questionnaire.

3.6 Limitations

The main limitations of this thesis were the potential miscommunication due to the language barrier, the possible respondent hesitance to disclose information due to the lack of anonymity, human error in performing estimations, the sampling methods which limit the generalizability of the results, the volume-based waste quantity measurements and the lack of inclusion of formal waste collection employees in the study. The impacts of these limitations on the results range in severity.

The questionnaires were conducted orally, face-to-face, to ensure the illiterate could participate. Although the participants' names were not recorded, the face-to-face method reduces anonymity so the participants may have wanted to give what they perceived as favourable responses. During the questionnaire phase, after the researcher and translator agreed that this might be occurring, subsequent respondents were asked to respond honestly. In the results section, questions are noted which were thought to consistently have been given favourable answers before the qualification that questions be answered honestly was added.

The questionnaires and interviews were conducted through a translator. The translator was not a certified academic translator, so before translation activities commenced, the importance of thorough and accurate translation was discussed. Completely conveying intended meaning is difficult when translating, so some details said in the interviews and questionnaires might have been missed or misinterpreted (Crane, Lombard, & Tenz, 2009). Also, the researcher was foreign to Mexico and may have misunderstood things said or done by respondents due to cultural differences. A few sporadic miscommunication or translation errors amongst the questionnaires, of which a large number were conducted, would not adversely affect the results because the errors would be masked by the large amount

of real results. However, consistent translation errors or miscommunications would skew the results. For questions where consistent miscommunication is suspected to have affected results the possible error is noted and discussed. The interviews were recorded so suspected translation errors were easily checked and corrected by a second translator.

Human error is introduced into the results wherever estimates are requested. The amounts of wastes generated, disposed and recovered, and waste composition were estimated by respondents so these data vary between respondents in accuracy. The generation, composition and recovery results cannot be certainly considered to give an accurate picture of the waste in Aguascalientes, so comparison of these results to waste in other areas must be made with the potential inaccuracy kept in mind. The results do however give a rough idea of the generation, composition and recovery of the waste in Aguascalientes and for this reason are valuable.

Although efforts were made to sample randomly and proportionally to neighbourhood size, two neighbourhoods were not randomly sampled and sampling within large neighbourhoods was not evenly dispersed, so the generalizability of the results was compromised. The SE Low neighbourhood Los Pericos and the SE High neighbourhood La Herradura were surveyed before a method of clustering was determined. Since these neighbourhoods were not randomly selected from their corresponding SE group, results with these neighbourhoods included are less generalizable then without them. However, including these two neighbourhoods in the study did provide valuable insight into the range of waste collection service provision.

Due to the small sample size, the results of the informal collectors' survey are not generalizable to the entire population of informal collectors in Aguascalientes. However valuable insights into the lives of informal collectors were gained through those surveys.

The estimates are volume-based rather than weight-based. Most other research on waste quantity is weight-based so these results cannot be accurately compared to those of other studies. Volume-based estimates were requested because volume was thought to be easier to estimate then weight. Weight-based measurements are more reliable as weight is consistent despite physical changes, whereas volume is affected by compaction. Comparisons of waste quantity and composition in Aguascalientes to weight-based waste measurements from other studies must be made in consideration of the densities of each waste material. Despite this limitation, volume-based measurements still have value as they show trends in waste composition and generation by income.

Although the researcher asked to interview formal collectors, no interviews were granted. Had these stakeholders had been interviewed, the description of the collection process would have been richer,

and a more accurate understanding of the social impacts of the collection system on these employees would have been acquired.

Chapter 4

Interview Results: A description of the waste management system in Aguascalientes

The interview results and information from government websites have been arranged into a description of the current waste management system and the future recyclables collection system in Aguascalientes. Some sections are supplemented with field observations. Indication is made when this occurs.

4.1 History

In the 1980s, rapid population growth and an increase in the waste generation rate created pressure for a more efficient method of waste collection. In 1987 the amount of waste generated by the city increased from 200 tonnes per day at the start of the year to 300 tonnes per day by the end of the year. The current container system was not created from scratch to replace a different system; rather, the current method of collection evolved from previous practices of waste storage and collection. Before the current container system existed in Aguascalientes, residents would take their waste, usually in bags or boxes, to designated street corners and leave them in piles on the ground for collection. The first large containers used to store waste until collection were large tanks that had been used to deliver water to neighbourhoods. The first official use of containers for waste collection was in 1987 as a part of the *Ciudad Limpia* (Clean City) strategy which was created in response to the rapidly increasing population (4.1% per annum between 1990 and 2006) and corresponding increase in the amount of waste produced. The first containers were $1m^3$ and $6m^3$. During collection, full containers were swapped with previously emptied containers and transported to the landfill for emptying. This process was inefficient, and the current collection system was designed and implemented in early 1991 for greater efficiency of collection.

The company that designed the containers and compaction trucks, named SR, is located in the city of Aguascalientes and was founded in the early 1980s when the company designed and obtained a patent for a system to transport bottled products, for which the company has contracts with major beverage corporations (Grupo SR, n.d.). When the company became involved with the design of the waste collection system in Aguascalientes, it sent representatives to several countries including the USA, Canada, Spain, France, Germany, Holland and Japan to study how waste was collected in cities in those countries. As a result of those trips, SR made agreements with major US companies to market those

companies' products to Aguascalientes to improve waste collection in the city. In the late 80s, SR received a contract, by the order of the governor of the state and the mayor of the municipality, to modernize waste collection in Aguascalientes. The manufacturing of the containers and compaction trucks occurs in Aguascalientes.

4.2 Municipal Organization

Within the *Secretaria de Servicios Públicos y Ecología* (Secretary of Public Services and Ecology) of the municipality of Aguascalientes there are two directorates with waste-related responsibilities. The *Dirección de Limpia y Aseo Público* (Directorate of Cleanliness and Public Sanitation) is responsible for street sweeping, waste collection, waste disposal and other activities[12] (*Instituto Municipal de Planeacion Aguascalientes* [IMPLAN], 2009). Within this directorate, the *Departamento de Recolección* (Department of Collection) is responsible for waste collection and transfer. The *Dirección de Ecologia y Salud* (Directorate of Ecology and Health) is responsible for the planning and operation of environmental education and recycling programs, but also pest control, environmental clean-ups, ISO regulations and ecological zoning.

4.3 Waste Collection Process

There are currently about 4,600 municipal waste containers distributed throughout the municipality of Aguascalientes. All neighbourhoods in Aguascalientes are provided with containers which are supposed to be, and usually are, emptied daily. In this sense, the service coverage is 100%. The containers are painted yellow and almost all have the number to call with complaints or questions, the container number, and the schedule for waste disposal painted on them. Three sizes of containers are used in Aguascalientes: 1.3m^3, 2.6m^3 and 5.5m^3 (see Figure 4.2). The largest size serves approximately 100 households and the medium size serves 50 households. The smallest size is considered to be inefficient and is being phased out. There is also a project in the works to phase out the medium containers leaving only the largest containers which are the most efficient for collection.

[12] In the municipal budget, this department's programs were listed as: Citizen Awareness and Inspection; Administrative Process and Citizen Service; Program of Urban Solid Waste Collection; Solid Waste Disposal; and Annual Program of Cleanliness and Public Sanitation.

Figure 4.1: The container number and schedule painted on the container.

Figure 4.2: The three container sizes from smallest to largest (left to right): 1.3m^3, 2.6m^3, and 5.5m^3.

Containers are placed on streets, not sidewalks, to allow for rear-loading truck access. The size of container is based on street width and length. The specific placement of each container must adhere to municipal regulations for the collection system.[13] These regulations define the distances the containers must be from the sidewalk, doors, windows, hospitals and places where food is sold. For example, containers must be at least 20cm from the sidewalk. In addition to adhering to placement regulations, municipal employees try to place the containers where they won't be bothersome to residents and traffic, but also where they won't be very far away from where most people live, since most people, including the elderly, walk to containers to dispose waste.

Container maintenance and repair is the responsibility of a department within the Directorate of Cleanliness and Public Sanitation. This department is responsible for checking the containers regularly for needed paint jobs, repairs or replacement and can also build containers. However, most container

[13] These regulations have ISO 2001 certification indicating that they adhere to state and federal environmental regulations. However, the researcher was unable to find ISO 2001 on the ISO website.

manufacturing is done by private companies. The 2.6m^3 container costs about 10,000 MXN ($845 CAD) and the 5.5$m^3$ container costs about 18,000 MXN ($1,520 CAD). Small containers are no longer manufactured. The average or expected lifespan of a container was not asked.

Aguascalientes is a rapidly growing city with many new residential developments that require containers. As a part of the approval process for new developments, proposals are sent to the Directorate of Cleanliness and Public Sanitation which will ensure that the streets will be wide enough for collection trucks and containers. This directorate will inform the developer the number of containers needed, which the developer must provide, but which then become property of the municipality. The developer is to obtain sufficient containers for the entire neighbourhood by the time construction is complete, but only place as many out on the streets as necessary as the neighbourhood becomes occupied.

Each container is emptied by a three man crew, with two collectors and one driver, using one of the city's 49 compaction trucks. Before every run, the driver must perform a vehicle check during which he checks the oil, water, mirrors, and winch. Everything must be in order and a report stating this must be filled out. The time required to empty each container, from when the truck is parked to when the truck departs, is about three to four minutes. Before a container is emptied, the collectors may collect a few recyclables from the containers and store them in a bag that hangs off the side of the truck. These recyclables are kept and sold by the collectors as supplementary income. To empty a container, the truck is backed up to one end of the container such that a bar running along the edge of the container rests on hooks at the base of the back of the truck. The hook from a winch attached to the top of the truck is attached to the other side of the container such that as the winch is tightened, the container is tilted and emptied into the truck. While the container is tilted, the inside of it and an area 2m^2 around where it rests are swept in accordance with ISO 2001 regulations. A 'wand' is touched to a microchip attached to the bottom of the container (a system further explained in the Microchip System subsection below). The truck mechanically compacts waste towards the front of the truck. Figure 4.3 shows the container emptying process. The collection truck either takes waste directly to the landfill or to one of the two compaction and transfer stations in the city, whichever is closest.

Figure 4.3: The container emptying process.

There are 44 waste collection routes in the city, all of which operate daily. Twenty seven (27) routes run during the day and the other 17 operate at night. Forty-one (41) of the routes are free (no service fees) and for the use of the public, one route collects from public schools, and two routes provide paid-for service to large commercial establishments (office buildings, supermarkets and some restaurants), hospitals, factories and some condominiums and gated communities that chose not to use the free service. The number of containers emptied per route depends on the sizes of containers and ranges from 70 to 140. The average distance of a route is 60-80 km and each route fills the collection truck about 2.5 times. There are two shifts of collection in the city per day: morning, from 8am-3pm, and night, from 7pm-2am. Morning routes generally collect from the outer edges of the city while night routes collect from the centre of the city to avoid daytime traffic.

Waste is collected from rural areas of the municipality twice per week. There are fewer pick-ups from these areas because of the distance to them, the difficulty of collection due to dirt roads, and the low waste generation rates of the small populations. If these communities grow, the municipality will place more containers in them and maintain the number of pick-ups rather than increasing the frequency of pick-ups which would be more costly.

The city experiences a rainy season which runs from June to September with an average rainfall of 526mm per season. Collection during the rainy season is difficult because the ground is slippery, the waste is heavier and workers are more often sick. The collection process during rainy season remains the same as the rest of the year with the exception that the collection employees wear brightly coloured rain suits. Most of the containers have lids, which would reduce rain accumulation in the containers, but these are usually not closed. Whether or not the containers have holes for drainage was not ascertained. Leachate draining from containers would cause foul odours on streets and would eventually be washed into soil or waterways causing ground and water pollution.

The Department of Collection has a route monitoring department that is responsible for collection monitoring and report creation. Reports are made on the physical states and saturation levels of the containers at the time of collection, the time taken to empty each container, the speeds of the trucks and, if any containers were not emptied, which ones and why. The data for these reports are collected through microchip and Global Positioning System [GPS] technology.

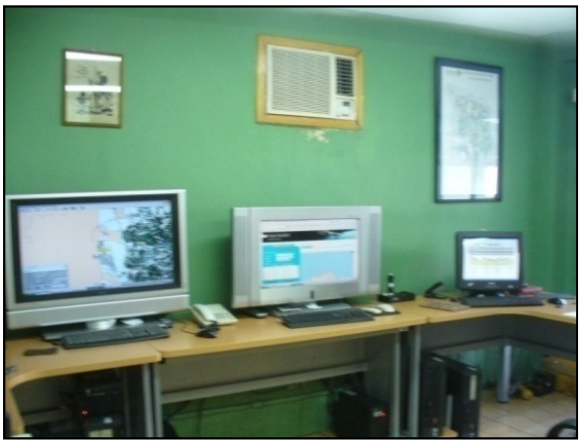

Figure 4.4: Route monitoring office.

A microchip containing a unique number is attached to the base of every container. In every truck is a panel of microchips, with each microchip being associated with a level of fullness, physical state of container or reason why the container was not emptied (see Figure 4.5). The collector will touch the microchip on the bottom of a container with a wand then touch any applicable microchips on the panel to record the fullness and condition of the container. If a container cannot be emptied, its microchip cannot be touched, so the microchip on the panel corresponding to the reason the container cannot be emptied would be touched. The wand stores this data which is later downloaded at the waste collection office for record creation. The microchip reading wand costs 4,000 MXN ($338 CAD). Aguascalientes implemented this technology in 2001 and was one of the first cities in Mexico to do so. This technology

allows for easier and faster reporting than paper and the reports created help ensure all of the containers are emptied daily.

a) b)

Figure 4.5: The front and back sides of the microchip panel carried in every collection truck. Translation starting at the top proceeding down and from left to right: a): Amount of waste - container ½ [full], container ¾ [full], container full, container saturated [overflowing], Reason not emptied - container without button [microchip], container blocked (i.e. by vehicles), container unofficially relocated, container up-side-down. b): State of the Container - good state, without covers, paint peeling, hit (i.e.by a car), perforated, burned, corroded, without holes (for the winch hook, due to corrosion).

One of the "amount of waste" microchips on the first panel is "container saturated" or overfilled. Overflowing containers are occasionally encountered, and when they are, the collection workers make a record of the occurrence using the microchip panel, and clean up the waste on the ground around the container. Overfilled containers are encountered most often on Mondays when residents dispose the weekend's waste and after special markets, festivals, special events and Christmas (see Figure 4.6). In anticipation of greater amounts of waste produced during festivals and markets that are at least one week long, collection services will place extra containers and/or larger containers in the affected areas. Containers found to be overflowing regularly not in relation to a special event, but rather due to an overall increase in waste generation and/or population growth, are permanently exchanged for larger containers.

Figure 4.6: An overfilled container in SE Low neighbourhood Benito Palomino Dena containing burning waste. The large amount of waste was generated during a market the day before.

Every collection truck has a GPS that transmits information directly to the route monitoring office. With this information the locations and speeds of all the trucks in the city are monitored. A computer in the collection monitoring office displays a map of the city with icons showing where the collection trucks are. At several points along each route the time and speeds of the trucks are recorded. A report is automatically created that shows if and which trucks were speeding or stopped for longer than three minutes (the amount of time required to empty a container). The GPS in each truck costs 10,000 MXN (about $845 CAD). Other cities in Mexico also use this technology.

Hazardous Wastes

There are two types of dangerous waste as defined by the *Secretaria de Servicios Públicos y Ecología*: waste that is dangerous, or hazardous, to health, including items that are corrosive, reactive, explosive, toxic, flammable and biological (infectious) such as solvents, fuels, acids, and hospital waste (that are herein referred to as hazardous waste); and waste that is dangerous to the collection equipment such as large branches or tree trunks, furniture and construction waste. None of these items are permitted in the containers. In this thesis the term “items not permitted in the containers” encompasses both of these types of waste.

If a resident wants to dispose of any of the above items, the waste collection manager said they are to contact the department, which they can do by calling the phone number on the containers, and the municipality will arrange for those items to be picked up and taken to the proper disposal location. This explanation disagreed with a request form on the municipal website which explains that residents can contact the municipality for free pick-up of furniture, dead animals, and other items that are not permitted

in the containers, except for hazardous waste, for which neither the form nor the website offer disposal instructions. If collection employees see dangerous waste in a container, they must call the supervisor and a special truck will be sent to empty that container. Waste that is dangerous to the collection equipment but not to human or environmental health is taken to the landfill, while waste that is dangerous to health is taken to a hazardous waste facility located outside of San Luis Potosi which is about 150 km northeast of the city of Aguascalientes.

The collection manager was not asked how the above information about types of hazardous waste and items not permitted in the containers, and how to dispose them, is communicated to the public. There was no signage about hazardous waste observed on or near the containers.

Collection Employees

The municipality employs 234 collection workers. All collection employees observed were male. Whether or not there are also female employees was not asked. Each day, about 80-90 work during the daytime and 60 work at night. For every five days of work each worker receives two days off. They have ten days of holiday every six months. If an employee works a holiday he receives extra pay. The salary for the truck driver is 1,400 MXN per week ($118 CAD) and the salary for the general collection employees is 1,000 MXN per week ($85 CAD). The average salary per month for a collection worker in Aguascalientes of 4,533MXN is 1.2 times more than the national average monthly salary for collection workers in 2008[14]. The general collection employees' salary is 3.8 times minimum wage (SAT, 2010b). This salary falls into the '2-5 times minimum wage' category, which was the largest category in Aguascalientes in 2005 with 42% of the employed population receiving wages within this range (INEGI, 2000). The drivers' salary is 5.4 times minimum wage and falls into the 'greater than 5 times minimum wage' category into which 18.04% of the employed population fell in 2005.

The municipality has created safety protocols to which all collection employees must adhere. Briefly, the safety protocols mandate the equipment employees must wear and the safety training they must take. Safety equipment includes: gloves, hard safety glasses, steel-toed boots, mask, helmet, a back-support belt, and municipal uniforms with bright colours and light reflecting strips (see Figure 4.7). The employees learn in safety training they must stand back from the container during emptying in case the container falls. This rule was made after a container fell on and killed an employee.

[14] The national average salary for a waste collection employee in Mexico, extrapolated from 2004 rates, was 3,662MXN per month in 2008 (ILO, 2010a; ILO, 2010).

Figure 4.7: The safety equipment and uniform of the collection employees.

On average there is one injury among the collectors every two weeks, or 26 injuries per year, yielding a probability of injury of 0.11 for each employee. For comparison, from 2004-2008 inclusive there was an average of 3,077 injuries in the workplace out of every 100,000 workers in Mexico (ILO, 2010b), which yields a probability of injury of only 0.03. Therefore waste collection employees in Aguascalientes have a 3.7 times greater risk of acquiring injury than other employees in Mexico. This rate of risk is less than those reported by Cointreau (2006) for other countries, both developed and developing.[15] Most injuries in Aguascalientes are mild such as mild back and shoulder injuries, or badly bruised elbows. About one serious injury occurs each year. Serious injuries have included crushed hands, lost fingers, permanent back or knee injuries, broken bones and death. When workers are injured, their medical expenses are covered and they receive compensation for lost workdays. In case of death, the family receives compensation. None of the above information was verified by a collector.

4.4 Compaction and Transfer Stations

At compaction and transfer stations waste from collection trucks is compacted into large containers for delivery to the landfill. There are two compaction and transfer stations in Aguascalientes, one in the northwest end of the city that has been in operation since 2001, and one in the south that has been in operation since 2006. Compaction and transfer stations improve fuel and vehicle efficiency of collection when the distance of waste transport is considerable enough to warrant them. In this case, the first compaction and transfer station was built shortly after the current landfill, which is further from the

[15] Denmark- 5.6 times greater risk of injury; USA- 10 times greater risk of death; Brazil- 43 times greater risk of injury (Cointreau, 2006; ILO,2010b).

city than the previous landfill, started operating in 1998. The current landfill is about 7km east of the edge of the city.

The north station was designed and constructed by a Spanish company using mostly Spanish materials and equipment, while the south station was made by a Mexican company (owned by a former employee of the Spanish company) out of Mexican materials and uses Mexican equipment. The transfer and compaction station supervisor interviewed believed the Spanish station's ramp to be of better quality and more durable.

All collection trucks are weighed at the transfer and compaction station before and after emptying to record mass of waste passing through the stations. After the initial weighing, each collection truck drives up a ramp and deposits its contents into a chute (see Figure 4.8). An employee looks down the chute to check for hazardous waste such as propane tanks. If the waste is deemed safe, it is compacted into a large container that, when full, is lifted on to a truck and transported to the landfill. Waste from about 3-3.5 collection trucks fills a compaction container. Each large truck makes six to seven trips to the landfill per shift, with two shifts, day and night, per day. The municipality owns five large trucks that transport the compaction containers, four of which are used regularly leaving one available for emergencies.

Waste is heavier during the rainy season with the waste in a compaction container weighing about 40 tonnes in the wet season and about 22-24 tonnes in the dry season. An average total of 550 tonnes of waste pass through the transfer stations each day.

Figure 4.8: The north compaction and transfer station in Aguascalientes.

4.5 San Nicolas Landfill

The engineered San Nicolas Landfill has been in use by the state of Aguascalientes since December of 1998. The landfill was intended to serve the municipality of Aguascalientes only, but before construction was completed a decision was made that the landfill would also serve the entire state. This was feasible because the municipality contains about ¾ of the population of the state, and the state is small in size (5589km^2, Gobierno del Estado Aguascalientes, 2010). The landfill was expected to last 15 years serving only the municipality, and now is expected to last 14 years serving the state. It is located about 5km east of the city, is 42 hectares large and contains four sections, three of which are filled and closed. The current section had 1.5-2 years of space remaining as of September 2009. A 5th section is being developed.

The landfill is engineered and has plastic liners covered with tires to prevent puncture of the liners, a leachate collection system, and an off-gas collection system (see BIOGAS section). Waste is compacted in layers 2.7m deep with 30cm of fine sand between each layer to a total depth of 40m. Clay is the preferred material to separate layers of waste, but is not locally available.

Figure 4.9: Unfilled section of the landfill.

There is no tipping fee for municipally collected waste from the municipality of Aguascalientes. The tipping fee is 185 MXN/tonne ($15.63 CAD/tonne) for all the other municipalities in the state, and 200 MXN/tonne ($16.90 CAD/tonne) for private companies. This is relatively low compared to developed countries. The tipping fee for general refuse at the Waterloo Regional Landfill is $68 CAD/tonne (Region of Waterloo, 2010).

All of the waste trucks entering the landfill are weighed before and after tipping to determine the amount of waste disposed in the landfill. The landfill receives 900-950 tonnes of waste daily from the state. More than 600 tonnes of that waste are from the municipality of Aguascalientes. The average daily per capita generation rate for the state is 0.79kg. The waste produced by the state is about 40% inorganic, 50% organic and 10% non-recyclable inorganic (including unsanitary waste such as bathroom paper).[16] As a part of a strategy to adjust to the growing population and subsequent increasing amount of waste produced, the mayor of the municipality and governor of the state were in the process of creating a new law mandating that all of the waste in the state of Aguascalientes be compacted before entering the landfill in order to extend the life of the landfill.

The San Nicolas landfill does not accept hazardous waste as defined above. Items that are dangerous to collection equipment and not permitted in the containers are accepted into the landfill. Municipal waste trucks are required to be checked for hazardous waste before arriving at the landfill so they are not checked again, but private trucks are checked by landfill employees before they are allowed to tip. If hazardous waste is brought to the landfill, the truck driver is given a rejection letter and must proceed directly to the privately operated hazardous waste treatment facility outside of San Luis Potosí where he will be given a letter verifying that the hazardous waste was disposed there. If hazardous waste is discovered in the landfill, caution tape will be put up and a truck from San Luis Potosí will be called to pick up the waste.

An independently organized group of 166 collectors was contracted by the municipality to collect recyclable material from the landfill. Security at the landfill is strict and only collectors from this group are permitted to collect from the landfill. The collectors are given 20 minutes to collect recyclables after a truck dumps waste before that waste is compacted.

The group is run by leaders who collect 120 MXN ($10.14 CAD) per week from each collector as insurance that is used to pay medical bills and support workers if they experience a work-related injury or illness. To prevent injury and illness, each collector wears a medical mask, safety glasses and gloves, and must be vaccinated (against which diseases was not learned). The leaders organize the workers into shifts such that there are collectors are working 24 hours per day, 365 days per year. The collectors organize themselves to collect different types of recyclables. Each collector owns what he collects and either transports them off-site to sell if he has a vehicle, or sells directly to buyers who have permission to enter the landfill. Only males were observed collecting: whether females also collect was not asked. The efforts

[16] The bathroom paper clogs the sewer system in Aguascalientes, so is not flushed.

of the landfill collectors result in 27 to 50 tonnes of recyclable material being removed from the landfill per day (3-5% of all waste) (values from the recycling interview and landfill interview respectfully).

Figure 4.10: Recyclable plastic bottles collected from the landfill.

4.6 BIOGAS

BIOGAS is a British company whose mandate is to reduce greenhouse gas emissions. This company reduces greenhouse gas emissions in developing countries including China, Mexico, Brazil, Chile, Dubai and Peru and generates revenue by selling carbon credits to companies in developed countries.

At the San Nicolas landfill, BIOGAS pays the municipality for permission to collect the gases produced by the decomposition of waste in the landfill. Off-gases are collected through wells (holes supported by cages filled with rocks distributed evenly throughout the landfill), piped to flares and cleanly burned. Through burning, methane, a greenhouse gas that is five times stronger than carbon dioxide, is converted into carbon dioxide. In the future, when the landfill is producing off-gases at an adequate rate, two gasoline engines will be setup at the landfill to convert the off-gases into electricity that will be sold to a local Nissan factory.

Figure 4.11: BIOGAS flares that cleanly burn methane. Only the flare on the right was in use when this picture was taken. The flares, which were designed in the UK, convert methane to carbon dioxide at an efficiency of 99.9999%.

BIOGAS shares waste management knowledge and standards from the UK with the municipality to maximize the biogas production rate. For example, BIOGAS suggested that the depth of layers of the waste be increased beyond 2.7m to increase gas production. The interviewee from BIOGAS also suggested that the municipality improve their leachate control system by using a less permeable capping material such as clay, and/or improving the drainage system so all of the leachate is drained.

4.7 Recycling Strategy

The *Dirección de Ecología y Salud* (Directorate of Ecology and Health) of the municipality of Aguascalientes, which is responsible for recycling programs and other environmentally beneficial programs, currently offers several recycling programmes (listed in Table 4.1). Through these programmes the municipality collected 1,533 tonnes of recyclables from 1999 to 2009. In 2009, the composition of recovered materials was 53.1% paper and cardboard, 30.4% plastic, 11.2% glass, 5.0% scrap and 0.30% aluminum. The amount collected annually has increased over time. From 2007 to 2008 the recycling rate increased 3% and from 2008 to 2009 the rate increased 7%. In 2009, 424 tonnes were collected. From 2009 to 2010 the rate is expected to have further increased due to the addition of the electronics and laminated cardboard recycling programs.

Table 4.1: Recycling programs in the municipality of Aguascalientes. Sources: Medina, 2009; Interview with the Recycling Planner. (The program names do not all translate well.)

Program Name	**Program Description**
Recycling Collection Centres	13 centres throughout the city located in the parking lots of major shopping centres for the collection of residential recyclables
Municipal Friend	Residents of low income areas exchange recyclables for food and household goods
Sustainable Municipality	Containers for the segregation and collection of recyclables were placed in municipal offices
Recycling Christmas Trees	Christmas trees collected and mulched
Playing and learning to manage my waste	Kids exchange recyclable material for sports equipment (skates, bikes)
Recycling electronic waste	Commenced in August 2009. A partnership between the municipality, a private company *Recicla Electrónicos México,* and the University of Aguascalientes for the collection and recycling of electronic waste
Recycling laminated cardboard containers	Commenced in 2009. Private company involvement: *Leche San Marcos* (milk company that packages with Tetrapak), *Tetrapak* (producer of laminated cardboard) and *San José* (producer of recycled paper products)
Get rid of your tires	Tires burned for energy to manufacture cement. Private company involvement: cement manufacturer *Crux Azul.*
Aguas put your batteries	Containers for collection of batteries in 80 convenience stores in the municipality
Markets' compost	Some markets in the city compost the organic waste produced in them

Figure 4.12: A municipal recycling centre. Two employees receive and sort recyclables.

There are no public engagement forums to garner stakeholder involvement and input prior to the implementation of recycling programmes, but the public can submit proposals for programmes. Proposals received by the *Director de Ecología y Salud* (Director of Ecology and Health) are assessed by him according to environmental impact and resources required to determine whether they should and can be implemented. Three of the existing recycling programs were proposed by residents .[17] Some programs were proposed by the private companies or universities involved in them. A program in development at the time of the interview was proposed by students from a local university.[18] To educate the public and to promote recycling, the municipality teaches public school children about recycling through an environmental education school, requires all university first year students to take a two week course that promotes environmental awareness, advertises the recycling programs to the public at large through radio announcements, and holds bi-annual recycling promotion events in the city centre.

Many low income residents of Aguascalientes collect recyclables from the waste containers for use or sale. The director could not estimate the amount of recyclables recovered by informal collectors and explained that this amount would vary depending on the price of recyclables and the unemployment rate. At the time of research, the unemployment rate and price of recyclables were relatively high so the recovery rate by informal collectors was also expected to be high. The resource recovery efforts due to informal collectors are not considered by the Directorate when calculating the overall recovery rate.

At the time of research for this thesis, the municipality of Aguascalientes was planning a program for the segregation and collection of recyclable materials through the use of specified containers. Three large containers, one each for metal, plastic and paper/cardboard will be placed in every second neighbourhood near locations that residents visit at least once a week such as large markets or churches. The reasons given as to why a few large containers will be placed in central locations rather than small containers placed adjacent to the existing waste containers were there is insufficient space on the streets for additional containers and there are insufficient funds to provide and empty a large quantity of containers.

[17] The three programs proposed by residents were: the battery collection program; a notebook recycling program (old school notebooks are taken to centres and their unused paper is used to create notebooks for children that can't afford notebooks); and the Christmas tree collection/composting program.

[18] A program was in development for the distribution of reusable cloth bags to shoppers in a market in a low income neighbourhood to reduce the amount of plastic bags used and discarded. Most low income residents can't afford to stock up on groceries and instead shop several times a week resulting in the one-time use of many small plastic bags.

Figure 4.13: The containers for separation and collection of recyclables. There is one container each for (in order of left to right) plastic bottles, aluminum and tin cans, and paper and cardboard.

The program was to be tested through a pilot project in ten neighbourhoods of varying socio-economic statuses and built forms commencing in June of 2010. Residents in each neighbourhood of the pilot project were to receive a package containing pamphlets explaining the use of the containers and the importance of recycling, and three plasticized canvas bags for the separation of materials within the household (see Figure 4.14). In conjunction with the pilot project, a mass media campaign promoting the waste hierarchy (reduce, reuse, recycle) to the general public was to be launched. Through the pilot project the municipality intended to determine the necessary frequency of collection, the appropriate size of container for different neighbourhood types, and the rate of public participation in the program. The municipality is funding the pilot project but private sponsorship will be necessary to expand the program to the entire city.

Figure 4.14:In-home component of the future segregation system of Aguascalientes.

The recycling containers for the pilot project have been imported from Europe. They have small openings for disposal and are designed such that manual collection of materials from them is not easy (see Figure 4.13). Unfortunately, disposal from the plasticized canvas bags shown above into the containers may also be difficult. Specialized collection trucks will empty the containers by lifting them above the truck box and triggering the release of recyclables out of the base of the containers. The Secretary of Public Services and Ecology plans to build a Materials Recycling Facility [MRF] for the sorting and temporary storage of collected recyclables.

The success of this program will depend on the level of public participation. The director admitted that currently the residents of Aguascalientes do not have the habit of separating wastes and recycling, but he hopes that through education, especially of children who will encourage their parents to recycle, this habit will develop. Since there will only be one set of recyclable containers for every two neighbourhoods, the distance to the recycling containers will be great for some residents, especially those who do not have a vehicle, but instead walk as their primary means of transport. The director admitted that this may limit the ability of those residents to participate, especially if they are elderly.

The long-term future of recycling in Aguascalientes may be influenced by fluctuations in political administrations. The current municipal administration is concerned about the environment and is working with several local organizations who share this environmental concern. There is a risk that if the administration changes, the current and planned recycling programs may be discontinued. A previous recycling container project in some neighbourhoods mentioned by some questionnaire participants was terminated when the political administration changed. The director expressed, however, that the success of recycling programs is determined by the co-operation of the public. He suggested that the levels of

public participation in current and future recycling programs will influence whether or not they are continued by subsequent administrations.

4.8 Public Involvement

The directorates responsible for waste collection and recycling do not hold public engagement meetings as a part of the decision-making process, but the public can get involved in decisions by submitting project proposals to the respective directorate. For example, the containers used today had their start as a part of a proposal submitted by the company that manufactures them. As mentioned in the recycling section, several of the recycling initiatives were born out of proposals submitted by residents including one by a group of university students. Residents can contact the Department of Collection with questions or complaints by calling the phone number which is printed on all containers. There is also a form to request the relocation of a waste container and a form to lodge an official complaint to the Directorate of Cleanliness and Public Sanitation, both of which are available at the Directorate headquarters and online (H. Ayuntamiento de Aguascalientes, 2011a).The request form for container relocation asks why the request is being made and for a proposed new location. Requests will only be fulfilled if relocating the container is feasible and will take at least a minimum of five days to be answered. The complaint form does not give an expected response time.

4.9 Economic Analysis

The financial state of the municipal office of Aguascalientes was researched to provide insight into the affordability of the collection system. Roughly 30% of the municipal revenue of Aguascalientes comes from municipal taxes while 70% comes from Federal support (HR Ratings de México, 2011). Financial statements from 2001 to 2007 show the municipality wavering between deficits and surpluses. There were deficits in 2001, 2004 and 2006 with the lowest being -23.3 million MXN in 2004 (1.96% of expenses), and surpluses in 2002, 2003, 2005 and 2007 with the highest being 74.9 million MXN in 2005 (5.25% of expenses) (Secretaría de Finanzas Pública, 2007). [19] In 2010 the municipality had a surplus of 18.9 million MXN, which was roughly 1% of expenses (HR Ratings de México, 2011).

The net municipal debt has wavered throughout the last 5 years as loans have been paid off and new ones withdrawn, but is about 12% of municipal income on average. The net debt was 214.3 million MXN in 2005 (15% of expenses) which was reduced to 155.4 million MXN in 2006 (10% of expenses) and 134.7 million MXN in 2007 (8% of expenses) but increased to 218.6 million in 2008 (14% of

[19] Historic values, not adjusted for inflation.

expenses) when two new loans were taken out (Bogarín, Erhard, Padilla, Alvarez, Martínez, 2007; Bogarín et al., 2009).

The Directorate of Cleanliness and Public Sanitation was initially budgeted 69.4 million MXN for 2010 which was adjusted to 72.2 million MXN in January 2011 (IMPLAN, 2009; Gobierno del Estado de Aguascalientes, 2011). The adjusted budget for this directorate was 3.3% of the municipality's total adjusted budget. This directorate also receives income from two paid-for collection routes, landfill tipping fees and the sale of carbon credits to company BIOGAS. The amount allocated to waste collection was not reported. A summary of the capital and operating cost for waste collection is given in Table 4.2.

Table 4.2: Capital and operating costs of waste collection in Aguascalientes. Operating costs include the transfer and compaction stations.

Capital Costs	Operating Costs per annum
49 trucks[20] equipped with GPS and microchip system = 34,987,715 MXN 4600 containers (assuming 2,800 sized 2.6m^3 and 1,800 5.5m^3) = 60,400,000 MXN	Salaries: 18,286,032 MXN[21] Estimated amount spent on fuel: Collection Trucks: 5,350,000 MXN[22] Transfer Trucks: 383,878 MXN[23] Other (parts, property/building expenses, office supplies): unknown
Total: 95,387,715 MXN	Total: 26,019,910 MXN + other costs

The Directorate of Ecology and Health was budgeted 15,000,000 MXN for 2010 which was adjusted to 18,749,196 MXN (IMPLAN, 2009; Gobierno del Estado de Aguascalientes, 2011). The amounts budgeted to, and spent on programs within this directorate were not reported. The recycling programs are funded primarily by municipal taxes with support from state taxes, private companies and the sale of collected recyclables. The municipality does not receive income from the recyclables collected through programs that have private company involvement, but in some cases receives in-kind donations[24]. The recyclables collected through programs that do not have private company involvement are sold

[20] Estimated 700,000MXN per truck based on a price paid for a compactor truck in a nearby municipality in the state of Aguascalientes in December 2010 ("Adquieren equipo", 2010).
[21] Sum of salaries of employees in the Department of Collection (H. Ayuntamiente de Aguascalientes, 2011b).
[22] Based on an estimated fuel efficiency for compaction trucks of 0.8L/km (Environment Canada, 1996), an average distance of route of 70km (median of the range of collection route distances reported by the waste collection manager), the average cost of diesel in Mexico in 2008 ($0.54USD/L, The World Bank, 2010a) and the average USD to MXN exchange rate in 2008 ($1 USD=11.016MXN, Central Intelligence Agency [CIA], 2011).
[23] Based on fuel efficiency of 2.5km/L for transfer trucks (Jaques, 1992), 13 round trips of 34km per day and the cost of diesel in the above footnote.
[24] Such as notebooks from recycled paper products company involved in the laminated cardboard recycling program

monthly to local buyers who offer the best prices. The income from the sale of those recyclables was estimated by the recycling manager to be between 50,000-60,000 USD per year.

Chapter 5
Questionnaire Results

The results of the questionnaire have been divided into the following eight sections for presentation:

1. *Distances to Containers* in which the average distances from respondent buildings to the containers, including by SE status, are presented;
2. *Waste Characterization* in which the volume of wastes produced per person per day and the composition of waste are presented;
3. *Waste Management Characteristic at the Level of Waste Generation* in which the waste management behaviours at the household and business level are presented including time of day waste is disposed, and upon whom the responsibility for taking waste to the containers falls;
4. *Concern for Environment* in which the percentages of respondents concerned about the environment and who considered their environment to be healthy are presented;
5. *Recycling Behaviours* in which the percentage of respondents that recycle, the willingness of respondents to participate in a recycling container program and the knowledge about and use of existing municipal recycling centres are presented;
6. *Knowledge of Waste Collection* in which knowledge levels about the different aspects of the waste collection system including the schedule, the existence of a phone number for complaints or questions, and the types of wastes that are not permitted in the containers are presented;
7. *Opinions* in which the likes, dislikes, suggestions and overall opinions of respondents regarding the waste collection system are presented;
8. *Informal Collector Questionnaire Results* in which the results of the informal collector questionnaires are presented including demographics of collectors and types and amounts of materials collected;
9. *Buy/Sell Businesses* in which information about the types, amounts and prices of recyclable materials that are bought and sold by small recycling dealers is presented.

In total, 282 questionnaires were conducted. There were 93 questionnaires from the SE High neighbourhoods, 92 from SE Medium and 97 from SE Low. Of the responses, 79.43% were households, 13.12% were small businesses and 7.45% functioned as both business and household. Figure5.1 to 5.3 give a visual impression of the differences in neighbourhoods by SE status. For the most part, households and small businesses were not distinguished in the analyses because they use the same containers.

Figure5.1: SE Low neighbourhoods. From left to right, Los Pericos Asentamieno Irregular, Vicente Guerrero, and Benito Palomino

Figure5.2: SE Medium neighbourhoods. From left to right Casa Blanca, Del Trabajo and Libertad.

Figure5.3: SE High neighbourhoods. From left to right La Herradura, Bosques del Prado Norte, and Jardines de la Concepcion II.

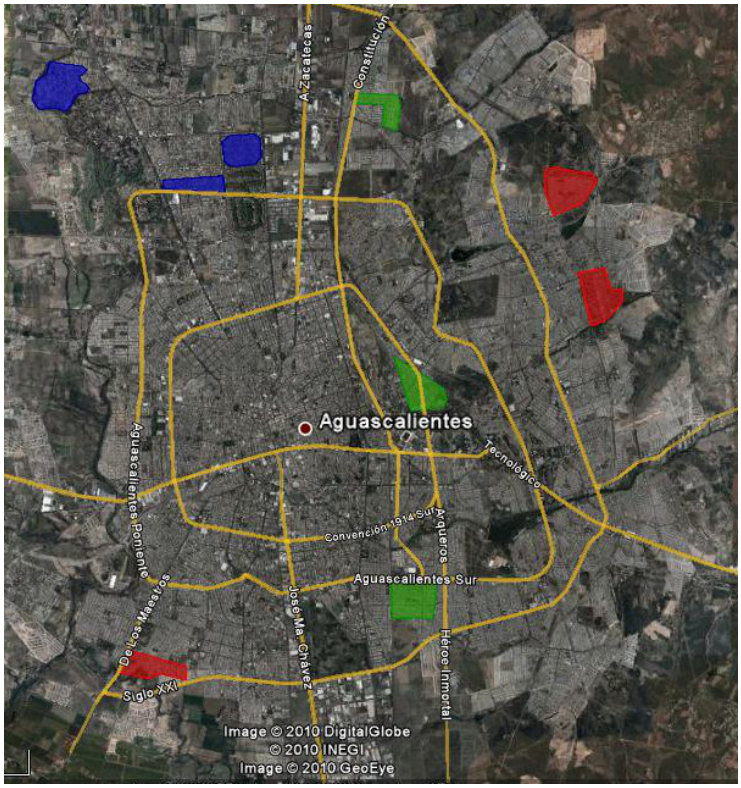

Figure 5.4: The locations of the neighbourhoods surveyed. Blue - SE High, Green - SE Medium, Red - SE Low.

5.1 Distance to Container

The one-way distances from households and businesses to the containers in their neighbourhood were found using the Network Analyst tool in ArcMap. For many respondents the closest container as determined by Network Analyst was not the one recorded as used. For each such occurrence, this was either the result of error by the researcher or analysis method, or because the respondent actually did use a container that was further away. A map of the city was analyzed to determine if, and which, of these instances were false due to the wrong container being recorded as the one used (research error) or double lined roads in the network on ArcMap (analysis error). The container used was thought to be incorrectly recorded when the distance between it and the corresponding respondent was very great and there were other containers closer, in which case the closest container was considered to be the container used. (There were seven errors of this sort.) Some roads were represented by a double line in the network on ArcMap. If a container was across a double-lined street from a respondent, then network analyst would not identify that container as the closest, in which case the straight line distance between the two points was used. The distances also have equipment error as each GPS recording had an error of +/- 3m.

Some of the distances found by Network Analyst are greater than the actual distances travelled by those respondents who walk to the containers since people tend to cut corners and cross streets diagonally when walking. Also, because the network roads were lines drawn down the centres of streets, the distances calculated by Network Analyst between respondent buildings and containers on the same side of the street are greater than the actual distances.

The terrain in Aguascalientes is fairly flat overall, with some shallow grades. Slope was therefore thought not to be a significant contributor to burden of participation in the collection system, so no grade measurements were taken. If similar studies are performed in areas with steeper terrain, grade ought to be measured for analyses of burden of participation.

Results are presented for distance to the closest container and the container used (Table 5.1 and Table 5.2). The analysis of distance to container was performed with and without Los Pericos and La Herradura (Table 5.1 and Table 5.2 respectively). Those two neighbourhoods were not randomly selected, so when they are removed the results are more generalizable. The mean distance to container used was greater than that to the closest container (for the overall results and within each SE group). The reasons why some respondents said they use further containers were because the difference in distances between the used and closest containers is negligible, the closest container is often full or, the most common response, the container used is along a path regularly travelled (i.e. to school, work or a local store).

Table 5.1**:** Means, standard deviations, maximum and minimum distances to from respondent buildings to containers for all respondents excluding Los Pericos (SE Low) and La Herradura (SE high). For maximum and minimum values the instrument error is +/- 3m.

		ALL (m)	**SE High (m)**	**SE Med (m)**	**SE Low (m)**	**Significant Difference Between Means (p<0.05)**
No. Responses		*216*	*92*	*92*	*94*	
Closest Container	**Mean**	**100**	121	94	88	Yes (sqrt transformation)[25] p=0.001
	St. Deviation	**54**	49	56	50	
	Maximum	**288**	253	288	269	
	Minimum	**7**	34	20	7	
Container Used	**Mean**	**103**	124	96	93	Yes (sqrt transformation) p=0.001
	St. Deviation	**57**	51	60	55	
	Maximum	**289**	253	289	269	
	Minimum	**7**	34	20	7	

When the results from only those neighbourhoods that were randomly selected were included (excluding Los Pericos and La Herradura), the mean distance from respondent building to container used

[25] This transformation, and all others, were preformed so the results would meet one-way ANOVA assumptions of equal variance and normal distribution.

was 100 m with a standard deviation of +/- 54 m (Table 5.1). The SE High group had the largest mean distance to container used (121 m) with distance to container decreasing significantly with decreasing SE status (Table 5.1, $p<0.01$). This trend can be attributed to the decreasing built form density with increasing SE status because, in areas where urban form is less dense, fewer containers by area are needed to provide sufficient volume capacity for the generated waste, resulting in greater distances between containers. Long distances are perhaps tolerated in SE High neighbourhoods because the residents often have maids who are responsible for disposing waste, so the residents, who have the influence to change the distance to container, do not experience the burden of participation. Also, some respondents in the SE High neighbourhood of la Herradura expressed that they prefer the containers not to be near their homes for aesthetic reasons.

Table 5.2**:** Means, standard deviations, maximum and minimum distances to containers for all questionnaires and by SE status (Max and Min +/- 3m)

		ALL (m)	**SE High (m)**	**SE Med (m)**	**SE Low (m)**	**Significant Difference Between Means (p<0.05)**
No. Responses		*278*	*92*	*92*	*94*	
Closest Container	**Mean**	**110**	126	94	110	Yes, p=0.003
	St. Deviation	**63**	61	56	67	
	Maximum	**351**	351	288	307	
	Minimum	**7**	31	20	7	
Container Used	**Mean**	**114**	133	96	114	Yes (ln transformation) p=0.001
	St. Deviation	**71**	77	60	72	
	Maximum	**460**	460	289	336	
	Minimum	**7**	31	20	7	

When the results from Los Pericos and La Herradura were included, the mean distances from respondent building to closest container and container used increased for the SE High group and the SE Low group (Table 5.2) indicating that both of those neighbourhoods had larger distances to container than the other neighbourhoods in their respective groups. The built form of La Herradura is less dense than the other SE high neighbourhoods, which accounts for why the containers were more spaced out. Los Pericos on the other hand, had large distances from respondent to container, but a very dense built form, indicating that there are more households per container in this neighbourhood than in most other neighbourhoods. The containers in this neighbourhood were all of the smallest size which supports the fewest households. No overflowing containers were encountered in this neighbourhood during surveying and the percentage of respondents from this neighbourhood that said they disliked the containers being full or overflowing was the same as the average for SE Low neighbourhoods (16%). An illegal dumping

area was observed in this neighbourhood suggesting that the distances to container did prove to be too great for many residents, including two respondents who did not use the containers. The closest container to them was 209 m and 183 m away.

5.2 Waste Characterization

Quantity

Respondents were asked to estimate the number of bags of waste generated in their household or business each week. Example small, medium and large bags were available to be shown to respondents to help them estimate. The number of bags of waste generated was converted into volume with a small bag being 7 L, a medium bag being 50 L and a large being 150 L. Estimates were in volume rather than mass because volume was assumed to be easier to estimate.

Figure 5.5 shows that the mean amount of waste generated for all households surveyed (excluding household/business combinations) was 5L/person/day based on respondent estimates. The large standard deviations show the great amount of variability between generation rates. SE High households generate the most waste in volume per capita, with SE low households generating the second most and SE medium generating the least (Figure 5.5). A one-way ANOVA test on PASW of the natural logarithm transformed generation rates showed a significant difference between the amounts of waste produced by SE group ($p<0.01$). There may be variation between the SE groups in ability to estimate since education factors were used in creating the groups. If this variation exists, error would be added to these results.

The same figure shows the generation rates by businesses and household/business combinations. The generation of a large dry cleaning business located along a main street of Aguascalientes was identified as an outlier using a Grubb's test, and not included in these results. The average daily generation rate per capita (number of employees and/or residents), was 12L/person/day. A one-way ANOVA test on PASW of the natural logarithm transformed results did not show a significant difference between the waste generation rates of businesses and household/business combinations by SE status.

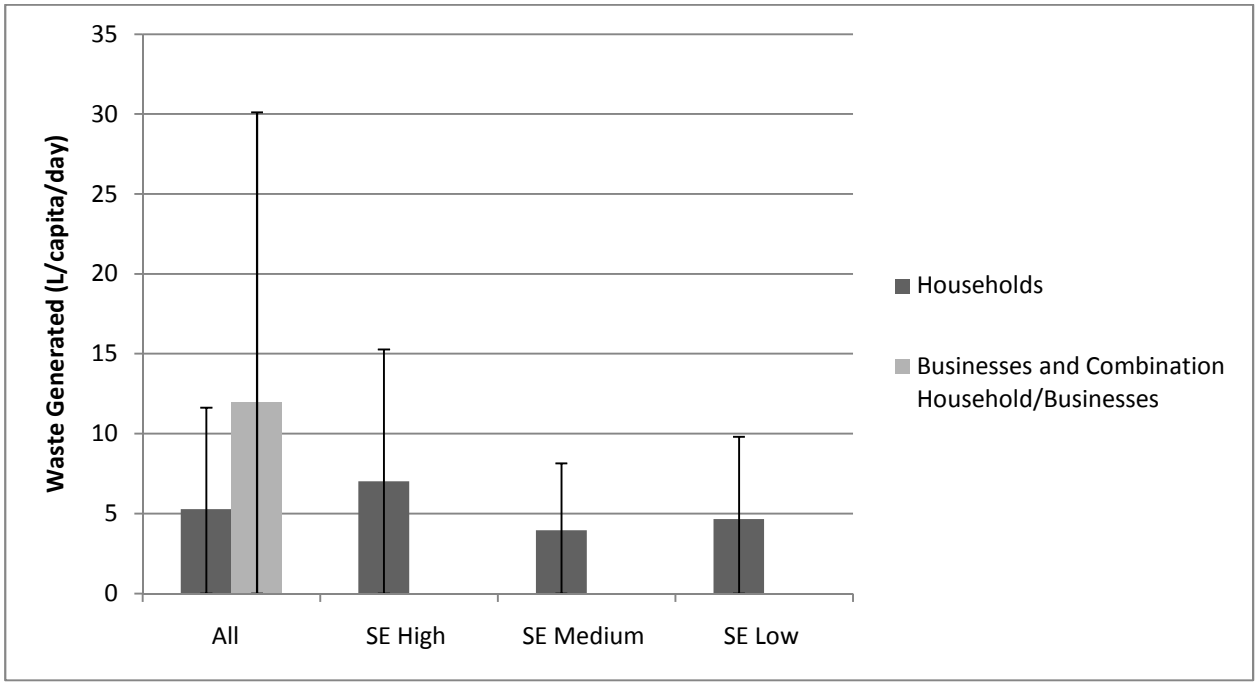

Figure 5.5: Volume of waste produced daily per capita. Error bars show standard deviations. (No. of responses: Households: All-226, SE High -84, SE Medium- 74, SE Low- 69; Businesses and Business/Household combinations: All-54.)

Composition

The waste composition question was changed twice during the questionnaire phase. This analysis was performed on the estimates of composition by percent of total waste generation that each type of waste occupied because the question pertaining to this had the most responses.[26] Some respondents had difficulty estimating, and some did not understand the concept of percentage.

The results combine the household, small business and combination small business/household results because, when analyzed separately, little difference was seen between these groups. There is a zero to one percent difference for most waste types except paper/cardboard of which small businesses generate about four percent more. There were insufficient small business and household/business combination respondents to compare the results between households, businesses and household business combinations with a one-way ANOVA because the assumption of equal variance would not be valid.

[26] The other two questions to estimate waste composition were: "What are top three types of waste produced in this household/business?" and "How many small bags worth of each type of waste are produced in this household/business?"

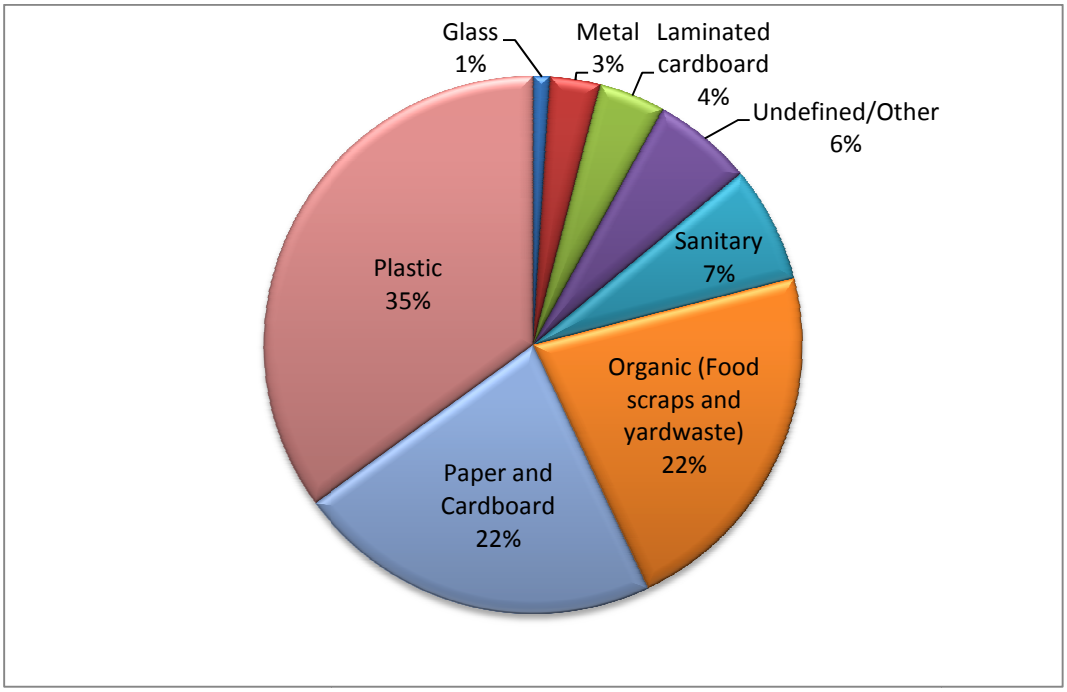

Figure 5.6: Average composition of household and small business waste in Aguascalientes based on respondent estimates by volume. No. of respondents: All- 178, SE High- 68, SE Medium- 38, SE Low- 72.

The three most commonly generated types of waste by volume (not compacted) were plastic (35%, mostly from plastic bottles - 29%), paper and cardboard (22%), and organic (22%). The results for each type of waste are shown in Figure 5.6. The category "sanitary wastes" includes toilet paper, which is not put in toilets because the sewer system would be clogged, and diapers. "Metal" includes scrap metal, tin cans and aluminum cans. One-way ANOVA tests were performed to compare the percent composition for each type of waste by SE status. The only significant difference found was between the average percent composition of organic waste with the SE High group having the highest average percent of organic waste by volume (28%) and the SE Medium group having the lowest (13%). For all other types of waste there were no significant differences in percent composition by SE status, excluding scrap metal and aluminum for which there was insufficient data to perform one-way ANOVA tests. The results in table form, including the results separated by SE group, are in Table C. 2 of Appendix C.

5.3 Waste Management at the Household/Small Business Level

The ways in which waste is managed at the household level, including storage and disposal, were sought via the questionnaire to contribute to the answer of the first research question "What are the characteristics and processes of the communal waste collection systems in Aguascalientes, Mexico, and in

developing countries in general?" The household management aspects learned about were method of disposal, person responsible for disposal, household storage of waste, frequency of disposal, method of taking waste to container, adherence to disposal schedule, and to whom recovered materials are sold.

A few respondents use methods of disposal in addition to, or other than the containers. Of the 278 respondents to the respective question, only eight use other methods of disposal with six using other methods in addition to the containers and two not using the containers at all. All of the respondents that use other methods were from the SE Low group. Three dump waste in urban areas, two bury waste, and three burn waste. The two households that do not use the containers dump waste in urban areas (see Figure 5.7 of a dumping area). They said they do so because there is no container in their area. The closest container to them was 209 m and 183 m away. Those who burned waste might have done so for warmth or to cook food. One of the respondents that burn waste said that they only burn wood scraps.

Figure 5.7: Dumping area in Los Pericos.

Respondents were asked who carries the responsibility of waste disposal in their household/business in order to learn any patterns of gender or age for this role. Figure 5.8 shows the percentages of persons responsible for taking waste to the containers by age group, gender and SE group. The responsibility for taking waste to the containers falls almost evenly between men and women with 47% of respondent households and businesses having men responsible for taking out the waste. This result reflects the population by gender of Aguascalientes which was 48% male in 2000 (INEGI, 2000). Greater differences in waste management responsibility between genders are seen when the results are sorted by socio-economic group. The responsibility is greater for females than males in SE High and SE Low neighbourhoods with 59% and 57% of respondents having females responsible for disposal in those groups respectively. Households in SE High neighbourhoods often employ female maids whose

responsibilities include waste management and disposal. The SE Medium group had fewer females responsible for disposal than males (44%).

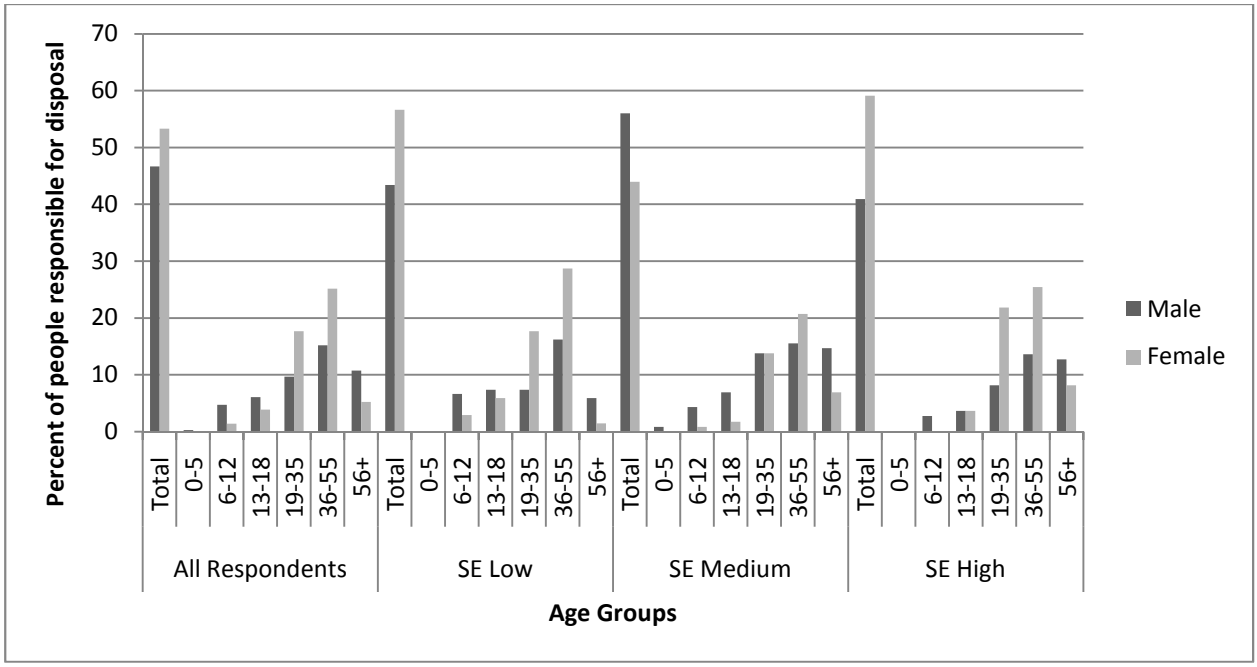

Figure 5.8: The responsibility for carrying waste to the containers by age group, gender and SE group.

The persons responsible for taking waste to the containers were mostly adults with 40% of persons responsible being from the 36-55 age group and 27% being from the 19-35 age group. In both of these groups, more females were responsible for taking out waste than males. Overall, the females who take out waste were mostly adults concentrated to above two age groups, while the males were more evenly spread throughout the age groups with more young boys and older men responsible for disposal than their female peers. Overall, 6% of the persons responsible for disposal were children aged 6-12, and 10% were teenagers aged 13-18. These results are presented in table form in Table C. 3 of Appendix C.

The ways waste is stored at the household level and how often respondents take waste to the containers was learned through the questionnaire. At the household level, waste was observed to be stored in small grocery bags or buckets. They were often stored outside in an enclosed patio (Figure 5.9). Waste is generally stored in households or on patios for one to three days with 59% of respondents disposing waste daily, 20% disposing twice weekly and 8% disposing weekly. The SE Medium group disposed waste most frequently while the SE High group disposed waste least frequently. Full results of how often wastes are taken to the containers are in Table C. 5 of Appendix C.

Figure 5.9: Various methods of waste storage at the household level.

The method of transportation to site of disposal was also asked. Nearly all respondents walk to the containers to dispose waste (94%), but a few drive or use other modes of transportation such as bicycling. The responses "drive only" were all from the SE High group and those who walk and drive were almost all from the SE High group, with one from the SE Medium group. These results suggest that car use increases with increasing SE status, but there were not enough responses for "drive" to perform a chi-squared test. Driving is consistently low relative to walking even in the SE High group in which 87% of respondents walk to dispose waste. Those who drive tend to live further from the container they use than those who walk (Table 5.3).The full results of method of transport to container, including by SE group, are in Table C. 7 of Appendix C.

Table 5.3: Distance to container according to method of transport of waste.

Method of Transport	**Walk only**	**Walk or Drive**	**Drive only**
No. of respondents	*254*	*7*	*3*
Average Distance (m)	109.98	177.15	328.70
St. Dev. +/- (m)	65.89	31.92	166.73
Minimum Distance (m)	6.89	133.19	141.02
Maximum Distance (m)	426.02	228.09	459.73

Adherence to the disposal schedule was examined to see if the containers were being used in accordance with regulations. Factors of adherence were also explored. The schedule for disposing waste is 7pm to 7am with the rationale that waste decomposes less rapidly at night than in the heat of the day. Table 5.4 shows the percentage of respondents who: adhere to the disposal schedule; know the schedule

but do not adhere; and don't know the schedule. Results of the times at which respondents dispose of waste are given in Table C. 6 of Appendix C.

Table 5.4**:** Time of day wastes are taken to containers

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of Responses	*273*	*Adherence: 89 Knowledge: 90*	*Adherence: 91 Knowledge: 90*	*Adherence: 93 Knowledge: 93*	
Adhere to schedule (7pm-7am)	59.78	32.58	71.11	64.13	Yes, p<0.001
Know the schedule but don't adhere	22.76	34.88	17.78	16.30	Yes, p=0.005
Don't know schedule	27.11	36.67	14.44	30.11	Yes, p=0.002

Note: Columns total greater than 100% because some respondents unknowingly adhere to the schedule.

Many respondents do not adhere to the schedule (40%). Ignorance of the schedule was one reason for the lack of adherence, with 27% of the respondents not knowing the schedule. However, 23% of respondents knowingly do not adhere to the schedule. The reasons given why respondents who know the schedule do not adhere are given in Table 5.5.

Table 5.5**:** Reasons for not adhering to schedule as percentages of respondents who know schedule but do not adhere.

	% Respondents who know the schedule	**% SE High**	**% SE Medium**	**% SE Low**
No. of Responses	*40*	*23*	*11*	*6*
The person responsible for disposing waste is not here during the scheduled hours	**42.50**	**52.17**	**36.36**	**16.67**
The schedule is not convenient	**32.50**	**21.74**	**45.45**	**50.00**
I take waste out right before the truck comes	15.00	13.04	18.18	16.67
It is not important to me to follow the schedule	5.00	4.35	0.00	16.67
Trucks come often	2.50	4.35	0.00	0.00
No reason	2.50	4.35	0.00	0.00

The most common reasons for knowingly not adhering to the disposal schedule were "the person responsible for disposing waste is not here during the scheduled hours" (43%), "the schedule is not convenient" (33%) and "I take waste out right before the truck comes" (15%). Households with maids

responsible for disposing waste, businesses that are not open during the schedule hours, and households in which the person responsible for waste disposal works during the schedule hours tended to give the most common response. Those who find the schedule inconvenient may be those who like to make efficient use of their time by taking waste out while running other errands. Twenty-five percent (25%) of respondents regularly, and 15% occasionally, said they run other errands while taking waste to the containers. Those errands, such as dropping off kids at school, which was often mentioned, may not occur during the scheduled disposal hours. The third most common response shows respondents realize the disposal schedule does not reflect the collection schedule and they understand that waste ought not to sit in the containers for long periods of time.

The SE High group had the lowest disposal schedule adherence with only 33% of respondents adhering to the schedule (Table 5.4). This is partly explained by the large amount of SE High respondents who did not know the schedule (37%). Many of the people who answered the questionnaire in SE High neighbourhoods were not responsible for waste disposal so they would be less likely to know the schedule as they would not often see the schedule printed on the containers. However, this group also had the highest amount of respondents who know the schedule but do not adhere (35%). Of those who know the schedule but do not adhere, the most common reason given by this group for not adhering was "the person responsible for disposing waste is not here during the scheduled hours" (52%, Table 5.5). SE High households often have maids or other employees responsible for taking out the waste who generally do not work during the scheduled disposal time.

The SE Medium group had the greatest adherence with 71% of respondents adhering to the schedule. Knowledge of the schedule likely facilitated this adherence as this group had the highest amount of respondents who knew the schedule (86%). Likewise, the amount of respondents from the SE Low group who adhere (64%) closely reflects the amount of respondents who knew the schedule (70%).

The results of to whom recyclables materials are sold by those who sell them provide insight into how selling recyclables occurs in the city. Most of the respondents who sell materials recovered from waste take them to small businesses that deal in recyclables (89%). Full results are presented in Table C. 4 of Appendix C.

5.4 Concern for Environment

Respondents were asked if they were concerned about the health of the environment and if they considered their environment to be safe and healthy. There was occasionally translation error in the use of the word environment. The word environment was intended to mean natural environment, but many

respondents mentioned crime rates when answering these questions indicating that they understood the word to mean social environment. After this was realized, later questionnaires added the specification that the word environment in those questions referred to land, air and water.

The percent of respondents concerned about the health of the environment was high overall (95%) and high for each SE group (no significant difference between groups, $p>0.05$). Consideration of the environment as safe and healthy was a separate question from concern for the environment. Sixty percent (60%) of respondents consider their environment to be safe and healthy. The amount of respondents that consider their environment to be safe and healthy decreased with increasing SE status, (significant at $p<0.01$). Thirteen percent (13%) of respondents thought their environment was "more or less" safe and healthy, implying that they think the environment is fairly safe and healthy, but not to the extent it could be. Full results are given in Table 5.6.

Table 5.6**:** Responses to the question: "In your opinion, is your environment safe and healthy, or not?"

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference ($p<0.05$)**
No. of responses	*272*	*89*	*91*	*92*	
Yes	60.29	50.56	60.44	69.57	Yes, $p<0.001$ when the responses "I don't know" and "other" are removed
No	25.37	35.96	23.08	17.39	
I don't know	0.37	1.12	0.00	0.00	
More or Less	13.60	11.24	16.48	13.04	
Other	0.37	1.12	0.00	0.00	

5.5 Recycling Behaviours

This section presents and discusses the following information about the recycling behaviours of residents of Aguascalientes: the recovery rate of reusable, compostable and recyclable wastes from the waste stream by the efforts of households/small businesses; the percentages of respondents that attempt to reduce amounts of waste generated and recover resources by method of recovery (Table 5.7); the relationships between environmental concern and recovery behaviour; recovery rates by type of waste; the willingness of the public to separate recyclables and the distance they are willing to take them (Table 5.9); the amount of respondents that know about, and use, the recycling centres; how often the recycling centres are used; and the reasons given for not using the recycling centres (Table 5.8).

The resource recovery rate was calculated as the total amount of waste not thrown in the containers divided by the total amount of waste generated (with totals being for all results, not individual

results). A dry cleaning company that generates a large amount of waste and recycles nearly all was excluded from the resource recovery results as an outlier. With this business included the resource recovery rate increases dramatically. The question asking what amount of waste was thrown into the containers was added partway through the questionnaire phase so the resource recovery rate is based on only about half of the questionnaire responses.

The resource recovery rate was 33% by volume.[27] The SE High group had the greatest recovery rate (41%). The recovery rate did not decrease in correlation with SE status as the SE Low group had the second highest recovery rate (32%). In SE Low areas many people sell recovered waste. The SE Medium group had the lowest recovery rate (19%). Unfortunately the differences in the recovery rates between SE groups could not be tested because significance tests compare means and the recovery rates were not calculated as means. The calculation for each group's recovery rate divided the total amount diverted per group by the total amount generated, rather than averaging the individual recovery rates within each group, as that average would not be equal to the total recovery rate of that group.

Sixty-five percent (65%) of respondents said they try to reduce the amount of waste they generate (Table 5.7). This response significantly decreased with decreasing SE status ($p<0.01$). There was no simple method to verify whether or not the respondents actually do reduce the amount of waste they generate.

Table 5.7**:** Percentages of respondents that reduce, reuse, recycle, compost and/or sell waste.

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference ($p<0.05$)**
No. of responses	*279*	*92*	*92*	*95*	
Attempt to reduce amount of waste generated	65.02	74.39	68.96	53.19	Yes, p=0.008
Reuse (use plastic or metal containers for storage, and/or reuse paper)	26.07	30.11	21.74	25.26	No, p=0.120
Recycle, (take wastes to recycling centres (public or private), school, recycling container and/or give recyclables away)	44.29	49.46	50.00	33.68	Yes, p=0.038
Organic Recovery (compost, give food scraps away, and/or feed food scraps to animals)	18.21	9.68	11.96	32.63	Yes, p<0.001
Sell Recyclables	14.64	8.60	3.26	31.58	Yes, p<0.001

[27] See more accurate resource recovery rate presented in Addendum C.

Table 5.7 shows broad categories of recovery behaviours by percentages of respondents who participate in them. Forty-four (44%) of respondents recycle, 26% reuse, and 18% recover organics. All of the behaviours except reusing were significantly related to SE status ($p<0.05$). Organic recovery behaviour decreased with increasing SE status. The SE Low group had significantly less recycling behaviour, but significantly more selling behaviour than the other two groups ($p<0.05$). Full results of specific methods of recovering resources from waste are given in Table C. 9 of Appendix C. Respondents often use more than one method of recycling or reusing wastes.

Figure 5.10: Household separated waste that will be taken to a private recycling centre.

Each type of recovery behaviour was tested using a Pearson's chi-squared test for a relationship with consideration of the environment as safe and healthy[28]. With consideration of the environment as safe and healthy as the factor and the response "I don't know" removed, "recyclable materials sold", "food fed to animals", "recyclable materials to recycling depots", and "recyclable materials given away" all had significant results with respect to consideration of the environment as safe and healthy ($p<0.05$), while "reuse" and "recyclable materials to children's school" did not have significant results. The remaining behaviours had too few observed counts in chi-squared tables for the test to be valid. However, consideration of the environment and the above behaviours were all significantly related to SE status, so the above relationships may have been mere reflections of the SE status effect. Chi-squared tests were re-performed with SE status as a layer so the relationships with consideration of environment and the above behaviours within each SE group could be seen. These tests showed no significant relationship between consideration of the environment as safe and healthy and recycling behaviours when SE status is held

[28] Relationships with concern for the environment were not tested because there were too few responses in some categories for chi-squared tests to be valid.

constant, but unfortunately more than 20% of observed results in the chi-squared tables were less than five so these tests were invalid. Had the questions about concern for the environment and consideration of the environment as safe and healthy been asked as evaluations on a gradient (i.e. rate how concerned you are on a scale of one to five), rather than as yes or no questions, their relationships to recycling behaviours could have been more accurately analyzed.

Data about the amounts of each type of material recovered from waste was collected in two ways. Either percentages by volume, or the number of bags of each type of waste recycled, reused or composted were estimated. Sometimes respondents would give the number of bottles or boxes recycled instead of a number of bags or percentage estimate. To estimate the percentage by volume, one box flattened was considered to have a volume of 15L (based on estimated dimensions 100cm*50cm*3cm), and a box of 24 bottles was considered to have a volume of 26L (based on dimensions of 26.7cm*40.6cm*24.1cm). If both a number of bags and a percent were given, and they did not agree, the number of bags was assumed to be more accurate and used, and, if necessary, the percentages of other materials recovered were adjusted accordingly. Originally, the question asked for percentages of materials recycled, reused or composted to be estimated in the categories of <50% and >50%. For analysis, such responses were converted to useable values with <50% converted to 25% and >50% converted to 75%. If the amount of a specific type of material recovered was given, but not the amount generated, the amount recovered was entered into the amount generated. This assumes a recovery rate of 100% for those materials. This is a reasonable assumption because some respondents may not have include the materials they recover in the amount of waste generated because they may have been only including the waste they throw in the containers in the amount generated.

The recovery rates by type of recoverable materials were as follows. Glass had the highest recovery rate (93%), aluminum had the second highest (67%) followed by tin cans (58%), scrap metal (57%), paper and cardboard (45%) and plastic bottles (39%). Full results of recovery rates by types of recoverable material, including by SE group, are provided in Table C. 10 of Appendix C.

The amount of respondents that reuse, recycle or sell by type of reusable/recoverable material was also recorded. The materials most respondents reuse, recycle or sell were plastic bottles (44% of all respondents), paper and/or cardboard (35%) and tin cans and aluminum (19%). Full results of percentages of respondents who recover each type of waste are provided in Table C.11 of Appendix C.

Outside of the questionnaire results, another method of resource recovery was observed. Sometimes bags of food, old clothes or other items that might be of use were left on top of or beside containers to prevent them from getting mixed in with other waste and to allow them to be easily pick up

by someone who could use them. This was observed in SE Low and SE Medium neighbourhoods. See Figure 5.11.

Figure 5.11: Leftover food and reusable shoes and clothing were sometimes observed on top of or beside containers for anyone who wanted them to take.

The knowledge and use of the 13 municipal recycling centres in the city were measured through the questionnaire. Fifty-six percent (56%) of all respondents knew about the recycling centres but only 30% have used them at least once[29]. Both the knowledge of the existence of the recycling centres and the use of them at least once increased significantly with increasing SE status ($p<0.01$). The SE High group had the most respondents who knew about the recycling centres and who had used them at least once (77% and 47% respectively). The recycling centres are located beside large commercial shopping centres that are used mostly by SE High residents. Most SE High residents have vehicles with which they can transport recyclables to the centres. Full results of knowledge of the recycling centres are presented in Table C.12 of Appendix C.

Of those who know about the recycling centres, 54% have used them at least once, and only 36% use them regularly, at least once per month. The frequency of use of the recycling centres appears to increase with increasing SE status as the largest portion of SE High respondents who take waste to the recycling centres take them every 2 weeks (28%), while most from the SE Medium group take them once per month (36%) and most from the SE Low group take them every 2 months (43%). Full results of how often wastes are taken to the recycling centres are presented in Table C. 13 of Appendix C.

[29] The amount of respondents who have used them at least once is greater than the amount of respondents that said they "take recyclable materials to one of the 13 municipal recycling centres in the city" as a method of recovery (15%) because people generally only mentioned this as a recovery behaviour if they took waste there regularly.

Reasons given by respondents who knew about the centres and don't use them as to why they don't are presented in Table 5.8. Thirty percent (30%) of respondents who knew about the centres but do not use them use a different method of recycling or sell wastes, and 22% said they don't have time to use them (Table 5.8). There were no significant differences in reasons for not using the centres by SE group.

Table 5.8**:** Reasons for not using the recycling centres as percentages of respondents that know about recycling centres but do not use them and were asked the pertaining question.

	Respondents who know about the centres but don't use them
No. of Respondents	*46*
I use a different method of recycling (including selling)	30.43%
I don't have time	21.74%
I don't produce many recyclables	10.87%
No reason	10.87%
The centres are too far	8.70%
I don't believe centres keep recyclables separate	4.35%
I don't want to store recyclable materials on my property until I have time to take them	2.17%
It would be too much of an inconvenience for me	2.17%
I don't think recycling is important	2.17%
Other (just move/don't know/centre in area no longer exists)	10.87%

To learn what the reaction might be to the proposed recycling container system, respondents were asked if, and how far, they would be willing to travel to deposit separated recyclable materials into specified recycling containers. Ninety-four percent (94%) of respondents said they were willing to separate recyclables and take them to recycling containers. Fifty percent (50%) said they would only do so if the containers were in the same location as their waste container. Interestingly, SE High respondents were the most willing to walk 30 or more minutes to recycling containers. (Most SE high neighbourhoods had maids, who would most likely be responsible for taking out recyclables.)

Table 5.9**:** Willingness of respondents to separate recyclables and distances they are willing to take them. Responses by percent to the question: "If two more communal containers were put in your neighbourhood, one for only paper, and one for only glass, plastic, and metal, would you separate out these wastes and put them in these containers?"

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*266*	*85*	*90*	*91*	
Yes, even if they were a 30 min walk away, or further	12.41	21.18	10.00	6.59	Yes, p<0.001 when the results are regrouped such that walk 15-30 minutes and less than 15 minutes are grouped together, and drive 15-30 minutes and less than 15 minutes are grouped so there are enough observed counts to validate a chi-squared test.
Yes, even if they were between 15-30 min walking distance away	2.26	1.18	2.22	3.30	
Yes, if they were within a 15 min walking distance	7.14	8.24	7.78	5.49	
Yes, but only if they are in the same location as my current waste container	**49.62**	**36.47**	**57.78**	**53.85**	
Yes, even if they were a 30 min drive away, or further	12.78	5.88	8.89	4.40	
Yes, even if they were between 15-30 min driving distance away	7.52	4.71	6.67	26.37	
Yes, if they were within a 15 min driving distance	1.88	21.18	2.22	0.00	
No	6.39	1.18	4.44	0.00	

5.6 Knowledge of aspects of the waste collection system

The number of respondents knew about different aspects of the collection systems, such as the existence of the number on the containers to call with complaints or problems and types of hazardous wastes, was quantified through the questionnaire. Respondents were also asked whom they would contact with complaints or questions. Those results were included in this section as they seemed to be influenced by respondents' knowledge levels.

Table 5.10**:** Percents of respondents that know various aspects of the waste collection system including: the schedule, the existence of a phone number for complaints/suggestions or pick-up of items not permitted in the containers, the types of waste not permitted in the containers, the types of wastes considered hazardous and where to take hazardous waste.

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*273*	*90*	*90*	*93*	
Know schedule	72.89	63.33	85.56	69.89	Yes, p=0.002
No. of responses	*274*	*92*	*89*	*93*	
Know there is a phone number on the container for complaints or questions	56.57	56.52	58.43	54.84	No, p=0.884
No. of responses	*247*	*90*	*89*	*68*	
Know all items not permitted in containers	0	0	0	0	Yes, p=0.016
Know some items not permitted in containers	55.47	60	61.80	41.18	
No knowledge of items not permitted in containers	44.53	40	38.20	58.82	
Know all types of hazardous waste	2.43	2.25	3.37	1.45	Yes, p=0.003, when "all" and "some" knowledge results are grouped together (so there are sufficient observed counts for a chi-squared test)
Know some types of hazardous waste	59.51	65.17	66.29	43.48	
No knowledge of which wastes are hazardous waste	38.06	32.58	30.34	55.07	
No. of responses	*273*	*91*	*89*	*93*	
Know where to take hazardous waste	13.55	16.48	16.85	7.53	Yes, p<0.001, with those who only know where to take batteries removed because they did not know where to take other hazardous waste

Note: Hazardous wastes are solvents, acids, fuels and medical waste. Items not permitted in the containers are all hazardous wastes plus large branches, construction waste and furniture.

Table 5.10 shows the public knowledge levels of different aspects of the waste collection system. The only aspect not represented in Table 5.10 was knowledge of where to take batteries to dispose of them which 22% of respondents knew. Significant differences were found between SE groups for all knowledge levels except knowledge of the phone number on the containers (Table 5.10, $p<0.05$). The SE High and SE Medium groups had almost the same level of knowledge of types of hazardous waste and items not permitted in the containers, while the SE Low group had less.

The respondents were asked whom they would contact if they had complaints or questions about the waste collection system. Persons or groups that would be contacted were: the municipality (44% of respondents), neighbourhood board (9%), the local political representative (1%), the collectors (1%), other (3%), or no one (33%), and 9% of respondents did not know who they would contact. The most common response for the SE High and SE Medium groups was the municipality (46% and 54% respectively). The most common response for the SE Low group was no one (48%). The results differed significantly by SE group when "the collectors" and "other" were removed so there would be enough observed counts for a chi-squared test to be valid ($p<0.05$). Of the SE groups, the SE High group had the most respondents who said they would contact their neighbourhood board (13% SE High). The full results of whom respondents would contact with questions or complaints are in Table C. 14 of Appendix C.

A large percentage of people said that they would not contact anyone if they had questions or complaints about waste collection (33%). This response increased with decreasing SE status (SE High: 16%, SE Medium: 36%, SE Low: 48%). There were three possible reasons why a respondent would not contact anyone about complaints or questions: he/she did not know whom to contact; he/she had no complaints or questions; and, even if he/she had a complaint and knew whom to contact, he/she would choose not to lodge the complaint.

When asked whom they would contact with questions or complaints, four respondents shared experiences they had of raising concerns about the waste collection system to the municipality. Two respondents in SE High neighbourhoods and one in an SE Medium neighbourhood made complaints which were promptly addressed with favourable results. However, one respondent from an SE Low neighbourhood did not have his complaint resolved, even though he made his complaint formally and a municipal official promised action. Many respondents from SE Low neighbourhoods expressed that they did not see a purpose in making complaints to the municipality because they expected no action to be taken to resolve them.

5.7 Opinions of waste collection system

Respondents' opinions towards the waste collection system were gathered. Table 5.11 shows the most common aspects of the system that respondents liked, Table 5.12 shows the most common aspects they disliked, and Table 5.13 shows the most common suggestions given to improve the system. Lists of other likes, dislikes and suggestions are provided in Appendix C.

The most common aspect of the waste collection system that respondents liked was "the containers are emptied regularly/daily" (48% of respondents, Table 5.11). There were no significant differences for any aspects of the system that respondents liked between SE groups. The other aspects that respondents liked about the containers show that they appreciate the containerization of waste. In many other cities in Mexico, waste is left on street corners, uncontainerized, for collection.

Table 5.11**:** Aspects of the waste collection system that respondents **like** by percentage of respondents who like them.

	% All Respondents
No. of responses	*276*
The containers are emptied regularly/daily	**47.83**
Streets are clean	15.94
Easy to use	14.86
Municipal collectors clean up around the containers	7.97
Others	30.80
Nothing/No response	15.94

The other likes are in List C.1 of Appendix C.

The most common aspects of the waste collection system that respondents disliked were "wastes are on the ground near the container", "people do not use the containers correctly" and "recyclable materials are not separated" (Table 5.12). Respondents often commented that the municipal collection system was good, but that problems occurred when people did not use the system correctly. The dislike "wastes are on the ground near the container" significantly increased with decreasing SE status. One might think that waste on the ground would result from careless or incorrect use of the containers, but the dislike that people do not use containers correctly did not correspondingly differ by SE group. The higher observance of waste on the ground in SE lower neighbourhoods may be due to waste collection employees not sweeping around the containers as well as they are supposed to. However, there are more gravel and dirt roads in SE Low neighbourhoods which make sweeping around containers less effective (see Figure 5.12). The complaint that recyclable materials are not separated increased significantly with the increasing SE status ($p<0.01$).

Table 5.12**:** Aspects of the waste collection system that respondents **dislike** by percentage of respondents who dislike them. (i.r.t – insufficient results to test).

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*276*	*92*	*91*	*93*	
Wastes are on the ground near the container	21.38	10.87	**24.18**	**29.03**	Yes, p=0.008
People do not use the containers correctly	17.03	16.30	**24.18**	10.75	No, p=0.052
Recyclable materials are not separated	13.41	**23.91**	10.99	5.38	Yes, p=0.001
Sometimes the containers are completely full or overflowing	10.51	7.61	7.69	**16.13**	No, p=0.095
Sometimes the waste in the containers is on fire	7.97	2.17	2.20	**19.35**	i.r.t.
Bad odour in my building from the containers	3.99	0.00	3.30	8.60	i.r.t.
Bad odour, rats, and/or flies near the containers	3.26	2.17	5.49	2.15	No, p=0.342
The containers are too far	2.54	4.35	0.00	3.23	i.r.t.
Dogs pull waste out of the containers and make a mess around them	1.81	1.09	3.30	1.08	i.r.t.
Containers are not emptied when they are supposed to be	1.45	1.09	3.30	0.00	i.r.t.
Others	21.74	28.26	17.58	19.35	No, p=0.171
None	35.14	33.70	42.86	29.03	No, p=0.136

The other dislikes that respondents mentioned are listed in List C.2 of Appendix C.

Figure 5.12: Container in SE Low neighbourhood Benito Palomino Dena on dirt at the side of a road. Note the waste on the ground around the container.

The SE Low group had the greatest number of respondents who disliked that "sometimes the containers are on fire" although there were insufficient responses for this in the other groups to validate a chi-squared test so the significance of this result is not known. Some respondents explained that occasionally people will set a full container on fire to make space. Throwing flammable waste in containers may also cause fires. SE Low group had the lowest level of knowledge about types of hazardous waste so residents of this group might be more likely throw flammable waste in the containers.

There were more respondents in the SE Low group than the other groups that disliked that there is a bad odour in their buildings from the containers (although this could not be tested for significance). This may be a result of the density of urban form increasing as SE status decreases because high density urban form makes finding suitable locations for containers where they are far from windows and doors difficult.

The most common suggestions to improve the waste collection system were "provide containers for recyclable materials" and "people should use the containers correctly" (Table 5.13). The amount of suggestions "provide containers for recyclable materials" increased significantly with increased SE status ($p<0.01$).

The SE Low group had the most suggestions "lessen the distance to the containers". Of the SE Low respondents with this suggestion, 66% were from Los Pericos, the neighbourhood with the second highest average distance to container (Table 5.2). La Herradura, a SE High neighbourhood, had the greatest average distance to container. They were perhaps more content with the distance because they preferred the containers not to be near their house as two respondents in that neighbourhood expressed. The SE Low group also had the most responses for the suggestions "empty containers more often" and "put more containers in this area", although the numbers of respondents with these suggestions were all fairly low. This group also had the most respondents who disliked that "sometimes the containers are completely full or overflowing".

The most common response to both the dislikes and suggestions questions was "none" (35% and 32% respectively). This shows that the containers are not viewed negatively or critically evaluated by residents.

Table 5.13**:** Suggestions to improve the waste collection system presented as percentage of respondents who gave them.

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*276*	*92*	*91*	*93*	
Provide containers for recyclable materials	**26.09**	**36.96**	**27.47**	13.98	Yes, p=0.002
People should use the containers correctly	**15.94**	7.61	**21.98**	**18.28**	Yes, p=0.022
Educate the public more about recycling	4.71	**7.61**	4.40	2.15	i.r.t.
Empty containers more often	3.99	3.26	1.10	**7.53**	i.r.t.
Lessen the distance to the containers	3.99	2.17	0.00	**9.68**	i.r.t.
Put more containers in this area	2.90	2.17	1.10	**5.38**	i.r.t.
Make a more convenient disposal schedule	1.81	1.09	2.20	2.15	i.r.t.
Empty containers on schedule	1.09	0.00	2.20	1.08	i.r.t.
Provide better and/or more equipment (trucks)	1.09	0.00	2.20	1.08	i.r.t.
Others	31.52	39.13	21.98	33.33	No, p=0.028
None	28.26	21.74	35.16	27.96	No, p=0.130

The other suggestions that respondents made are listed in List C.3 of Appendix C.

To determine the overall satisfaction with the collection system, questionnaire participants were asked "How do you consider the waste collection service?"[30] to which the most common response was "good" (55%, Table 5.14). The SE Low group was the least satisfied overall.

Table 5.14**:** Overall Satisfaction Rate. Percentages of responses to the question "How do you consider the waste collection service?" Note: This question was added near the end of the questionnaire phase, hence the low number of responses.

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference by SE group ($p<0.05$)**
No. of responses	*165*	*61*	*44*	*60*	
Very poor	2.42	3.28	2.27	1.67	No, $p=0.162$[31]
Poor	3.64	0.00	4.55	6.67	
Normal	33.33	27.87	27.27	43.33	
Good	**54.55**	**65.57**	**52.27**	**45.00**	
Very good	6.06	3.28	13.64	3.33	

5.8 User Affordability

The first several participants were asked how affordable they found the waste collection system fees, but they were not able to answer because these fees are embedded in the municipal tax, so this question was removed from the questionnaire. One respondent in a SE Low neighbourhood did comment that the taxes were not affordable.

5.9 Informal Collector Questionnaire Results

Questionnaires were conducted with several informal collectors in order to learn about their collection activities, incidences of illness and injury, and livelihoods. Information was gathered about: their demographics, including age and gender; the registration process; the locations from which they collect; the types and amounts of materials collected; the safety equipment used; how often they experience illness or injury; methods of transporting the materials collected; what is done with collected items; sources of income; and opinions of the collection system.

[30] This question admittedly sounds awkward, but it was used because the original question "What is your overall satisfaction level with the collection system?" did not translate into Spanish well.

[31] When very poor and poor are grouped and good and very good are grouped to improve chi-squared validity. However, despite this grouping the percentage of observed counts <5 was still >20% (22.2%).

Twelve informal collector surveys were conducted, two of which represent couples. For the demographics, registration and location results there were 14 participants (both individuals of the couples are included), while the rest of the results, including health impacts and opinions, had 12 participants (one individual from each couple responded). Participants include individuals who were observed collecting from the containers and approached, and household questionnaire respondents who mentioned they collect from containers. The number of participants is low, so the results are not generalizable, but they do give insight into the activities of informal collectors. More questionnaires would need to be conducted to obtain generalizable results and to estimate the recovery rate due to informal collectors in Aguascalientes.

The average age of the informal collectors surveyed was 49 with a standard deviation of +/-18 years. A full list of ages is provided in Table C. 15 of Appendix C. Two collectors were female and the other 12 were male.

Five collectors surveyed were registered. Registered collectors are municipally recognized as collectors and legally allowed to collect. Collecting is otherwise illegal. Seven were not registered. The first two collectors surveyed (a couple) were not asked if they were registered because the researcher learned about the registration program during the second survey. Figure 5.13 shows a registration card.

Figure 5.13: An informal collector's registration.

Eight participants collect in SE Low neighbourhoods, four were found collecting in SE Medium neighbourhoods, and two in SE High neighbourhoods. The numbers of collectors in each specific neighbourhood are given in Table C. 16 of Appendix C. Five participants said they collect from other neighbourhoods in addition to the one in which they were observed collecting. Five said they only collect from the neighbourhood they live in, while four said they only collect in neighbourhoods other than their

own. Respondents were not asked which neighbourhood they were from, but of those who said they lived in the neighbourhood they collect from seven were observed collecting in SE Low neighbourhoods and two in SE Medium neighbourhoods.

Participants were asked if they collect from any other sources. Six said they only collect from the containers, three also collect from the ground and two collect from the ground and a dumping area. Three of the 12 respondents said they have at least once asked for recyclable materials directly from households or businesses. One collects cardboard from a clothing store regularly every two weeks.

The items collected by the most collectors were cardboard and aluminum cans (collected by eight and seven collectors respectively). The items of which the greatest masses were collected were paper (average amount collected 212 kg/week), cardboard (145 kg/week) and scrap metal (99 kg/week). The amounts collected varied greatly between collectors. Full results of the types and amounts of materials collected are presented in Table C. 17 of Appendix C.

All but one collector used some form of protective equipment. The most common safety-related equipment was a stick used to rummage through waste with eleven collectors each using one. Five collectors regularly wear a face mask while two sometimes wear one. Six wore gloves. Only two of the 12 collectors surveyed reported that they had experienced injury or illness as a result of collecting. One had a stomach infection, and the other had an injury.

Four participants transported collected materials by bike, two of which had bikes modified with a front storage cart. One used a donkey and cart and three did not use a vehicle. These results are based on observation so the forms of transportation the participants who were surveyed at home used were not learned. See Figure 5.14.

Figure 5.14: The various modes used to transport collected items.

Most respondents (nine) sell all collected materials to buy/sell businesses and use them for no other purpose. In addition to selling recyclable materials to buy/sell businesses, two respondents keep and use some scavenged items, such as clothing, and one other respondent sells usable items such as toys to

individuals. For the majority of informal collectors surveyed, selling recyclables is their only source of income (eight respondents). Of the remaining respondents, collecting is the primary source of income for one and a secondary source for two. One participant chose not to give an answer when asked about his sources of income.

The questionnaire participants were asked about their opinions towards the collection system through open-ended questions without prompts. When informal collectors were asked what they liked about the waste collection system, the most common answer, with six responses, was "the containers are easy to collect from". Two respondents said they liked everything about the collection system, one didn't like anything, and one liked that collecting is something one can do when he or she doesn't have a job. The most common response to the question "What do you dislike about the waste collection system?" was "nothing" with five respondents. Other dislikes, each of which were said by one respondent, were: "the containers are sometimes full so collecting from them is difficult"; "you can get sick"; "you need to be registered to be allowed to collect"; and "collectors have to clean up around messy containers even if they didn't make the mess because if they don't and the police see the mess they would be accused of making it". (Many respondents of the household questionnaire said they dislike that informal collectors make a mess around the containers.) The most common response to the question "What would you suggest to improve the waste collection system?" was "nothing" with six respondents. Two respondents suggested separate containers for recyclables be provided and one suggested people separate their recyclables into different bags so they are easier to collect.

When asked to whom they would go with questions, complaints or suggestions, most respondents said no one (eight). One said he would talk to the municipality, another said he would talk to the person in charge of registering collectors, and one had no complaints.

To learn how informal collecting may be impacted by the proposed separate containers for recyclables (paper/cardboard, and/or metal/glass/plastic) the informal collectors were asked for their opinions on how these containers will affect their work. For this question, sometimes possible responses were offered as prompts. More than one response could be given. An equal number of positive and negative responses were given towards the idea of separate containers for recyclables. Five respondents said the containers would make collecting recyclables easier, while another five thought they would increase competition for recyclables materials. Three said the containers would benefit them as a collector, while three said the containers would negatively impact their work. One respondent supposed that informal collectors won't be allowed to collect anymore. During the questionnaire phase the researcher did not yet know that the proposed containers for recyclables were to have small openings

designed to make collection from them difficult. If this were known and described to the collectors, their opinions would probably have been more negative.

5.10 Recyclable Materials Buy/Sell Businesses

Three small businesses that buy and sell recyclable and reusable materials were encountered in Los Pericos. They were asked what types of materials they buy and sell, what they pay and charge for each material and how much of each material they receive. All results are presented in Table C. 18 of Appendix C. All three businesses buy from informal collectors or residents that save household recyclables and sell to larger companies. The percent increase from the buying price to the selling price ranged from 10% for paper and cardboard to 90% for glass bottles (Table 5.15). The average percent increase overall was 23%.

Table 5.15: The average buying and selling prices, and the percent increases in prices of materials dealt by three buy/sell businesses.

Material	No. of shops that deal (out of three interviewed)	Avg. buying price (pesos/kg)	Avg. selling price (pesos/kg)	Avg. % increase in price
Copper	3	63.3	70	12.2
Bronze	3	34	42.5	27.5
Aluminum	3	12.7	14	11.9
Iron	3	2	2.2	10.8
Glass Bottles	2	1 peso/bottle	1.9 pesos/bottle	89.6
Cardboard	3	1	1.1	10
Paper	1	1	1.1	10
Plastic Bottles	3	1.4	1.6	19.2
Hard Plastic	1	1.5	1.7	13.3

Of the three buy/sell businesses, the newest had just opened that week and the oldest had been in business two years. About 50 people regularly sell items to the largest, oldest business. Each business had one or two employees. Two businesses also buy and sell car scraps. See Figure5.15 a) and b) below of a buy/sell business.

a. b.

Figure5.15: Buy/sell business pictures. a.) sign advertising buy prices, b.) inside recyclable materials are sorted into piles.

Chapter 6
Discussion

6.1 Introduction

Is the collection system in Aguascalientes successful from an Integrated Solid Waste Management framework? If so, which aspects contribute to the system's success? Can those aspects be applied to other developing urban areas, especially areas with less income, and if so, how? This discussion explores the results of the interviews and questionnaires in consideration of the information from the literature review to answer those questions. The discussion is divided into the following sections:

1. *Factors of Participation:* Factors of participation in waste collection, adherence to waste collection policies and resource recovery are discussed.
2. *Assessment according to ISWM:* The results are divided by aspect into the categories of social, environmental, economic and management to discuss how well this system meets the principles of ISWM of social acceptability, environmental effectiveness, and economic affordability. The principles are considered concurrently to make an overall assessment of the system.
3. *The path to improvement*: The drivers that led to the improvement of the collection system in Aguascalientes are surmised. The roles of the population, the municipality, and the company that designed the containers and collection trucks in influencing the decision to change the collection system are briefly discussed.
4. *Application to other developing areas:* Ways in which developing areas can overcome barriers to CCC including lack of participation, lack of adequate planning and lack of financial means are suggested.
5. *ISWM Assessments:* The use of ISWM to assess existing waste collection systems is discussed.

6.2 Factors of Participation

Aguascalientes has a very high rate of participation (99%) by residents in the waste collection system. While participation rates in CCC in other developing areas were not reported in the literature, there were many discussions about poor participation, so presumably participation in those areas is low. Factors which contribute to the high participation rate in Aguascalientes may reveal ways in which increased participation can be facilitated in other areas.

Only two participants in this study did not use the containers, so comparisons cannot be made between those who do and do not participate in the collection system to determine factors of participation. Instead, the case study results are analyzed in consideration of participation factors discussed in the literature to draw out characteristics of the system that garner participation. Table 6.1 presents factors of participation identified in the case study and supported by developing country waste management literature.

Table 6.1: Factors of participation in collection.

Factors of Participation in Collection	Support from this Thesis	Developing Country Literature
Culture	**Yes**: Residents of Aguascalientes have a "culture of cleanliness"	Holmes, 1984
Distance to container	Distance not found to limit participation in Aguascalientes where maximum one-way distance from household to closest container is 360m.	Flintoff, 1976; Ogawa, 1989; Parrot et al., 2008; Bhide & Sundaresan, 1984
Convenience	**Yes**: Containers that are further away will be used if more convenient than closest container	Bhide & Sundaresan, 1984
Regular and thorough collection	**Yes**: Respondents liked the regular, thorough collection and infrequent overflowing containers	Cointreau, 1984; Korfmacher, 1997; Sharholy et al., 2007
Extent of behaviour change	Evolution of the current collection system out of previous methods thought to have facilitated participation as a low amount of behaviour change was required.	Not a factor identified in collection literature, but developed country recycling literature supports: Perrin & Barton, 2001
Financial incentives or fines	**No**: There are no fees /financial incentives, and fines are rare, but participation rate is high	Korfmacher, 1997; Fullerton & Kinnaman,1995

"Limpia es nuestra cultura", which translates to "cleanliness is our culture" is a common phrase in Aguascalientes (see Figure 6.1). Several participants mentioned this culture of cleanliness, which was expressed in the observable cleanliness of the city. Holmes (1984) found that cultural attitudes, beliefs and values towards waste and waste management influence participation in various waste management programs. The culture of cleanliness in Aguascalientes is thought to motivate residents to walk as far as a few blocks to keep their neighbourhood clean by participating in the container system.

Figure 6.1: Painted sign in public bus. Translated into English: "Demonstrate your culture - no littering. Thank you"

Distance from homes to containers is often cited as a limiting factor of participation in CCC systems (Flintoff, 1976; Bhide, 1984; Owaga, 1989; Parrot et al., 2008; Blight & Mbande, 1996). In Aguascalientes, just over 80% of respondents live within 160m of a container and almost 90% live within 200m (Figure 6.2). Only one of the 30 of respondents who live further than 200m from a container made a complaint about the distance. In fact, several respondents use a container that is further than the closest one to them because the container they use is on route to daily destinations. The results of this thesis suggest that in areas with flat terrain, distances of mean 114+/- 71m one-way from households or places of work to containers do not discourage participation in a collection system. However distance cannot be considered in isolation of other factors of participation. If other factors are unfavourable, for example if a community does not have a culture of cleanliness, the length of distance to container tolerated by that community may be lower.

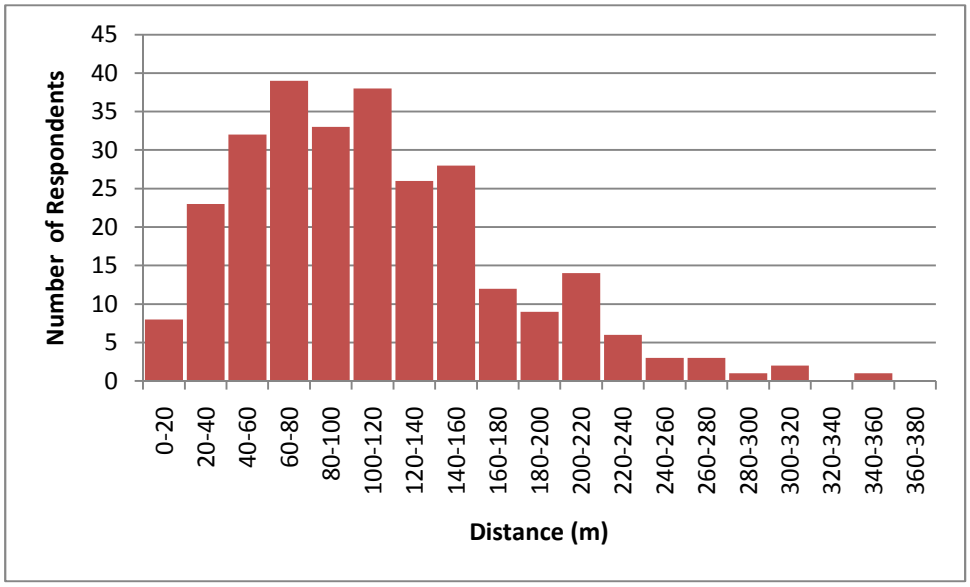

Figure 6.2: Histogram of distances to closest container.

Respondents like that collection occurs regularly and is thorough. The literature cited that irregular and incomplete collection to discourage participation because waste piles up and repels users (Cointreau, 1984; Korfmacher, 1997; Sharholy et al., 2007). The case study results show the same phenomenon from a positive perspective, where high participation is sustained by regular and thorough collection. There were however some "dislikes" of containers overflowing. While overflowing containers are undesirable, the high participation rate shows that a low level of irregular or insufficient collection can be withstood without reducing participation.

The method of waste collection in Aguascalientes changed from the deposit of waste on corners for collection, to the unofficial storage of waste in empty water containers, to the municipally-sanctioned use of containers. These gradual changes over about ten years allowed users to adapt to each successive method of collection. Had the container collection system been imposed on an area that did not have a similar collection method before, the unfamiliar system likely would not have garnered as much initial participation.

A lack of potential dumping sites in Aguascalientes may contribute to the high participation rate in the container system. The urban form of Aguascalientes is very compact being mostly comprised of attached row houses with only a few undeveloped lots. Most neighbourhoods do not have access to natural areas or waterways. Perhaps if there were more, and more conveniently located, waterways and undeveloped areas more residents would indiscriminately dump waste. For example, the two households that did not use a container were closer to the riverbed they dumped waste into than the nearest container. Based on the amount of waste in this riverbed, more residents in the area presumably also dump waste there. Nearly all of the few undeveloped areas encountered by the researcher were littered to some extent.[32]

A notable exception to the factor postulated above is the clean riverbed behind La Herradura. This SE High neighbourhood has the longest distances between households and containers out of all the neighbourhoods questionnaired. Residents in La Herradura used to dump waste into the nearby riverbed, which eventually developed an offensive odour. To get rid of the odour, the community decided to have the riverbed cleaned up.[33] Since the community, not an outside party, made the decision to have the riverbed cleaned, the community wants to keep that area clean. For this reason, the community is motivated to go to great lengths, or ensure their maids and gardeners go to great lengths, to use the containers.

The collection system in Aguascalientes has obtained a high participation rate without the use of financial incentives or fines. Korfmacher (1997), Fullerton and Kinnaman (1995) found financial incentives and fines to encourage participation in waste collection. Unfortunately, the communal nature of container systems makes the use of financial incentives and the administering of fines difficult. While the municipality does have policy outlining fines for the misuse of the system, fines are difficult to enforce.

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[32] There were open areas that could not be developed due to underground utilities with several small piles of waste dumped on them (mostly rubble - concrete rubble is not permitted in the containers). There were a few empty lots observed in residential areas that had small amounts of litter on them.

[33] By whom the riverbed was cleaned is not known. The wealthy community may have hired cleaners, or may have lobbied the municipality to take the responsibility of getting the riverbed cleaned.

The lack of enforcement of the fines affects proper use of the container system, but does not affect participation in the collection system. If other factors are favourable, such as the existence of a culture of cleanliness, financial incentives and/or fines are not necessary to gain participation in waste collection.

Factors of Proper Use

The extent to which waste collection regulations are adhered to can have social, environmental and economic impacts which affect the success of that system. Pickford (1984) and Bhide (1984) both found co-operation by the public to be important to the success of a waste management program. In Aguascalientes, adherence to municipal regulations regarding hazardous waste management and the schedule for waste disposal is low. Factors of adherence to regulations in Aguascalientes were found to be: knowledge; convenience, which is influenced by suitability to local lifestyle; and perception of importance/effectiveness (Table 6.2). Since no studies regarding factors of adherence to waste collection regulations were found, the literature on factors of recycling behaviour is referenced to support the case study findings.

Table 6.2: Factors of adherence to waste collection regulations.

Factors of adherence to regulations	Support from this thesis	Support from the literature on factors of recycling behaviour
Knowledge	Low knowledge levels contribute to low adherence to hazardous waste management and the disposal schedule	Gamba & Oskamp, 1994; Sidique et al., 2010; Perrin & Barton 2001; Troschinetz & Mihelcic, 2009
Convenience/ suitability to lifestyle	Inconvenience discouraged participation in disposal schedule Work hours for some respondents clashed with disposal schedule	Matsui et al., 2007; Bartelings & Sterner, 1999; Gamba & Oskamp, 1994; Sidique et al., 2010; Perrin & Barton, 2001; Ekere, et al., 2009
Perception of importance/effectiveness	In areas of the city where the disposal schedule is not coordinated with collection some respondents don't adhere because they perceive the schedule as irrational and unnecessary	Matsui et al., 2007

Improper use of the collection system was due in part to lack of knowledge about the system's regulations. Only 73% of the respondents knew the disposal schedule and only 60% adhere to the schedule. Even fewer respondents had knowledge about types of hazardous waste and how to dispose of them.[34] Without knowledge of the regulations of a collection system, whether or not one will adhere to them is left up to chance.

[34] Thirty-eight percent of respondents did not know any types of hazardous waste and only 14% of respondents knew where to take hazardous waste.

The convenience of a regulation affects adherence. About one third of respondents who knew the disposal schedule but did not adhere said they did not because of the inconvenience of the schedule. The SE High group had the lowest adherence to the disposal schedule (33%) and also had the most participants who knew the schedule but chose not to adhere (35%). Most SE High households employ maids who work daytime hours and usually dispose waste when they leave work in the afternoon before the start of the scheduled disposal time. The disposal schedule was not planned with the lifestyle of these employees in mind. The social acceptability principle of ISWM states, and Troschinetz and Mihelcic (2009) found, that public lifestyle needs to be considered when planning waste management.

Low adherence suggests that the disposal schedule is not regarded as necessary or important. The rationale for the disposal schedule is organic waste won't spoil as quickly in the cooler temperatures of the night. This rationale makes sense if the containers are emptied in the early morning, but in many areas of the city the containers are not emptied until the afternoon or early evening, so waste deposited the night before sits in the containers all day. The respondents who said they don't follow the schedule because they dispose of waste right before their container is emptied (15% of those who knowingly don't adhere to the schedule) show understanding that the less time waste sits in a container the less unpleasant that waste becomes. This is evidence that perceptions of the rationality and importance of regulations are also factors of adherence.

The impact of adherence to a regulation on the success of a collection system depends on the social, environmental and/or economic importance of that regulation. In Aguascalientes, the lack of adherence to the disposal schedule and lack of synchronization of the disposal schedule with the collection schedule do not affect the success of the collection system because collection is daily. With daily collection of waste, disease vector reproduction is limited which mitigates negative health impacts. Lack of adherence to hazardous waste management regulations does negatively impact the environment and public health.

Factors of Participation in Resource Recovery

The resource recovery rate by volume at the household/small business level in Aguascalientes was found through this study to be 33%.[35] This rate is similar to that of many other developing and developed countries (Troschinetz & Mihelcic, 2009). Factors of participation in resource recovery frequently identified in the recycling literature include SE status, distance to recycling location and convenience (Table 6.3).

[35] See more accurate recovery rate presented in Addendum C.

Table 6.3: Factors of recycling behaviour.

Factor Affecting Recycling Behaviour		Developing Country Literature	Developed Country Literature	Support by this Thesis	
Socio-economic status	Income	**No:** Beall, 1997; Troschinetz & Mihelcic, 2009	**No:** Derksen & Gartrell, 1993,	**Non-proportional**: More recycling via programs by SE High group, more recycling via selling by SE Low group.	
			Ambiguous: Sidique et al., 2010		
	Education		**Yes:** Hasan, 2004; Parizeau, 2006; Derksen & Gartrell, 1993, (weak)		
			Ambiguous: Guerin et al., 2001; Sidique et al., 2010		
Inconvenience/ difficulty of use Includes sorting effort, storage requirements, distance to recycling facilities		**Yes:** Ekere, et al., 2009, (time requirement)	**Yes:** Matsui et al., 2007 Bartelings & Sterner, 1999; Gamba & Oskamp, 1994; Sidique et al., 2010 (distance, sorting time); Perrin & Barton 2001, (strong); Larsen et al., 2010 (distance); Dahlen et al., 2007 (distance)	**Distance as a factor of difficulty of use – Yes, but evidence is weak[36]:** Most respondents were not willing to travel further than to their current container to use recycling facilities **Inconvenience – Yes for specific programs, but other more convenient methods may be used:** Of the respondents who knew about centres but didn't use them, 1/3 did not use them because they are inconvenient. Another 1/3 uses a different method of recycling.	
Knowledge about recycling programs and/or types of recyclable materials		**Yes:** Troschinetz & Mihelcic, 2009	**Yes:** Matsui et al., 2007 – (strong effect); Gamba & Oskamp, 1994; Sidique et al., 2010; Perrin & Barton, 2001, (types of recyclables)	**Yes, for specific programs but other methods are often used**	Only 56% of respondents knew about recycling centres. Use of those centres was low (15%), but other methods of resource recovery were frequently used (74% of respondents recover resources)
Access to recycling program/facilities			**Yes:** Derksen & Gartrell, 1993, (strong)		More SE Medium and High respondents use the municipal recycling depots than SE Low which may be in part because the shopping centres where the depots are located are closer to SE Medium and SE High neighbourhoods

[36] Evidence is weak because the second most common response to the question asking how far they would be willing to travel to use containers for recycling was 30 or more minutes, but this response was thought to be influenced by lack of anonymity during the questionnaire.

This study found SE status was related to recycling behaviour, but not proportionately since the resource recovery rate by volume was highest for the SE High group (41%) and lowest for the SE Medium group (19%). This non-proportional trend reflects the ambiguity found in the literature surrounding how SE status affects recycling behaviour. The results of this study suggest that the ambiguous relationship between SE status and recycling seen in the literature may be due to recycling having a positive relationship with education and a curved relationship with income such that high and low income both motivate more recycling behaviour than medium income.

Individuals who have more education about environmental issues may be more motivated to recycle for the environment benefits than those with less education. Since education is a factor of SE status, a positive relationship between education and recycling behaviour would create a positive relationship between SE status and recycling behaviour. All children in public and private schools in Aguascalientes receive environmental education. When the environmental education program started was not asked. Many adults likely did not receive environmental education if they went to public school, but may have if they went to a private school or onto higher education. There was positive relationship between SE status and suggestions for more recycling facilities in the case study, which may be evidence of education positively impacting recycling.

Recycling behaviour appears to have a curved relationship with income. High income enables recycling while low income motivates selling recyclables for supplementary income. High income enables recycling because those who can afford a vehicle can more easily transport recyclables to depots and those who employ maids can have them perform recycling activities. This may explain why the SE High group had the highest resource recovery rate. The SE Low group had significantly more respondents who sell recyclable materials than the other SE groups which is evidence that low income motivates selling recyclables.

The combined effects of education and income on recycling behaviour would confound one another when recovery behaviours are compared by SE status. Rather than studying the effect of SE status on recycling, studies should examine the relationship between income and recycling, while holding education constant, and vice versa. Unfortunately such studies would be difficult because education and income are generally closely linked.

Increased distance to recycling location was hypothesized to decrease recycling behaviour. This hypothesis was supported by the case study results that a high number of respondents were not willing to travel further than to their current container to divert recyclables and that some respondents do not use the existing recycling depots because they are too far away. This hypothesis was also supported by findings

in the literature that curbside recycling collection yields higher recovery rates than programs where recyclables must be dropped off at collection depots or centres (Larsen et al., 2010; Dahlen et al., 2007).

There were however, a large number of respondents who said they were willing to walk more than 30 minutes to use the proposed recycling segregation containers. This contrasts with the large number of respondents who knew about the existing recycling centres but did not use them. A cultural trait in Mexico is not to offend others, especially those with whom one is not closely acquainted and is speaking directly, even at the expense of honesty. The willingness to travel long distances to use the recycling containers may have been asserted by respondents because they thought this was the response that the researcher wanted to hear, in which case the results do not accurately explain how distance to recycling facilities affects resource recovery behaviour. If the clause, "in your honest opinion" had been added to the respective question, and if paper copies of the questionnaire were handed out to respondents who were literate to increase anonymity while answering the questions, the responses to this question may have been more honest and accurate.

Convenience is a factor of participation in recycling. The most common response (50% of respondents) to the question regarding willingness to use the proposed recycling containers was "only if they are in the same location as my current waste container". This shows that respondents are more likely to recycle if recycling does not require much change to their established routine. The less change to established routine, the more convenient a recycling method will be. If various modes of recycling are available, convenience may only be a factor of the method of recycling used, and not a factor of whether or not recycling occurs. This is the case for the many respondents (30%) who said they do not use the existing recycling depots because they use a different method of recycling.

Although waste-related systems should be designed with public lifestyle in mind in order to minimize behaviour change and better facilitate participation, some behaviour change will always be necessary when a new system is introduced. Extensive behaviour change may be desirable in some cases to increase environmental and/or economic effectiveness of the system. The municipality attempts to promote increased recycling behaviour through campaigns in schools and at public events about the environmental importance of recycling. The school campaigns are effective because many kids and their parents are learning which materials are recyclable and are participating in recycling through school programs. The researcher believes that these campaigns are working to gradually increase environmental awareness and recycling behaviour in Aguascalientes. In conjunction with the launch of the new recycling container program, the municipality was planning an extensive mass media campaign to educate the public on the use of the system and the environmental benefits of recycling. Hopefully this campaign has

and will encourage the behaviour change necessary to garner and sustain extensive participation in the new system.

6.3 Assessment According to ISWM

The waste collection system in Aguascalientes was assessed according the principles of social acceptability, environmental effectiveness, economic affordability and effective management to determine if the system is successful from an ISWM framework. The following sections break the results of the interviews and questionnaires into the aspects of social, environmental, economic and management for discussion and assessment. The collection system was the primary focus of this assessment, but some indicators, such as the extent of pollution, were broadened in scope to include the method of final disposal. In doing so, the collection system was thoroughly assessed, and the waste management system was partially assessed.

SOCIAL

The way waste is managed affects human health and disparities between groups of people. A socially acceptable waste collection system would be one in which human health is not negatively impacted by waste, and existing social inequalities aren't deepened by inequalities in collection service. Table 6.4 shows the indicators used to measure social acceptability, their measurements or qualitative descriptions and their impacts on social acceptability.

The collection system is used by nearly all of the population (99% of respondents) which indicates that the system is accepted by the public. There are no municipally-initiated public engagement events when changes are made to the waste management system, but the public can get involved by submitting project proposals and addressing complaints to the municipality. This suggests that public involvement does not have to be sought out by the provider in order to produce a waste collection system that is socially acceptable. This is an important finding considering that many developing cities may not be able to afford municipally-initiated public involvement.

Differences in distance to container by SE status may indicate inequality in service provision. The distances to container significantly increased with increasing SE status when the results from the non-randomly selected neighbourhoods were not included. However, over 90% of all households within each SE group surveyed (not including non-randomly selected neighbourhoods) were within 200m of a container, so, regardless of SE status, the distances to containers are not very large for most respondents. The trend of increased distance to container with increasing SE status is due to urban form density

decreasing with increasing SE status in Aguascalientes. The containers are more dispersed in areas with lower density to maintain efficient use of container capacity.

Table 6.4: Assessment of social acceptability.

Indicator	Measure/Description	Impact on social acceptability
Public participation in collection	High - 99%	Positive
Level of public involvement in waste related decisions	Publically-initiated • Individuals and groups can submit project proposals • Forum for complaints	Positive
The existence/level of waste collection inequality	Evidence that collection service decreases slightly with decreased SE status • Longer distances to containers in SE Low neighbourhood Los Pericos • No. of complaints of fires in containers and waste on ground increases with decreasing SE status	Slightly negative
Overall quality of service	Overall opinions towards collection system are 93% neutral or positive	Positive
Treatment of informal collectors	The municipality recognizes, supports and attempts to control informal collecting through registration program Recycling containers that do not permit collection will have negative impact on informal collectors	Positive Negative
Negative health impacts due to waste	Low prevalence of illness/injury amongst public and collectors	Positive
Working conditions and compensation for collection employees	Labour laws govern work hours, holidays and compensation for injuries Fair salaries: 3.8 -5.4 times minimum wage and 1.2 times the national average for collection workers	Positive
Overall	Somewhat socially acceptable. Less acceptable for informal collectors and residents in very low income neighbourhoods.	

There was one notable exception to the trend of increased distance to container with increasing SE status. Los Pericos had the second largest average distance from household/small business to closest container out of the neighbourhoods surveyed, despite having a very compact urban form. One might hypothesize that this low income neighbourhood would have a lower rate of waste generation than those with higher income, and would not need as many containers. In fact, Los Pericos generates close to the same mean amount of waste as other SE Low neighbourhoods, and more than SE Medium. The longer

distances to containers in Los Pericos indicate that this neighbourhood receives a lower standard of waste collection service than others in Aguascalientes. Municipal tax income from Los Pericos may be low due to the low income of residents and the suspected transient nature of some residents (as some of the families surveyed had not lived there very long). Waste collection providers in other cities have provided a low level of service to low income areas arguing that people should not receive a service for which they do not pay (Mungai, 1998; Pickford, 1984).

The differences in dislikes between SE groups indicate that waste collection service decreases with decreasing SE status. More complaints about fires in containers were made by respondents in the SE Low group. If a container is full, someone may set the waste on fire to make space.[37] A high frequency of full containers may indicate that there are too few, or too small containers. The complaint of waste being on the ground around containers increased in frequency with decreased SE status, which may indicate that the collection employees do not sweep around the containers as well in SE Low and Medium neighbourhoods as in SE High. Based on the experiences shared by a few respondents who had addressed complaints to the municipality, the responses to SE High and Medium complaints were more favourable than those to SE Low, which also indicates lower service in and less consideration of SE Low neighbourhoods.

Whether or not there exist inequalities by gender with respect to the burden of waste management also influences social equality. In Aguascalientes, men and women are equally responsible for taking waste from houses or small businesses to the container. This opposes the expected result based on the literature that women are carry more responsibility for household waste management than men (Ekere et al., 2009; Beall, 1997). Which gender carries the most responsibility of preparing waste for disposal was not investigated.

Comparing the service levels between SE groups does not give insight to whether or not the service is poor or fair overall. The consideration by the public of the overall quality of service was examined to further evaluate the social acceptability of the collection system. Evidence suggests that the public finds the system to be satisfactory. Ninety-three percent of respondents neutrally or positively rated the waste collection system[38] and there were both more likes and suggestions about the collection system than dislikes overall. However, when asked for their opinions about the collection system, very few respondents seemed to have critically evaluated, or even briefly thought about, the system before. Rather

[37] Also, spontaneous burning may occur if flammable waste is disposed in the bins. Flammable materials such as fuels, oils and solvents are not permitted in the containers, but many respondents did not know any of the types of waste not permitted in the containers (44%).

[38] Ninety-three percent of respondents rated the collection system as normal (neutral opinion), good or very good.

than consciously evaluate a waste collection system, people tend to adapt to and be content with established systems unless they experience a problem that directly affects them.

The municipal relationship with informal collectors shows both stimulation and repression/neglect as described by Medina (2005). Several programs demonstrate stimulation including: the food for recyclables program in low income neighbourhoods; the registration and licensing program to permit informal collection from the containers; and the contracting of the collection of recyclables from the landfill. However, the proposed recycling containers, which are designed in such a way to prevent, or at least severely discourage, the recovery of materials, will repress informal collection activities.

The recycling containers will reduce the amount of recyclable items that can be collected by informal collectors both by their design and because the amount of recyclables deposited in the regular waste containers will decrease if participation in the new system is high. If the supply of recovered recyclable materials drops significantly, then many of the small businesses that buy and sell recovered items will probably go out of business. Fewer buy/sell dealers will decrease the opportunities for informal collectors to sell recovered items, perhaps to the point where informal collecting as a means of income is completely abandoned.

This study found that informal collectors sometimes use safety equipment, a behaviour which was not reported in the literature. All of the collectors surveyed use at least one form of safety equipment. The municipality requires registered informal collectors to wear gloves and a facemask. Blight and Mbande (1998), Thomas-Hope (1998) and Gardner, Hamilton, and Ruiz (1998), each mentioned the need for informal collectors to wear safety equipment, which implies that the informal collectors they observed did not.

The social acceptability of a waste collection system is also indicated by the prevalence of negative health impacts due to waste amongst the general population and waste collectors. Health problems due to waste were never mentioned by questionnaire participants when asked for their complaints, and the containers prevent contact with waste produced by others, so the health impacts due to waste on the general population appear to be low to non-existent.

The risk of injury encountered by the waste collection employees in Aguascalientes is low relative to that of other developing and developed countries.[39] The low accident rate in Aguascalientes may be attributed to the safety training and protective equipment required of workers, and the labour laws of Mexico which protect worker rights and health.

The prevalence of illness amongst the collection workers was not determined. Illness would results from exposure to biologically hazardous waste. Many residents in Aguascalientes bag their sanitary waste (tissues, toilet paper). Some questionnaire respondents said that bagging sanitary waste was required, but the waste collection manager made no mention of this.

The negative health impacts experienced by informal collectors in Aguascalientes seem to be low as only two of the twelve collectors surveyed reported that they had been sick or injured as a result of collecting. However, whether or not an illness or a chronic health problem results from collecting is difficult to determine. More research is needed to estimate the overall health status of informal collectors in Aguascalientes.

The working conditions and compensation for the waste collection employees are socially acceptable. As mentioned above the safety protocol acts to decrease the risk of illness and injury for employees. The labour laws in Mexico ensure collectors are not overworked and receive compensation for work-related injuries or illnesses. The wages are 3.8-5.4 times greater than minimum wage and 1.2 times greater than the wages of waste collectors in other municipalities of Mexico.

From the results of this study, the waste collection system of Aguascalientes appears to be socially acceptable due to the high rate of participation, the overall positive regard for the collection system, the low incidence of health impacts of waste on the general population and collectors, and the fair compensation for collection employees. Nonetheless, the municipality could ensure equal service is given to each neighbourhood to improve social acceptability. The design of the proposed recycling containers should be changed such that collection from them will be possible to make them socially acceptable to informal collectors.

ENVIRONMENTAL

Waste management systems should attempt to minimize harm to the environment while being socially acceptable and financially affordable (Kollikkathara, 2009, citing McDougall et al., 2001). The indicators of environmental effectiveness considered in this discussion were the resource recovery rate,

[39] The collection employees experience only a 3.7 times greater risk of injury than other workers in Mexico. This is low compared to the relative risks encountered by collection workers in Demark, who have a 5.6 times greater risk of injury, and in the United States, who have a 10 times greater risk of death than other workers (Cointreau, 2006).

the extent of hazardous waste management, fuel usage and the final disposal method. Table 6.5 shows a summary of the assessment of the environmental effectiveness of waste collection and the overall waste management system in Aguascalientes.

Table 6.5: Assessment of environmental effectiveness.

Indicator	Measurement/Status	Impact on environmental effectiveness
Resource Recovery Rate	33% by volume[40] which is within the range of recycling rates of other developing and developed countries	Positive, but could be improved
Extent of Hazardous Waste Management	Hazardous waste protocol and disposal facilities exist, but a lot of hazardous waste is improperly disposed due to low knowledge levels amongst residents about types and disposal	Negative
Fuel Use	Fuel use is minimized by several design features	Positive
Method of Final Disposal	Sanitary landfill with leachate and off-gas collection	Positive
Overall Assessment	Somewhat environmentally effective. The recovery rate and participation in hazardous waste management could be improved	

The resource recovery rate within households and small businesses was found to be 33% by volume.[40] The total recovery rate for waste generated in households and small businesses is likely greater due to the resource recovery efforts of informal collectors, formal collectors during waste collection, and landfill collectors. By mass, the recovery rate is probably smaller than the rate by volume because recyclable materials are typically less dense than organics and the organic recovery rate is not high. The recycling rate by mass probably falls into the range of recycling rates found in developing countries by Troschinetz and Mihelcic (2009) of 0-41% (where the recycling rate includes recovery of paper, plastics, glass and metal but not organics). Aguascalientes may also have a recycling rate similar to many developed countries, which also fall into this range (EU 18%, US 30% Troschinetz & Mihelcic, 2009; Canada 22% from 2004 to 2006, Statistics Canada, 2008).

The resource recovery rate was higher than expected considering that the collection system does not offer recycling pick-up, and there are only 13 municipal recycling drop-off centres in the city. Resource recovery in Aguascalientes largely occurs by residents selling and giving away organics and recyclables, and taking recyclables to school or depots (public or private). This demonstrates that

[40] See more accurate recovery rate presented in Addendum C.

recovery can occur at a fairly high rate without having recycling and/or organics collection programs co-ordinated with regular collection.

Although the recovery rate is higher than expected and comparable to that of other developing and developed countries, the rate could be improved to increase the environmental effectiveness of the collection system. A high volume of paper products and plastics are generated in Aguascalientes the recovery of which could be increased.

The new recycling container system may improve the resource recovery rate, but will negatively impact informal collectors and add to the cost of waste collection. Some of the resource recovery of the recycling containers will be due to a loss in recovery by informal collectors. If the recycling container system does not significantly increase the recovery rate overall (taking into consideration the loss in recovery by informal collectors), then the municipality ought to abandon the recycling container program and invest in recovery methods which are more cost-effective and supportive of informal collectors.

Items which are hazardous to public health or collection equipment are not permitted in the waste containers in Aguascalientes. Questionnaire participants knew little about the types and disposal of those items, so improper disposal was probably common. If residents wish to dispose of items that are hazardous to collection equipment they can contact the Directorate of Cleanliness and Public Sanitation to arrange for them to be picked-up at no charge. Unfortunately, this service is not well communicated to the public. The municipality does not collect items that are hazardous to public health, but there is a hazardous waste landfill 150km from the city to which the municipality refers those items. Unfortunately there is no clearly communicated or inexpensive way for residents to arrange for hazardous waste to be transported to this landfill. The municipality should consider organizing and paying for the collection of waste that is hazardous to public health via regularly scheduled and well communicated pick-up days on which residents place only hazardous waste into the containers. The types of hazardous waste could be communicated through signs (word and picture) on the containers.

Minimizing fossil fuel use reduces air pollution and the emission of greenhouse gases. The waste collection system in Aguascalientes has several features which reduce fuel consumption. Collection systems with containers that can be lifted and dumped into collection trucks require less idling time and therefore less fuel, than those which require waste to be shovelled or gathered by hand and placed into vehicles. Transfer stations reduce fuel use because fewer, and fuller, trucks travel to the landfill. Larsen et al. (2009) pointed out that the distance to a waste treatment facility (such as a landfill) ought to be minimized to reduce fuel use. The landfill for Aguascalientes is only 12km outside of the city. All of

these features conserve fuel. However, collection is daily in Aguascalientes, so fuel consumption is higher than that of systems with less frequent collection.

Aguascalientes has an engineered sanitary landfill, complete with a lining and a leachate collection system, both of which reduce soil and water contamination from decomposing waste. A system is in place to collect and cleanly burn methane to CO_2, reducing the potency of the landfill's greenhouse gas [GHG] emissions. When the landfill produces a sufficient amount of biogas, an energy-from-waste [EFW] facility will be built that will mitigate almost all of the landfill's GHG emissions and reduce dependence on fossil fuels for energy.

The environmental effectiveness of the waste management system in Aguascalientes was better than expected for a single stream collection system, but could be improved. The transportation system and landfill function well to reduce fossil fuel emissions and mitigate air, soil and water pollution due to decomposing waste. The recovery rate is similar to that of other developing and developed countries, but could be increased by recovering a greater portion of the large amount of paper and plastics generated in Aguascalientes. The new recycling container system and corresponding recycling education program may increase the recovery rate. Although there is a hazardous waste disposal system in place, the communication and ease of proper disposal ought to be improved.

ECONOMIC

A waste management system will not be socially acceptable or environmentally effective if it is not also economically sustainable in the long term. The waste collection system in Aguascalientes was found to be economically affordable. The indicator results about the financial stability of the waste management system in Aguascalientes are presented in Table 6.6.

The proportion of the municipality's operating budget allocated to waste management indicates the extent to which the provision of waste management impacts the municipality's ability to provide other services. Only 3.3% of the operating budget was designated to the Directorate of Cleanliness and Public Sanitation which is responsible for waste collection and disposal as well as other activities (IMPLAN, 2009). This percentage is low relative to that of other developing countries (10-40%, Cointreau, 2006; 20-50%, Arlosoroff, 1991). This indicates that the cost of waste management in Aguascalientes does not greatly impede the municipality's ability to provide other important services.

Financial stability and extent of debt indicate whether or not a municipality can afford, and continue to afford, its waste management system. In the past decade, the municipality of Aguascalientes has run very close to a balanced budget, alternating almost annually between deficits and surpluses of less

than 5% the amount of the total budget. During the past decade the municipality has paid-off and borrowed such that the debt has risen proportionally to the increase in municipal income (due to population growth) and ranges from 8-15% the amount of each annual budget. These indicator measurements show that the municipality is in a financially stable state and has demonstrated fiscal responsibility.

Table 6.6: Assessment of economic affordability.

Indicator	Measurement/Status	Impact on economic affordability
Proportion of the municipal operating budget allocated to waste management and collection	3.3% Lower than that typical in other developing countries	Positive
Financial Stability of the municipality	Financially stable: Municipality alternates between surpluses and deficits of <5% of the annual budget	Positive
Whether or not debt is incurred by the municipality, and if yes, the extent	Yes, the amount of debt is about 12% of the amount of the municipal operating budget on average for the last 5 years	Positive, debt level is stable
Degree of cost recovery	Whether or not the collection system has a balanced budget is not known. The municipality is financially stable which indicates that sufficient income is obtained through taxes and other sources to pay for collection. Sale of recyclables does not cover costs of recycling programs.	Positive
Affordability of waste collection/management fees to the users	Fees are affordable because they are incorporated into municipal taxes which are proportional to income	Positive
Long-term sustainability of the system	Current system has been in operation for 20 years	Positive
Overall Assessment	Economically affordable	

Degree of cost recovery indicates the financial self-sufficiency of a waste collection system. Self-sufficient sources of income include service fees, fines for misuse, and profits from the sale of recyclables, but not government subsidies. In Aguascalientes, municipal and state revenue from taxes make up a large proportion of the financial resources used to pay for waste collection. This money can be considered to be the service fees paid for collection by residents, since fees are not recovered by any other means. There are regulations about the use of the system, and presumably fines for misuse, but the

communal nature of the container collection system makes enforcement of these regulations and the collection of fines, difficult. The directorate responsible for waste management also receives income from the sale of carbon credits and landfill tipping fees, which are self-sufficient sources of income. The directorate responsible for recycling receives income from the sale of recyclables and through private company partnerships, but this income is not sufficient to cover the cost of the programs, which also receive municipal and state funding.

The degree of cost recovery can be indicated by whether the collection system runs a balanced budget. Unfortunately this financial information was not obtained. In the past decade, the deficits of the entire municipality have been low relative to the municipal budgets and have been offset by surpluses. Whether or not the collection system contributed to the deficits is not of great importance because the municipality is financially stable overall.

The impact of the waste collection fees on the users to provide for their families' needs indicates the affordability of the collection system to the users. The waste collection fees are integrated into municipal taxes so respondents could not comment on whether or not, or to what extent the waste collection costs impact their abilities to meet their families' needs. Since the fees are integrated into the taxes, and the taxes are proportional to income, the cost of collection is likely more affordable for low income residents than a flat rate would be. However, the taxes may be too burdensome for some very low income residents as one respondent expressed.

In addition to the above indicator measurements, several observations suggest that the waste collection system is affordable to the municipality of Aguascalientes. The municipality was able to make an initial capital investment of about 95 million MXN (~$7.8 million CAD) into the container collection system. The collection system has financially efficient features which aid in making the system affordable. Having at most one container every 50 buildings saves time and gas relative to curbside collection if the collection frequency is held constant. The compaction and transfer stations and short distance to the landfill also reduce fuel expenses.

Overall, the waste collection system in Aguascalientes is assessed as economically affordable for the following reasons. The municipality was able to afford substantial capital costs to commence operation in 1991 and has been able to maintain and improve operation since then. The proportion of the municipality's operating budget allocated to waste management is low relative to that of other developing countries such that waste management does not greatly impede the provision of other important services. Although the municipality is in debt, the debt level is stable. Finally, since the costs of waste collection

are covered mostly by income from taxes, and as taxes are proportional to income level, the costs of the system are thought to not be a great burden to users.

MANAGEMENT

Management is the means by which the social, environmental and economic aspects of waste management are balanced and optimized. The aspects of management examined in this analysis are: efficiency of collection and labour; governance capacity, as indicated by the effectiveness and enforceability of policies, the extent of communication, and the treatment of different SE groups; and the extent to which the system is tailored to context. Cost efficiency is controlled by management, but was discussed in the economic affordability section and so is not discussed here. A summary of the effectiveness of the management of the waste collection system in Aguascalientes is provided in Table 6.7.

Table 6.7: Assessment of effective management.

Indicator	Measurement/Status	Impact on effectiveness of management
Efficiencies of collection, labour and cost	Containerization, mechanical loading, monitoring and reporting allow for thorough collection, save time, and require low amount of labour.	Positive
Extent to which system is tailored to context	Collection routes are adapted to traffic patterns. Daily collection adapted to hot climate. Collection equipment/technology appropriate to financial means and waste composition.	Positive
Governance capacity: Effectiveness and enforceability of policies, Extent of communication, Treatment of different SE groups	Some policies are enforceable, some are not. The enforceable policies are effective at achieving their purposes. Low levels of communication about types and disposal of hazardous waste. Slightly poorer collection service and response rate to complaints for SE Low group.	Negative
Overall	Some governance issues, but otherwise effectively managed.	

The municipality of Aguascalientes uses innovative methods to improve collection and labour efficiency. The containerization of waste and mechanization of loading and unloading allow the collection system in Aguascalientes to be more labour efficient than systems in which waste is not containerized and is manually loaded and unloaded. The automated reporting and monitoring systems which use GPS and microchip technology are more accurate and time-efficient than paper reporting, and allow administers to

identify and fix problems in a timely manner. GPS technology allows the length of breaks, time efficiency of container emptying, route completion and speeds of trucks to be monitored so disciplinary action can be taken when necessary. The microchip technology used to record the physical state and fullness of each container reduces paper work, can be used by employees who cannot write, and improves labour efficiency.

A key aspect of ISWM is that a waste management system ought to be tailored to local context (Kollikkathara, 2009; Korfmacher, 1997). The waste collection system has several features that were tailored to the context of Aguascalientes. Daily collection is tailored to the hot climate and lack of storage space in most homes in Aguascalientes. The technology and collection equipment are appropriate to the waste composition and the financial means of the municipality. The timing and routing of collection are tailored to the city's traffic patterns. The system can be easily adjusted to accommodate localized fluctuations in waste generation. The disposal schedule however, is not tailored to the social context and is not necessary because collection is daily.

Aguascalientes has compaction collection trucks with mechanical loading. Cointreau (1984) found that trucks with mechanical lifts and compaction are the most capital intensive type of collection vehicle and for that reason are not suited to developing countries. Other authors mentioned that waste management technology from developed countries is not usually affordable for, or suited to developing countries (Brunner & Fellner, 2007; Holmes, 1984; Arlosoroff 1991; van de Klundert & Anschutz, 1999). Aguascalientes is able to afford this type of truck, and compaction trucks were also observed to be used in other cities in Mexico, so wariness of technology may not apply to middle-income countries. Cointreau (1984) and Korfmacher (1997) also warned that compaction trucks are not suited to the high organic content of waste common in developing countries. Aguascalientes does not have the very high organic composition seen in some developing countries, but does have a high composition of plastic bottles which have potential for significant compaction.

Night collection is suggested by Oluwande (1984) and Boadi and Kuitunen (2005) to avoid traffic congestion and to reduce the spread of odours. In Aguascalientes, waste in the city centre is collected at night to avoid high traffic volumes. The urban area surrounding the city centre is less congested, so waste collection in the daytime there does not cause traffic problems. Containers are not located on the large, main, heavy volume roads (including the ring roads), to avoid creating congestion during collection. The compaction trucks enclose waste which mitigates the spread of odour. The collection schedule in Aguascalientes demonstrates that night collection is not necessary in areas with low traffic volume and when odours are contained.

To adjust the collection system to special events or gradual increases in the waste generation rate in Aguascalientes, containers in the affected areas are swapped for different sized containers. Changing the size of containers rather than the number has the advantages of not requiring collection route alterations, user behaviour change, or more street space. Flexibility to fluctuations in waste generation is an important benefit of portable communal container waste collection.

Lack of governance capacity has been identified in literature as a barrier to waste management in developing countries (Wilson, 2007; Oluwande, 1984; Troschinetz & Mihelcic, 2009; Lopez de Alba Gomez, 2010; Boadi & Kuitunen, 2005; Buenrostro & Bocco, 2003; Korfmacher, 1997). Governance capacity influences: the creation of effective, enforceable policies; the extent of communication with the public; and the fair and equal treatment of all constituents.

Waste management policies are not effective unless they can be enforced (Buenrostro & Bocco, 2003; Farsi & Hammouda, 1984). In Aguascalientes, policies are in place to limit the negative health consequences experienced by residents and employees due to exposure to waste. Regulations that govern the minimum distances containers must be from doorways, windows and curbs are enforceable and are effective at ensuring the placement of the containers is as socially acceptable as possible. The safety protocol and other policies which the formal collectors must adhere to are enforceable because the formal collectors are supervised, while the policies outlining the safety equipment that registered informal collectors must wear are less enforceable and less effective[41]. The hazardous waste regulations are also difficult to enforce resulting in reduced environmental effectiveness.

Communication determines the knowledge levels amongst users about a waste management system, and knowledge impacts the proper use of that system. Lack of knowledge about hazardous waste diminished the proper use of the collection system in Aguascalientes which reduced the system's environmental effectiveness. The municipality ought to improve communication of the phone number to call in case of questions or complaints, the types of hazardous waste, and hazardous waste disposal.

Good governance gives equal consideration to all residents. The consideration of the different SE groups by the municipality of Aguascalientes does not seem to be equal. Some respondents from the SE Low group expressed that they did not feel the municipality would address their complaints. A respondent from the SE Low neighbourhood Los Pericos who, on several occasions through the formal procedure, requested a container be placed in an area where illegal dumping occurs, received promises of action but never a container. Complaints regarding container placement made by one respondent from the SE

[41] One of the two registered informal collectors surveyed was not wearing the required safety equipment. More registered collectors would need to surveyed in order to determine if the lack of use of safety equipment is prevalent among registered informal collectors.

Medium group and one from the SE High group were responded to favourably. The municipality should be aware of the differences in responses to residents based on their SE status, and attempt to give similar responses to similar complaints regardless of their origin.

The waste collection system in Aguascalientes is overall effectively managed as evident by the monitoring system which encourages efficient and thorough collection, collection times which avoid traffic congestion, the use of appropriate equipment and technology, and policies which limit human contact with waste. However, the waste managers could improve communication to encourage proper disposal of hazardous waste and take measures to ensure all residents are given equal consideration regardless of socio-economic status.

Several authors of waste management literature emphasize the need for good governance, efficient operation and effective administration (Wilson, 2007, Oluwande 1984 (specifically wrt curbside collection); Troschinetz & Mihelcic, 2009; Boadi & Kuitunen, 2005; Bhide, 1984; Gomez, 2010; Buenrostro & Bocco, 2003). While many of these sources include examples of lack of good governance leading to poor and inadequate waste management,[42] this thesis, for the most part, shows that efficient administration and operation, and good, enforceable policy can positively impact a collection system.

Overall Assessment According to ISWM

The communal container waste collection system in Aguascalientes is generally viewed as satisfactory by users, has a resource recovery rate similar to that of other developing and developed countries, is affordable, and has several management features that make the system well suited to the needs and context of the municipality. However, improvements could be made to make the collection system more socially equitable, to increase the resource recovery rate and to ensure proper disposal of hazardous waste. The collection system is therefore assessed as somewhat meeting the goals of ISWM. Table 6.8 shows a summary of the ISWM assessment.

[42] With the exception that Farsi and Hammouda (1984) discussed the aspects of the waste collection planning in Jeddah, Saudi Arabia, that led to positive improvements.

Table 6.8: Assessment of the waste collection system in Aguascalientes according to ISWM

Principle	Aspects that contribute to success	Aspects that do not work well and could be improved
Social Acceptability	• High participation rate • Public involvement – by public's initiative • Overall public satisfaction • Current system allows registered informal collectors to collect from containers • Low level of negative health impacts from waste experienced by the public, collection employees and informal collectors • Favourable working conditions and fair compensation for collection employees	• Slightly lower level of service to SE Low neighbourhoods • Proposed recycling system will adversely impact informal collectors
Environmental Effectiveness	• Resource recovery rate is comparable to other developing and developed countries • The containers, compaction trucks and transfer & compaction stations reduce fuel use • The landfill has leachate and off-gas collection systems to mitigate pollution	• Hazardous waste often improperly disposed • Potential for increased resource recovery
Economic Affordability	• Proportion of budget allocated to waste management is low relative to other developing countries • Municipality was able to afford initial capital costs and has been able to maintain operation for 20 years • The collection system has several labour and fuel efficient features to reduce operating costs • Cost of system to users is integrated into taxes which are proportional to income, so costs do not over-burden users	

Effective Management	• Monitoring and reporting systems promote thorough collection and labour efficiency • Policies governing container placement and employee safety reduce negative health harms • Daily collection mitigates negative public health impacts from waste • Technology/equipment used is affordable and improves labour efficiency • Collection schedule and routing minimizes traffic congestion during collection	• Communication about types and disposal of hazardous waste ought to be improved • Disposal schedule is not necessary, and does not impact the success of the system

6.4 The path to success

Exploring the path that led to the creation of this collection system gives insight to drivers that push for, and circumstances that are favourable to, waste collection improvement. This section addresses the following two questions: Why did the municipality of Aguascalientes decide to improve waste collection? How was the municipality able to create such a successful collection system when so many other developing cities have inadequate systems?

Municipal bulletins following the introduction of the container system state that the increase in waste generation created the need for improved waste collection (historical archives interview). Recognizing increased waste generation as a problem, and choosing to address this problem, were probably political decisions motivated by the culture of cleanliness in Aguascalientes.

Investing in waste collection probably limited the municipality's ability to invest in other programs. Choosing to invest in waste collection rather than other services might have been a political decision motivated by the visibility and widespread positive benefits of improved waste collection. Improved waste collection benefits all constituents, even the most powerful, while more localized development projects, like providing piped water to houses in poor neighbourhoods, would only be noticed by residents in those areas—residents who hold little political influence. A political desire to improve and maintain the cleanliness of the city in order to attract business and tourism may also have motivated the decision to improve waste collection. This postulation is supported by the state website which lists the favourable ecological environment as one of the states' competitive advantages (Aguascalientes State Government, 2010).

The business which supplies the containers and compaction trucks played a large role in designing the container collection system. This company proposed the container collection system to the municipality, and as a result was given a contract to provide the container and trucks. Whether or not the municipality requested the company submit a proposal is not known. This company, by having experience in glass bottle collection, and performing research on waste collection in other cities, brought expertise to the planning process for the container system. In this way private company involvement helped Aguascalientes overcome the lack of expertise barrier to waste management cited in the literature (Boadi & Kuitunen, 2005; Buenrostro & Bocco, 2003).

6.5 Application to other developing areas

Can successful features of the collection system in Aguascalientes be applied to other developing urban areas, particularly those with less income than Aguascalientes, to improve waste collection in them? This section presents suggestions for garnering participation in container systems and overcoming financial limitations in order to improve the success of CCC in developing cities. The most effective ways development funding agencies can contribute to improving waste management are outlined. Despite suggestions to reduce capital and operating costs, cities in countries classified as low income by the World Bank (2010a) will find providing affordable CCC that is effective according to an ISWM framework to be difficult.

Public participation is necessary for waste collection systems to function properly. This is especially true for communal container systems which by their nature require a lot of participation. Unfortunately, waste management is a low priority for many people in developing countries who struggle daily to obtain basic necessities. People need to know why waste management is important to them, especially if they are in a desperate situation, before they can consider dedicating their precious resources, time and energy to participating in collection. Extensive education about the negative impacts of uncontrolled waste, especially negative health impacts, may help to create demand for improved waste collection. Such education campaigns ought to precede attempts to introduce more intensive methods of collection into communities where waste management is a low priority. Once a container system is implemented, clear, easy to understand signs placed on or near containers to announce why proper waste disposal is important may encourage participation.

Programs in public schools, which not only teach students the importance of waste management, but also involve practical activities, can be very effective at garnering participation. For example, the public schools in Aguascalientes have a program in which students bring recyclable materials to school with each class competing to bring the most. This program tends to get parents involved in separating recyclables from other waste, a behaviour which may become habit.

The residents and municipality of Aguascalientes pride themselves in their culture of cleanliness and this pride motivates participation in the waste collection system. Many other places may not proclaim to have a culture of cleanliness, but most people keep themselves, their homes and their businesses clean within their means to do so. However, in some places residents do not feel responsible for the cleanliness of the public realm. The Secretary of Public Services and Ecology of Aguascalientes promotes the culture of cleanliness to residents to encourage continued and further participation in keeping the city clean. Municipalities of other communities could identify cleanliness behaviours that residents take pride in and,

through mass media, encourage the extension of those behaviours and that pride from within homes to streets and public spaces.

Unsatisfactory waste collection in developing countries is often due in part to ineffective planning (Bhide & Sundaresan,1984; Buenrostro & Bocco, 2003), as poorly planned and designed systems are typically neither socially acceptable nor affordable. Investing in good planning will save money in the long term. Planning costs may include the expenses associated with hiring waste management experts, building or buying prototype containers and trucks, and conducting pilot studies. In Aguascalientes, a lot of the planning for the collection system, including research and development, was performed and paid for by the company that was awarded the contract to provide the containers and compaction trucks. Similarly, other municipalities in developing countries could save on planning costs by having a competition for a contract to provide the collection equipment, with the competition judged not only on proposed cost, but also on how well the system is expected to function. Those municipalities may need to hire waste management experts to judge the proposed collection schemes. Local business involvement in the design of a collection system will provide greater understanding of the local context including cultural influences on participation than could be provided by foreign experts.

Municipalities may wish to go one step further by offering contracts for the provision of waste collection. This may seem cost-effective from the municipality's perspective, but private collection providers may not give sufficient service to low income areas with residents who cannot pay waste collection fees. This is the case in some areas of Mexico that have private collection (Ojeda-Benítez & Beraud-Lozano, 2003).

Distance to container and regular collection were found to be factors of participation in waste collection through the case study and in the literature. Unfortunately when funds are limited waste collection providers may find that they cannot provide both regular collection and a sufficient number of containers to sustain participation. Increasing the amount and dispersion of containers increases the cost of collection since vehicles must start and stop frequently and travel along more streets. Systems with lots of containers at close intervals may be expected to be socially acceptable and garner participation, but if those containers cannot be emptied regularly and overflow they will repel participation and pose a public health risk. A system with an amount of containers that can be affordably emptied regularly with those containers placed at strategic locations would have fewer overflowing containers and may sustain more participation. Strategic locations for containers would be along routes that people frequently travel keeping in mind that many people in developing countries travel primarily by foot.

Funding from external development agencies will likely be needed by cities in low, lower-middle, and some upper-middle income countries in order for them to establish effective waste collection systems (income classifications according to The World Bank, 2010a). Unfortunately, there are dangers associated with external funding. Foreign funding agencies have in the past implemented waste collection systems that use inappropriate technology which cannot be locally maintained (Arlosoroff 1991; van de Klundert & Anschutz, 1999). If funding supplements operation and maintenance costs, the collection system may not be sustainable by local income if that funding is removed. External funding would be most effective if invested in implementation costs including planning, campaigns to garner participation, and capital, but shouldn't be used to support operation and maintenance. Funding agencies involved in planning collection systems and/or providing capital, and municipalities receiving funding, should be conscientious about creating collection systems which can be operated and maintained by local income. Local experts and the public should be involved in the planning process, and the system should use locally available vehicles and equipment. Taking these measures will increase the likelihood that the collection system will be socially acceptable and will continue to operate after the funding is removed.

The capital costs of a container collection system are mostly comprised of the costs of the containers and the collection vehicles. In the past, technology-heavy equipment that was imported from developed countries has failed in developing countries because the parts and skill for maintenance were not locally available and were too expensive (Arlosoroff 1991; van de Klundert & Anschutz, 1999; Holmes, 1984). In Aguascalientes however, the compaction trucks and containers are manufactured right in the city, so the parts and skill for maintenance are locally available. This shows that technology-heavy equipment does not have to be avoided altogether as some literature suggests, but should only be used if locally available. Buying local equipment also has the benefit of strengthening the local economy.

If a variety of local equipment is available with varying degrees of mechanization, the impact of mechanization on initial cost and operating efficiency ought to be considered. Mechanisms on vehicles that improve efficiency include compactors, tippers, and loaders. Compactors allow vehicles to hold more waste resulting in fewer trips to transfer stations or disposal sites and reduced labour and fuel costs. However, compaction trucks do not significantly improve efficiency when the density of waste is high (Cointreau, 1984), so low income cities which produce high organic content should not invest in compaction trucks. Tipper vehicles which mechanically dump their contents are more efficient than vehicles with stationary storage compartments that have to be manually unloaded. Likewise, vehicles with mechanical loaders to lift and dump containers save time, are more labour efficient, and reduce contact between collection employees and waste relative to vehicles that have to be manually unloaded

(Cointreau, 2005). While cities in low income countries can avoid the use of compaction trucks without greatly reducing collection efficiency, those cities may find vehicles with tippers and loaders to improve efficiency and be cost effective in the long term.

Mechanisms for tipping and lifting do not have to be complex and expensive. The winches on the collection trucks in Aguascalientes used to lift containers are quite simple. They could be retrofitted on to compaction trucks or trucks with box storage. The retrofit would have to be done well because if a winch fails or breaks, a falling container could cause serious injury or death.

Low and lower-middle income countries can have lower capital costs than Aguascalientes by foregoing the GPS and microchip systems. However, some form of monitoring and reporting should be used with CCC systems to ensure collection is thorough and complete. Collection employees could carry a paper checklist to record which containers were not emptied and why, container fullness at the time of emptying, and any needed repairs. Time-efficiency could be easily monitored without GPSs by recording the times at which each vehicle leaves for collection and returns. The downfall of this method is that speeding cannot be monitored for or factored into time-efficiency calculations.

Since the municipality of Aguascalientes can afford its waste collection system, affordable operating costs in other cities can be estimated[43] to be those that are approximately the same portion of their per capita income as that of Aguascalientes such that

$$\frac{\text{affordable operating cost in city } x}{\text{income of city } x} \cong \frac{\text{operating cost in Aguascalientes}}{\text{income of Aguascalientes}}$$

which can be rearranged to

$$\frac{\text{affordable operating cost in city } x}{\text{operating cost in Aguascalientes}} \cong \frac{\text{income of city } x}{\text{income of Aguascalientes}}$$

Table 6.9 shows the ranges of per capita incomes of low and lower-middle income countries as percentages of the per capita income of Mexico. According to the above estimation, the operating cost of collection in low and lower-middle income countries as a percentage of the operating cost in Aguascalientes would have to fall into the respective range of percentages of income presented in Table 6.9 in order to be affordable.

[43] This estimation of affordability assumes that the difference in cost of basic necessities and services (such as clean water provision) between city *x* and Aguascalientes is proportional to the difference in incomes. If this assumption holds true, the operating costs calculated for city *x* would not impact the ability of residents to pay for basic necessities. Unfortunately, the cost of basic necessities and services may not vary greatly between cities or countries. Despite this, the estimation is still used to give a rough idea of the operating costs of CCC that would be affordable in low and lower-middle income countries.

Two trends impact the operating costs of waste collection in cities with less income than Aguascalientes. First, cost of labour decreases with decreasing national income. Using GDP per person employed (in 1990 constant international dollars) as an estimate of average cost of labour, the average cost of labour in lower-middle income countries is 48%, and in low income countries is 15%, of that of Mexico. Second, the cost of fossil fuel tends to increase with decreasing national income (The World Bank, 2010b). The only petroleum company in Mexico is publically owned and subsidizes prices (Coerver, Pasztor, & Buffington, 2004), so the cost of fuel in Mexico is lower than the average for middle income countries (The World Bank, 2010b).

To determine if cities in low and lower-middle income countries could afford the waste collection system used in Aguascalientes, the relative operating costs of that system in those income groups were calculated using the relative labour and fuel prices (Table 6.9). The operating cost calculation assumes that the quantities of waste produced and the urban densities are the same as those of Aguascalientes. For low and lower-middle income countries, their operating costs relative to those of Aguascalientes are greater than their incomes relative to the income of Mexico. This shows that lower labour costs alone are not sufficient to reduce the operating costs of collection in low and lower-middle income cities to be as affordable as collection is in Aguascalientes.

Lower waste generation rates enable the operating costs of collection to be reduced. Waste generation tends to decrease with decreasing income (Cointreau, 1984; Flintoff, 1984; Blight & Mbande, 1996) but can vary substantially between cities or countries (Cointreau, 2006). The waste generation rate in Aguascalientes of 0.75kg per person per day falls into the ranges of waste generation in low income and middle income countries reported by Cointreau (2006). Cities with less waste generation than Aguascalientes will be able to lower their operating costs by providing either less frequent collection or fewer containers. Collection that is less frequent than daily, but still often enough to limit offensive odours and prevent the spread of disease, would be more socially acceptable than collection at a high frequency via more dispersed containers. Providing collection every other day, or twice a week may be frequent enough to keep odours and pests at bay even in warm climates. Collection in some places in Mexico occurs only once every three days (Ojeda-Benítez & Beraud-Lozano, 2003) and 41% of survey respondents in Aguascalientes dispose their waste less than every day. Table 6.9 shows the reduction in operating costs that would result from reducing the frequency of collection. Reducing the frequency of collection to every other day would make a CCC system similar to that of Aguascalientes affordable in some lower-middle income cities. Collecting only every 3rd day would not reduce the operating costs enough to be affordable in low income cities.

Table 6.9: Approximate relative costs of Aguascalientes' collection system in lower-middle and low income countries based on relative labour and fuel costs. Source of data: The World Bank, 2010a and 2010b

World Bank Classification	GNI per capita (USD)	GNI[44] per capita relative to that of Mexico	GDP per person employed relative to Mexico[45]	Average diesel fuel price at the pump relative to Mexico	Operating costs of collection relative to Aguascalientes[46]	Impact of less frequent collection
Lower-middle income	$996 - $3,945	12-47%	48%	152%	67%	• Collect every 2nd day • Operating costs per year: 33.5% that of Aguascalientes • Falls into target range
Low income	>$996	<12%	15%	191%	53%	• Collect every 3rd day • Operating costs per year: 18% that of Aguascalientes • Above target range

Small cities that do not need and do not use transfer stations will have lower operating costs per person relative to Aguascalientes. According to the economic haul distance for 2-6 tonne trucks reported by Cointreau (2006), transfer stations do not improve collection efficiency in cities with less than 30km between the furthest collection area and the landfill. The largest distance between a collection area and the landfill in Aguascalientes is about 22km along roads, and the municipality reports that the transfer

[44] Gross Domestic Product [GDP] would be a better indicator than Gross National Income [GNI] of the income locally available to contribute to waste collection costs. GNI per capita was used here because the range of GNI per capita for each World Bank country classification was readily available, while only the average GDP per capita for each classification was available. The average GDP per capita fell into the range of GNI per capita, so the values are close enough to warrant the use of GNI. The GNI per capita of Aguascalientes would be more suited to the purpose of this calcuation, but this information was not available.

[45] In constant 1990 international dollars to yield purchasing power parity [PPP]

[46] Based on relative labour and fuel costs, where average cost of labour is estimated to be GDP per person employed, and the operating cost breakdown for waste collection in Aguascalientes shown in Table 4.2. The relative operating costs only includes the costs of salaries and fuel, and not parts, supplies or property/building costs. Depending on the costs of these items in low and lower-middle income countries relative to their costs in Aguascalientes, the relative operating costs may be higher or lower than that reported.

stations do reduce operating costs. This suggests that the size of city that does not need a transfer station to lower operating costs may be smaller than that suggested by Cointreau's economic haul distance.

If cities with more waste generation but less income than Aguascalientes wish to implement a CCC system similar to that of Aguascalientes, those cities will have to allocate greater proportions of their incomes to waste collection than Aguascalientes does. Cointreau (2006) reported that the cost of proper waste management as a percentage of per capita income increases with decreasing income. Allocating a greater proportion of income to waste management may seem unfeasible for cities with very low income, but the improved health and environmental impacts of thorough waste collection and good waste management will have positive economic impacts. Improved health effects will increase the capacity of residents to take care of and provide for themselves, their families and their communities, and a cleaner city will be more attractive to external business. If the income of a city increases due to positive economic benefits triggered by improved waste management, or for any other reasons, the operating costs of waste collection will be relatively more affordable.

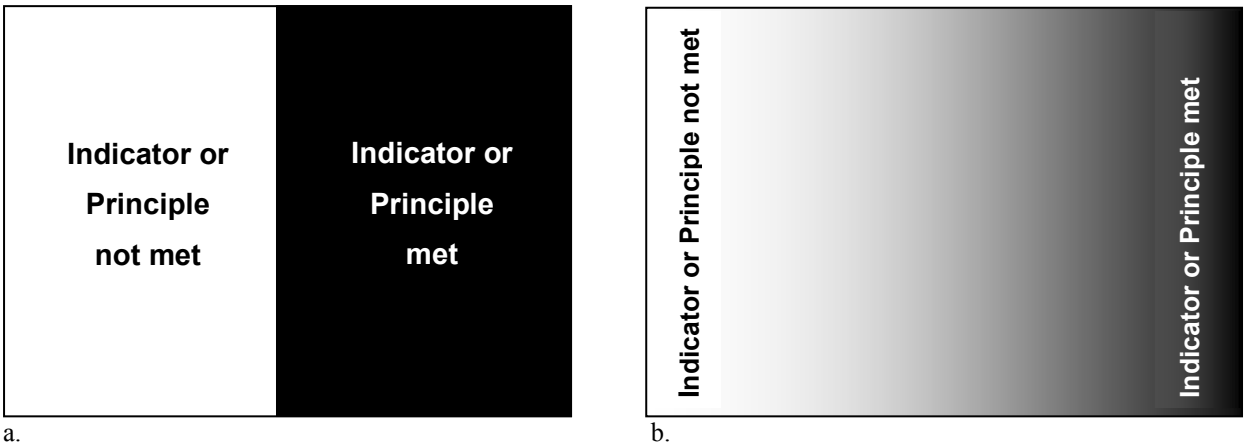
6.6 Discussion of ISWM as an Assessment Tool

Most existing waste management assessments methods and evaluative tools tend to value cost and environmental effectiveness over social acceptability (Pires et al., 2011). The principles of Integrated Solid Waste Management have perhaps never been used as the framework to assess an existing waste collection system before. For this reason, the lessons learned may be of interest to waste management system assessors. To provide insight into the use of ISWM as an assessment tool, the limitations, barriers, benefits, and indicators used are discussed.

The main barriers to the use of the ISWM framework as an evaluative tool realized during this study were the subjective nature of assessments, the difficulty of determining if an ISWM indicator or principle has been met or not, and the complexity of weighing indicators and principles against one another. Assessments are by nature subjective. The indicators to be measured and the measurement levels considered to be acceptable or satisfactory are determined by the evaluators and influenced by their values. Since subjectivity cannot be avoided, detrimental effects can be mitigated by including an outside party, with no vested interest in the waste management system being assessed, and stakeholders, who have a better understanding of the local context, in the preparation for and the performance of the assessment.

According to ISWM theory, an effective waste management system is one that meets the principles of ISWM. In practice, whether a waste management system meets a principle or not does not

have a simple yes or no answer. Even whether or not the measurement of a single indicator is acceptable does not necessarily have a simple yes or no answer. In many cases, the measurement of acceptability of an indicator and the degree to which a principle is met occur on a gradient (see Figure 6.3). Most of the indicators measured in this study had percentage results, such as the recovery rate. If an evaluator sets a cut-off percentage for whether or not an indicator measurement is or is not acceptable, then the black and white model could be used. However, determining a cut-off percentage would also be subjective and enter cumbersome rigidity into the evaluation. Using the gradient model, the evaluator(s) does not necessarily have to say whether each indicator measurement is acceptable, but can consider each indicator in comparison and in balance with other indicators for the same and other principles to rationally and intuitively assess whether or not the system is acceptable given the limited feasibility of perfectly achieving each principle. Consider the resource recovery rate indicator for example. As long as there is less than 100% diversion of divertible materials the recovery rate could be improved, but achieving total recovery would be very difficult in practice. As recovery nears completion the amount of material recovered per unit of recovery effort diminishes as remaining recoverable materials become smaller and more dispersed. Achieving total recovery would come at great economic cost and potentially require too much effort by the public to be socially acceptable. Rather, the environmental effectiveness a collection system is best assessed by considering the recovery rate in balance with other indicators for this and other principles.



a. b.

Figure 6.3: Conceptual models of how an indicator or principle can be assessed. a). The indicator measurement is deemed acceptable or not, or principle is simply met or not met, b) the value of an indicator measurement affects the degree of acceptability, or the principle is met to varying degrees.

Once the evaluation of each principle is complete, the evaluator assesses overall whether or not the system meets the goals of ISWM. If the system fails to meet one or more principle, then it may be

judged as ineffective from an ISWM framework. However, if the system is mediocre in achieving one or more principle, the assessment becomes more difficult as the principles must be weighed against one another. How much leniency should be given to a waste management system that is mediocre in one or more principle before that system is not considered to be acceptable according to ISWM? Answering this question once again enters subjectivity into the evaluation.

In consideration of the above limitations, unless standards or criteria of success are set, the ISWM framework is probably more useful as a tool to compare two or more waste management systems than to evaluate a single system. In comparing two or more waste management systems, the system with the better value or state for each indicator will be apparent. Subjective judgements will still have to be made if no one system produces the best results for the most (and/or most important) indicators. In general, comparing two or more systems, rather than comparing one system to an abstract "acceptable" system, will yield more concrete results.

Despite limitations, the ISWM framework has value as an evaluative tool. Evaluating according to an ISWM framework allows for an in-depth analysis of the waste management system from several perspectives and exposes areas that need improvement (or a complete redesign). Also, by performing an ISWM assessment, if stakeholders are involved in the assessment, their valuable opinions will be considered and perhaps integrated into system improvements.

Furthermore, an assessment from an ISWM framework gives equal consideration to all principles (social, environmental and economic) which may not occur in practice. Often in practice economic affordability and the participation rate trump environmental effectiveness and social equality since the system will not be financially sustainable or functional without the former aspects, while the negative impacts of an environmentally ineffective or socially inequitable waste management system often aren't felt in the short term. Other waste management assessments reviewed tend to focus on environmental and cost effectiveness while undermining social aspects (Chambal et al., 2003; Abu Qdais, 2007; Pires et al., 2011; Mbuligwe & Kaseva, 2006), but ISWM gives equal consideration to these aspects and values the balance of them.

In this assessment, the waste collection system in Aguascalientes was considered to be mostly acceptable overall from an ISWM framework, with weak areas noted and suggestions for improvement made. There was no attempt to define "acceptable" as used above. Rather, the assessment was made rationally-intuitively based on consideration of all of the results. The collection system was evaluated by only one person, the researcher, based on input from several stakeholders. The evaluator hesitated to assess the waste management system as definitely being acceptable according to an ISWM framework

because in some areas the system was not functioning well. For example the lower level of service in SE Low neighbourhoods reduces the system's social acceptability. Performing this assessment was beneficial because areas in need of improvement were identified, and stakeholders were involved and empowered by having the opportunity to voice their opinions and give suggestions to improve waste collection.

Table 6.10 shows the indicators suggested by van de Klundert and Anschutz (1999) to assess waste management systems according to ISWM in comparison with the indicators used in this study. Notes about the indicators used and reasons why certain indicators suggested by van de Klundert and Anschutz were not included are presented in the table. The indicators proposed by van de Klundert and Anschutz had not been used by them to perform an assessment.

Although the indicators used in this study could be used to assess any collection system, they were created with the collection system of Aguascalientes in mind. For example, the indicator *extent of communication* was added because communication was known to be a problem area for the waste collection department of Aguascalientes. For assessments of other waste management systems, some degree of adjustment of the indicators used in this study may be necessary.

The indicators vary in importance to the assessment. Van de Klundert and Anschutz (1999) mentioned "Assessment of the degree of 'integrated sustainability' needs ... a mechanism to weigh these different indicators against each other" (p.10). A method of weighing the indicators against each other was not proposed by this thesis. Rather, the weighting of indicators and the overall assessment of this study was rational-intuitive, not formulaic. The model for value-based waste management assessments outlined by Chambal et al. (2003) could be used to formulaically compare indicators. However, that model requires all indicators be designed such that they are quantifiable which will be difficult to do for indictors which lend themselves better to qualitative assessment such as *treatment of informal collectors*.

Table 6.10: Indicators for ISWM assessments suggested by van de Klundert and Anschutz, (1999) and used in this study.

Principle of ISWM	Indicators proposed by van de Klundert and Anschutz, 1999 p. 10	Indicators measured in this study	Notes about indicators	Reasons for not including specific van de Klundert and Anschutz indicators
Social	• service coverage - % of citizens receiving minimum required waste collection service e.g. twice a week • working conditions- number and duration of sick leaves, health complaints • user satisfaction with the service by area of the city	• use of the collection system - participation rate • formal and informal working conditions and number of health incidents • social injustices - differences in waste collection service between socio-economic groups • public satisfaction with the collection system • extent of public involvement	• all indicators used are thought to work well and give a thorough picture of a social situation • hard indicators - show what is actually happening, but not motives or internal experiences - *service coverage, participation rate, social injustices, and working conditions* • soft indicators - motives and internal experiences that drive the participation rate and reveal social injustices - *user satisfaction and public involvement*	• the indicators used include all of van de Klundert and Anschutz's social indicators except *service coverage* which was accounted for by *differences in service between SE groups*
Environmental	• amount and % of waste recycled • extent of pollution of air, soil and water • amount of energy and natural resources saved through recycling	• resource recovery rate • extent of hazardous waste management • fuel use/distance of waste transport • method of final disposal	• *resource recovery rate* - accounts for composting and recycling • *extent of hazardous waste management, fuel use/distance of waste transport* and *method of final disposal* indicate the extent of air, soil and water pollution	• *extent of pollution of air, soil and water* is difficult to measure directly without complex monitoring equipment • the indicator *amount of energy and natural resources saved through recycling* requires extensive, complex analysis but information gained would be valuable

Principle of ISWM	Indicators proposed by van de Klundert and Anschutz, 1999 p. 10	Indicators measured in this study	Notes about indicators	Reasons for not including specific van de Klundert and Anschutz indicators
Economical	• degree of cost recovery • overall cost of waste management services provided • labour productivity - amount of waste collected per worker	• proportion of the municipal budget allocated to waste management and collection • degree of cost-recovery • whether or not debt is incurred by the municipality and the extent • affordability of waste collection/management fees to the users	• *affordability of waste collection/ management fees …* - added b/c van de Klundert and Anschutz's economic indicators do not encompass whether or not the system is affordable to users • *the proportion of the operating budget …* indicates the extent to which the collection system impacts the ability of the municipality to provide other services • *whether or not debt is incurred …* - the overall financial situation of the municipality affects whether or not the collection system is affordable	• *overall cost of waste management* is not relevant from an ISWM framework as overall cost only reflects affordability if the wealth of the area is also known - would be of interest when comparing two or more waste management systems • *labour productivity* - only relevant if cost of labour and cost of equipment are also considered since equipment impacts labour productivity

Principle of ISWM	Indicators proposed by van de Klundert and Anschutz, 1999 p. 10	Indicators measured in this study	Notes about indicators	Reasons for not including specific van de Klundert and Anschutz indicators
Management [NB: van de Klundert & Anschutz, 1999 did not have a management section but rather Institutional, Policy/Legal and Technical were three separate sections]	• *Institutional* - degree of formalization of informal sector - existence of feedback mechanisms for citizens • *Policy/Legal* - degree of decentralization of authority and funds - height of budget earmarked for waste management • *Technical* - amount of waste collected by area of the city - durability of equipment - existence of a separate hazardous waste management system - existence of preventive maintenance procedures	• efficiency of collection, labour and cost • governance capacity - effectiveness and enforceability of policies, extent of communication, treatment of different SE groups • extent to which system is tailored to context	• indicators used give a thorough picture of all aspects related to a collection system's functioning	• *height of budget* .. overlaps with economic affordability and could perhaps be better placed there • *amount of waste collected* ... indicates social inequality so would be more appropriately placed as a social indicator • *degree of formalization* ...and *degree of decentralization* ...demonstrate subjectivity as they value the formal over the informal and decentralization over centralization - valuing one over the other contradicts the ISWM principle that waste management be tailored to context

Chapter 7
Conclusions

Effective waste management, especially in developing countries, improves lives–probably even saves them. This thesis has several significant implications. Communal container collection [CCC] could be applied to other cities in Mexico, other developing countries, and even some areas of developed countries, to improve waste collection. Lessons learned from the design of the collection system in Aguascalientes can be applied to other areas to promote successful implementation of CCC. The approaches of this thesis, of examining a success story to draw-out aspects that work well, and of using ISWM as an assessment tool, ought to be applied to more waste management studies.

Aguascalientes has demonstrated that transferring from ground collection to CCC while maintaining a high rate of participation is possible. If funds can be obtained for the initial capital expenditure and the equipment is locally available, communal container systems ought to be implemented in areas that currently leave waste on the ground for collection. CCC could also be implemented in developing urban areas that have many small illegal dumpsites. Containers could be placed near dumpsites, provided those containers can be emptied regularly. The World Bank and NGOs ought to consider providing support and loans for the planning and initial capital investments for CCC in developing countries which have the financial and governance capacity to operate and maintain those systems.

CCC could be applied to rural areas of developed and developing countries. In the past few years many rural areas in Canada have implemented curbside collection to replace non-collection (in which case users took waste directly to the landfill). Curbside collection in rural areas may reduce illegal dumping, but is more costly than non-collection. Containers placed at major regional road intersections that most rural-dwellers regularly cross would be more convenient than non-collection and more cost-effective than curbside collection.

Communal containers tend to be used for single-stream collection of co-mingled waste. If alternative methods of resource recovery are available, such as selling recyclables or taking them to a depot, collection of co-mingled waste may not be less, or much less environmentally effective than collection with source separation, which would be more expensive. If there are not many available alternative methods of resource recovery, or if the alternative methods do not yield a high recovery rate, collection with source separation may improve environmental effectiveness. Source separation could be facilitated by placing two or more small containers at each collection location with clear signage about

materials permitted in each container. Collection of recyclables from segregation containers should be easy so the economic livelihoods of informal collectors can be maintained. A resident of Aguascalientes suggested that residents could be required to separate waste by type into different coloured bags or clear bags which are disposed into the waste containers. Bags containing recyclable materials could be placed into containers well before the collection truck comes to allow informal collectors to recover them. This method would be less expensive than providing and collecting from separate containers for recyclables, and would make informal collecting easier, faster and safer. At least sanitary waste (toilet paper, diapers, tissues) should be placed into bags to reduce exposure to biologically hazardous waste by informal collector. If after testing the bag method, the recovery rate is still less than desirable, and if funds are available, a waste collection provider could consider setting up a Materials Recovery Facility [MRF] to separate out the remaining recyclables before final disposal. Materials recovered could be sold to offset costs.

The urban form of an area impacts the method of waste collection that can be implemented there. Urban planners should design waste collection systems to be adapted to existing urban form, and likewise should ensure future developments be designed to accommodate the existing waste collection system. Collection via communal containers requires streets of sufficient width such that containers do not impede traffic. Not all streets need to be able to accommodate containers, but sufficiently wide streets ought to be dispersed throughout an area such that the distance to nearest container is tolerated by residents.

While many waste collection studies in the literature examined faulty systems to find their sources of weakness, this thesis focused on a fairly successful collection system. Successful collection systems seem to be ignored by development professionals, perhaps because those systems do not need improvement. Studies of successful systems provide valuable lessons about methods that work well which could be applied to other cities to improve collection. Success stories can also encourage development professionals who are often jaded and discouraged. For these reasons, more studies ought to be performed on successful waste collection systems.

Presumably, based on an absence of documentation in the literature, prior to this study ISWM had not been used as an assessment tool with social acceptability, environmental effectiveness, and economic affordability as the goals against which to evaluate a waste management system. The social aspects of waste management tend to be valued less than cost and environmental effectiveness by waste management decision makers and other assessment tools (Pires et al., 2011). The use of ISWM as an assessment tool gives equal consideration to all aspects of waste management. For this reason ISWM should be regularly used as an assessment tool for waste management systems. The World Bank could

add ISWM to its repertoire of assessment tools and make such assessments mandatory prior to waste management development projects. Existing waste management assessment tools, such as the value-based assessment outlined by Chambal et al. (2003), SWOT analyses, and cost-benefit analyses, which leave the goals of waste management up to the person or group requesting the assessment, could instead use the principles of ISWM as the goals of waste management. Other assessment tools which focus on only one aspect of waste management, such as cost or environmental impact assessments (for example material flow analyses and lifecycle assessments) could be used within an ISWM assessment to help assess the aspect of waste management to which that tool pertains.

7.1 Recommendations to the Municipality of Aguascalientes

Based on the findings presented in this thesis, the following recommendations to the municipality of Aguascalientes have been made.

1. The Directorate of Cleanliness and Public Sanitation should look into the number of waste containers in SE Low neighbourhoods to ensure that these neighbourhoods are receiving the same waste collection service as SE Medium and SE High neighbourhoods. Specifically, the directorate should look into placing one or more containers in the south-eastern corner of Los Pericos.
2. In response to the low knowledge rates about types of hazardous waste and how to dispose of them, the directorate should improve the communication of this information with the public.
3. In response to the dislikes *"garbage is on the ground near the containers"* and *"people do not use the containers correctly"* the directorate should consider monitoring problem areas to ensure the containers are swept around well by employees and used correctly by residents..
4. To improve convenience of the collection system, the directorate should consider eliminating the waste disposal schedule. The pick-up schedule does not mirror the disposal schedule making the night-time disposal unnecessary.
5. To reduce the negative impacts of the proposed recycling container system on informal collectors, the recycling containers should be designed so collection from them by hand is possible.

7.2 Suggestions for Further Research

The following are areas in which further research could be conducted to increase the understanding of the waste collection system in Aguascalientes and communal waste collection systems in general:

- A more in-depth study could be conducted on the activities of informal waste collectors. This study could find a better estimate of the recovery rate due to informal collectors, and lead to a better understanding of the impact of their collection activities on environmental effectiveness, their own financial well-being and the economy of the municipality.

- In some rural areas surrounding the city of Aguascalientes the container system is used, but collection only occurs once per week. A study could examine if and how the less frequent collection and less dense urban form impact participation.

- A study that compares this system and a communal container waste collection system that does not appear to function as well could be performed to better understand which features of communal collection do and do not work well, which management techniques improve functioning, and which aspects can and ought to be tailored to context.

Addendum A

Waste composition in Mexico

The data on the waste composition in Mexico reported in this thesis was from prior to 1984 and is no longer accurate, so recent data is presented here. In 1998, the waste composition in Mexico by mass was organic (food and yard waste) 52.4%, paper and cardboard 14.1%, glass 5.9%, plastic 4.4%, metals 2.9%, clothe 1.5%, and other (fine residues, rubber, diapers) 18.9% (Ministry of Social Development, 1999 as cited by Buenrostro & Bocco, 2003). The waste compositions of four different cities in Mexico are presented in Table A. 1. The differences in composition between cities may be due to differences in income, as the proportion of organic waste tends to decrease with increased income. The cities arranged in decreasing order of percent increase in GDP in 2006 are Guadalajara, Chihuahua, Mexicali and Morelia. The differences in composition may also be affected by the year and season in which the data was collected (Gomez, Meneses, Ballinas & Castells, 2008).

Table A. 1: Composition of waste in Mexico and in four Mexican cities. Adapted from Gomez et al. (2008).

Component	Mexico[a] %	Chihuahua[b] %	Guadalajara[c] %	Mexicali[d] %	Morelia[e] %
Organic	52.4	48.0	54.0	55.6	57.1
Paper	14.1	16.1	7.1	8.8	11.0
Plastic	4.4	11.9	9.0	6.1	7.9
Metal	2.9	2.4	1.5	1.9	1.8
Glass	5.9	5.6	4.1	3.5	4.7
Other	20.4	16.0	24.4	24.1	17.5

a Source: Ministry of Social Development, 1999 as cited by Buenrostro & Bocco, 2003. Data from 1998.
b Source: Gomez et al, 2008. Data collected April 2006.
c Source: Bernache-Perez et al., 2001. Data collected June to August 1997.
d Source: Ojeda-Bentíez et al., 2003. Data collected May to June 1999 and March to April 2000.
e Source: Buenrostro et al., 2001a. Data collected February to March 1998.

Addendum B

Recommendations for planning waste collection in developing countries

Valuable lessons about the social, environmental and economic aspects of waste collection in developing countries have been learned through this case study. Drawing from these lessons, recommendations for planning waste collection systems in developing countries according to an ISWM framework were made. The recommendations have been divided into three major planning steps: ISMW assessment of the existing collection system; collection of data to describe the local context; and design of a new collection system, or modification of the existing system. Recommendations specific to the planning of communal container collection are offered.

Step One: ISWM Assessment

Agencies intending to improve or create a new waste collection system should first perform an ISWM assessment such as the one used in the case study to assess the level of success of the existing collection system. Assessing the collection system according to ISWM allows for the identification of strengths and weaknesses of the social, environmental, economic and management aspects of the existing system. The weaknesses identified should be focused on as areas to be improved in the new/modified system. The indicators suggested in this thesis, and any additional indicators specific to the characteristics of the community being assessed, can be used for the assessment.

Step Two: Local Context Data Collection

Thorough data collection of the local characteristics of a city is a necessary part of planning a modified or new collection system to ensure that new/modified system is appropriate and tailored to the local context. Developing cities vary in: financial capacity; climate; urban form, including built density and quality of city streets; and social/cultural norms; waste generation rates; and resource recovery rates (Cointreau, 1984). Aguascalientes is more financially secure, has a greater proportion of straight, wide, paved roads and more participation by residents in public cleanliness than many other developing cities. In consideration of context differences, communal container collection systems implemented in other cities must be designed to function according to their specific social, physical/environmental and economic characteristics. Suggested data to collect are presented in Table B. 2. Context data can be collected concurrently with the data for the ISWM assessment. If communication between the waste collection planner(s) and each neighbourhood begins during the data collection phase, local knowledge

could allow for rapid estimates of waste characteristics, current waste management activities including resource recovery behaviours, and physical characteristics of each neighbourhood.

Table B. 2: Suggested context data to be collected prior to modifying or designing a new waste collection system.

ISWM Aspect	**Local Context Data**

Social	• Socio-economic data by neighbourhood (map out)
	• Participation potential of each neighbourhood
	  • Interest in improving waste collection and willingness to take responsibility for waste management activities
	  • Priority given by residents to WM

Physical/Environmental	• Waste characterization data for each neighbourhood
	  • Waste generation rates
	  • Waste compositions
	  • Resource recovery rates
	• Physical characteristics
	  • Slope
	  • Climate (temperature and rainfall ranges)
	  • Built form density
	  • Roads (widths, paved or not, radii of curves, roughness)

Economic	• Identify inefficiencies in current system • Identify and price locally available technology* • Cost of labour • Cost of fuel • Ability to pay fees by neighbourhood

*The importance of using locally available technology is discussed on pg. 130 of this thesis.

Step Three: Design of modified/new collection system

Considering the local context, and the areas in need of improvement identified by the ISWM assessment, whether or not the existing system should be modified or a completely new system implemented can be decided. The type of collection system (for example CCC, block, or non-collection) that is best suited to the local context can also be decided. Different types of collection may be suited to specific neighbourhoods within one city (Farsi & Hammouda, 1984). For example neighbourhoods that have high recovery rates due to household and informal collector activities may not need collection systems designed with source separation while neighbourhoods with low recycling behaviour might.

The community should be involved in designing the modified or new collection system. Community participation is a key ingredient in the success of a waste collection system (Korfmacher, 1997). Participation was high in the collection system in Aguascalientes partially due to the culture of cleanliness. Allowing residents to take ownership of the modified collection system will likely increase the participation rate. Also, if residents take on a greater burden of waste management, by going to greater distances to throw away waste and by recovering resources at the source, the cost of waste collection to

the municipality decreases (Korfmacher, 1997). Each neighbourhood should be encouraged to consider the design of system that best meets the specific characteristics of their neighbourhood, and to assess their willingness to take on waste management responsibility. Increased participation in proper waste disposal and recovery of resources could be encouraged through education about the negative health and environmental impacts of uncollected waste, and the environmental and economic benefits of proper waste disposal and resource recovery.

Recommendations specific to planning CCC

CCC has the potential of being well suited to developing cities if well designed. The following suggestions for determining container placement have been developed based on the lesson learned from the system in Aguascalientes.

Distance from household to container affects the use of the containers (Flintoff, 1976; Ogawa, 1989; Parrot et al., 2008; Bhide & Sundaresan, 1984). The distance to container in Aguascalientes, for which the average was 115m, was not a barrier to participation. Therefore, an average distance to container of 115m can be used as a standard for other cities planning CCC. Aguascalientes is fairly flat, and the culture of cleanliness is thought to encourage participation, so areas with steeper slopes or less willingness amongst residents to participate may need a shorter average distance.

An algorithm could be created to triangulate container locations such that participation is maximized and cost is minimized using the following inputs:

- Average distance
- Roads that can support collection vehicles (based on minimum width, minimum curve radius, maximum slope, and minimum degree of roughness)
- Cost of collection (as a function of distance (fuel costs) and time (labour costs))

The size of container in each location should be based on the waste generation rate in that area. A panel of residents should review the collection locations and make changes necessary to improve social acceptability (while maintaining approximately the same number of containers so the cost is not greatly affected). For areas where the roads are impassable by collection vehicles, the containers should be placed along the closest accessible roads giving preference to major walking routes such that the container locations as convenient as possible for residents of those areas.

In many developing cities there are large informal settlement areas which tend to have narrow, winding, dirt streets which are virtually impassable by collection vehicles (Korfmacher, 1997; Bhide & Sundaresan, 1984; Oluwande, 1984). In these areas, efficient waste collection using CCC may only occur

if the residents take on the responsibility for the collection and transportation of their waste to the nearest container. Wherever possible existing waste management activities should be built upon to maximize their effectiveness and achieve the goals of ISWM. Informal collectors and residents in those areas could be encouraged to take advantage of the entrepreneurial opportunities associated with the value of waste as a resource. Informal collectors could organize a collection service through which they could acquire income from selling recovered recyclables. If there is sufficient space, the organic waste could be composted which could be sold to those who have gardens. To encourage residents to give their waste to informal collectors, the collectors could pay to the residents a portion of the resale value of their waste. In consideration of the cost-saved by community-based waste collection, the waste official collection provider could support these initiatives financially and/or provide equipment and training for safe waste handling.

A very important recommendation based on the lessons learned from the case study is that the operating cost of waste collection should not be beyond what is locally economically sustainable. The provision of regular and thorough collection in Aguascalientes was an important factor of the social acceptability and environmental effectiveness of the collection system. The waste collection provider should design the collection system and fees such that the containers can be emptied at a frequency tailored to the climate, with sufficient sizes of container such that they will not overflow during the intervals between collections.

Reporting and monitoring are also very important to ensure thorough collection. The costs of reporting, monitoring, and other costs associated with administering and overseeing the operation of the collection system should be included in cost estimates.

Addendum C
Resource Recovery Rate Calculation

The resource recovery rate of Aguascalientes presented in this thesis was over estimated. The SE Middle group was underrepresented in the calculations. There were only 31 SE Medium responses for the relevant resource recovery rate question while there were 62 SE High and 77 SE Low responses for the same question. In the entire city of Aguascalientes the SE Medium group makes up 54% of the households, while the SE Low group makes up 26% and the SE High group 20%. The SE Medium group had the lowest recovery rate (19%). If the resource recovery rate is recalculated giving weight to each group's recovery rate based on the number of households in the city that are in that group, the resource recovery rate is 26% by volume. Like the previously calculated recovery rate of 33%, this more accurate recovery rate is also comparable to the resource recovery rates of other developing and developed countries.

To further improve the accuracy of the resource recovery rate, more responses to the relevant question would be needed. More responses are especially needed from the SE Medium group to give that group more representation based on the number of responses rather than by assigning more weight to the few available responses.

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Appendix A

Ethics Materials

CONFIDENTIALITY STATEMENT

I understand that as an interpreter / transcriber / research assistant (circle one) for a study being conducted by Janet Mader of the School of Planning, University of Waterloo under the supervision of Professor Murray Haight, I am privy to confidential information. I agree to keep all data collected during this study confidential and will not reveal it to anyone outside the research team.

Name: _____ Signature: _____

Date: _____ Witness Signature: _____

INFORMATION SCRIPT FOR SURVEYS

[If a child answers the door they will be asked to get an adult or a sibling who is 16 or older.]

Hello. My name is Janet Mader and I am a Master's student in the School of Planning at the University of Waterloo in Canada conducting research under the supervision of Professor Murray Haight on the waste collection process in the municipality of Aguascalientes. Would you consider participating in a fifteen to twenty minute survey about *the waste produced in your household and [italicized text for residential neighbourhood surveys only*] your experience with the communal waste bins?

[Wait for response.]

Thank you. Participation in this 20-minute survey is voluntary and there are no known or anticipated risks to your participation in this study. The questions pertain to waste and waste collection (for example, how far is it from your house to the communal bin that your household uses?) You may decline answering any questions you feel you do not wish to answer and can withdraw from participating in the survey at anytime by telling me. All information you provide will be considered confidential and grouped with responses from other participants. You will not be identified by name in my thesis or in any report or publication resulting from this study. The data collected through this study will be kept for a period of 2 years in Dr. Haight's locked office at the University of Waterloo. The final compiled results of this study will be shared with the Secretaria de Servicios Públicos y Ecologia. This study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo.

INFORMATION LETTER FOR DOOR-TO-DOOR SURVEYS

University of Waterloo

Date

Dear Resident or Business Employee,

I am a Master's student in the School of Planning at the University of Waterloo in Canada conducting research under the supervision of Professor Murray Haight on the waste collection process in the municipality of Aguascalientes. As you may know, the municipality of Aguascalientes has won awards and received ISO 14001 certification for the environmental standards of its engineered landfill. The way waste is collected can affect the health of the environment, the cost of the system to the tax payer, and whether or not residents will properly participate in the waste disposal and collection process. The communal bin collection system of Aguascalientes seems to work well while similar systems have generally met with limited success in other communities. This study will explore the functions, challenges and benefits of the waste collection system of Aguascalientes. As a user of a communal bin, your opinions are important to this study. I would appreciate the opportunity to speak with you about the waste produced in your household and your use of the communal bins.

Participation in this study is voluntary and would involve a twenty minute survey interview at your home. There are no known or anticipated risks to your participation in this study. The questions are about waste and waste collection (for example, how far is it from your house to the communal bin that your household uses?) You may decline answering any questions you feel you do not wish to answer. All information you provide will be considered confidential and anonymous. You will not be identified by name in my thesis or in any report or publication resulting from this study. The data collected through this study will be kept for a period of 2 years in Professor Haight's locked office at the University of Waterloo and then confidentially destroyed. The final compiled results of this study will be shared with the Secretaria de Servicios Públicos y Ecologia.

If after receiving this letter, you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact the translator at ***(phone number in Mexico)*** or by email at jemader@uwaterloo.ca. You can also contact my supervisor, Professor Murray Haight at 1-519-888-4567 ext. 33027 or email at mehaight@envmail.uwaterloo.ca.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. Should you have comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 1-519-888-4567, Ext. 36005.

Thank you for your assistance with this project.

Yours sincerely,

Janet Mader

INFORMATION LETTER AND CONSENT FORM FOR INTERVIEWS

Department Letterhead

University of Waterloo

Date

Dear ***(insert participant's name):***

This letter is an invitation to consider participating in a study I am conducting as part of my Master's degree in the School of Planning at the University of Waterloo in Canada under the supervision of Professor Murray Haight. I would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

As you know, the municipality of Aguascalientes has won awards and received ISO 14001 certification for the environmental standards of its engineered landfill. The communal bin collection system of Aguascalientes seems to work well while similar systems have generally met with limited success in other communities. This study will explore the functions, challenges and benefits of the waste collection system of Aguascalientes. As a *(insert: wastes system planner, waste collection manager/overseer, or waste collector)* I am interested in meeting with you to discuss how the system operates and to learn your opinions on which aspects of the system work well and which could be improved.

Participation in this study is voluntary. It will involve an interview of approximately one hour in length to take place in a mutually agreed upon location. You may decline to answer any of the interview questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher. With your permission, the interview will be audio recorded to facilitate collection of information, and later transcribed for analysis. After the interview has been transcribed, I will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish. All information you provide is considered completely confidential. Your name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used. Data collected during this study will be retained for 2 years in in Professor Haight's locked office at the University of Waterloo and then confidentially destroyed. Only researchers associated with this project will have access. There are no known or anticipated risks to you as a participant in this study. The final compiled results of this study will be shared with the Secretaria de Servicios Públicos y Ecologia.

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact me at ***(telephone number in Mexico)*** or by email at jemader@uwaterloo.ca. You can also contact my supervisor, Professor Murray Haight at 1-519-888-4567 ext. 33027 or email at mehaight@envmail.uwaterloo.ca.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes of this office at 1-519-888-4567 Ext. 36005 or ssykes@uwaterloo.ca.

I hope that the results of my study will be of benefit to the Secretaria de Servicios Públicos y Ecologia and enable them to continue to improve the environmental and social well being of Aguascalientes. This study

will also contribute to the general body of knowledge of communal waste bin collection systems which will hopefully help them to be successfully implemented in communities that would benefit from them.

I very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Janet Mader

CONSENT FORM

I have read the information presented in the information letter about a study being conducted by Janet Mader of the School of Planning at the University of Waterloo in Canada. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 1-519-888-4567 ext. 36005.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐ YES ☐ NO

I agree to have my interview audio recorded.

☐ YES ☐ NO

I agree to the use of anonymous quotations in any thesis or publication that comes of this research.

☐ YES ☐ NO

Participant Name: _____ (Please print)

Participant Signature: _____

Witness Name: _____ (Please print)

Witness Signature: _____

Date: _____

Appendix B
Surveys

Household/Residential Business Questionnaire

1. GPS Co-ordinates_____
2. This building functions as a:
    a) Home
    b) Business
    c) Both home and business
3. If it is a business or home/business what type of business is it? (circle one)
    a) meat store,
    b) cheese store
    c) fruits and vegetables
    d) pharmacy
    e) paper store
    f) beauty shoppe
    g) convenience store,
    h) repair shop,
    i) small goods retail
    j) restaurant,
    k) other _____
4. What is the distance from this building to the nearest communal waste container?
    a) Zone 1 (0-50m ~ less than one minute one way)
    b) Zone 2 (50m-225m less than one minute to three minutes)
    c) Zone 3 (>225m)

For the participant:

Possible responses are provided but questions are to be asked unprompted

5. How many people live in this house or are employed here? _____

Waste can be defined as the by-products of human activities that are discarded as useless or unwanted. Wastes are often reusable and may be considered a resource in another setting. (Adapted from Tchobanoglous et al.,1993)

6. Approximately, how many bags of waste are produced in this building each week? _____

7. How do you store wastes?
    a) Bags
    b) Bucket
    c) Boxes
    d) Plastic container
    e) Other
8. Approximately how much of each of the following types of wastes are produced in your household/business in one week (before wastes that are reused, recycled or sold are removed)?

Type of Waste	**None**	**< 1 small bag**	**# small bags**	**#large bags**
a. Organic (food)				
b. Scrap Metal				
c. Cans and Tins				
d. Glass				
e. Plastic Bottles				
f. Paper and Cardboard				
g. Cement or Brick Scraps				
h. Aluminum				
i. Bathroom Paper and Diapers				
j. Other Plastic				
k. Tetrapack				
l. Yard waste				
m. Other_____				
n. Other_____				

*Note: The sizes of small and large bags will be defined by example bags which will be shown to the respondents when they are asked this question

9. Do you make any efforts to reduce the amount of waste produced in your household/business?
    a) Yes
    b) No

10. In which of the following ways do you reuse or recycle wastes? *Multiple responses possible.*
    a) Feed food scraps to animals
    b) Use plastic or metal containers for storage
    c) Compost food scraps
    d) Sell recyclable materials
    e) Take recyclable materials to one of the 13 recycling centres in the city
    f) My kids take recyclable materials to school
    g) Give recyclable materials away
    h) Give food waste away
    i) Separate recyclables but throw them in the communal container
    j) Take recyclable materials to non-municipal recycling centre
    k) Take recyclable materials to recycling container in my neighbourhood (if there is one)
    l) Other_____
    m) Other_____
    n) No wastes are reused in this household/business
11. After recycled materials are separated and removed, how many bags of waste are taken the waste containers? _____

12. What wastes, and how much of them, do you reuse, recycle or sell?

Type of Waste	**100%**	**100-75%**	**75-50%**	**50%**	**50-25%**	**25-0%**
a. Organic (food)						
b. Scrap Metal						
c. Cans and Tins						
d. Glass						
e. Plastic Bottles						
f. Paper and Cardboard						
g. Cement or Brick Scraps						
h. Aluminum						
i. Bathroom Paper and Diapers						
j. Other Plastic						
k. Tetrapak Cartons						
l. Yard Waste						
m. Other _____						

13. If you sell wastes, to whom do you sell wastes? *Multiple responses possible.*
    a) An individual who comes to my door to collect it
    b) A business that comes to my door to collect it
    c) A business that I have to take the waste to
    d) Other _____

14. Are wastes from this building given to people who ask to collect them?
    a) Yes, regularly
    b) Yes, occasionally
    c) No, but we would if we were asked for them
    d) No, we haven't and we wouldn't if asked for them
15. What methods of waste disposal, other than the communal container, does your household/business use? Multiple responses possible.
    a) Dumping in open spaces within urban area
    b) Dumping in open spaces outside of urban area
    c) Burial
    d) Burning
    e) Other
    f) Only communal containers used for waste disposal
16. Where are wastes stored before disposal?
    a) Indoors
    b) Outdoors
17. What are the age and gender of the people who normally take the waste to the communal waste container? Multiple responses possible.
    a. 0-5 male
    b. 6-12 male
    c. 13-18 male
    d. 19-35 male
    e. 36-55 male
    f. 56+ male
    g. 0-5 female
    h. 6-12 female
    i. 13-18 female
    j. 19-35 female
    k. 36-55 female
    l. 56+ female
18. Are residents or employees of this house responsible for taking out the waste? *(For households only)*
    a) Residents
    b) Employees
    c) Both
19. Which container do you use? Container #_____

20. How far is it from your building to the communal container that your household/business uses?
    a) Less than a 1 minute walk
    b) 1-2 minute walk
    c) 2-5 minute walk
    d) More than a 5 minute walk
21. How often are your household's wastes taken to the communal container?
    a) More than once per day
    b) Once per day
    c) Every other day
    d) 2 times per week
    e) 3 times per week
    f) Once per week
    g) Less than once per week
22. How do you take out the trash?
    a) Walking
    b) Car
    c) Other _____
23. If two more containers were put in your neighbourhood, one for only paper, and one for only glass, plastic, and metal, would you separate out these wastes and put them in these containers?
    a) Yes, even if they were a 30 min walk away, or further
    b) Yes, even if they were between 15-30 min walking distance away
    c) Yes, if they were within a 15 min walking distance
    d) Yes, but only if they are in the same location as my current waste container
    e) No
    f) Yes, even if they were a 30 min drive away, or further
    g) Yes, even if they were between 15-30 min driving distance away
    h) Yes, if they were within a 15 min driving distance
24. Are you concerned about the health of your environment? (Where your environment is your local land, air and water.)
    a) Yes
    b) No
    c) I don't know
    d) I don't care
25. In your opinion, is your environment safe and healthy, or not?
    a) Yes it is safe and healthy
    b) No
    c) I don't know

26. What do you like about the current waste collection system? *Multiple responses possible.*
    a) Easy to use
    b) Streets are clean
    c) Affordable cost
    d) Containers are generally not full
    e) Municipal collectors clean up around the containers
    f) Containers are emptied daily
    g) Other_____
    h) Other_____
27. What do you not like about the current waste collection system? *Multiple responses possible.*
    a) Those who take out the waste complain of muscle pains from carrying the waste
    b) Distance to container is too far
    c) Sometimes the containers are completely full and/or overfilled
    d) Fees are too high
    e) Recyclable materials are not separated
    f) Bad odour, rats, and/or flies near the containers
    g) Bad odour in my building from the containers
    h) Wastes are on the ground near the container
    i) Containers are not emptied when they are supposed to be
    j) Sometimes the waste in the containers is on fire
    k) Dogs pull waste out of the containers and make a mess around them
    l) People make a mess around the containers do not use the containers correctly
    m) Other_____
    n) Other_____

    What do you think could be improved about the current waste collection system? *Multiple responses possible.*
    o) Shorter distances to containers
    p) Reduced fees
    q) Containers emptied on schedule (if not already regularly emptied on schedule)
    r) Containers emptied more often
    s) Separate containers for recyclable materials
    t) A more convenient disposal schedule
    u) More containers in this area
    v) People should use the containers correctly
    w) Increase the amount of public education about recycling
    x) Better and/or more equipment (trucks)
    y) Other _____

28. How do you consider the waste collection system service?
    a) awful
    b) bad
    c) regular
    d) good
    e) excellent
29. If you have a complaint or suggestion about the waste containers, who would you tell?
    a) My local political representative
    b) The municipal waste collectors
    c) The municipality
    d) My neighbourhood board
    e) Other_____
    f) No one
30. What time of day is the waste from this house disposed?
    a) 5-7 am
    b) 7am-12pm
    c) 12-3 pm
    d) 3-7 pm
    e) 7pm-5am
    f) Different times everyday but usually between 7am and 7 pm
    g) Different times everyday but usually between 7pm and 7 am
    h) Different times everyday
31. Do you take the waste out while preforming other errands?
    a) Yes normally
    b) Yes occasionally
    c) No
32. Do you know the schedule for disposing waste?
    a) Yes
    b) No
33. If the schedule is not adhere to, why not? *Multiple responses possible.*
    a) The person responsible for disposing the waste is not here during the scheduled hours
    b) The schedule is not convenient for me
    c) I do not think it is important to follow the schedule
34. Did you know that there is a number on the containers to call if you have any questions or complaints?
    a) Yes
    b) No

35. Do you know which types of waste you are not allowed to throw in the containers?
    a) Yes
    b) No
    c) Leaves, grass and branches
    d) Batteries
    e) Toxic materials
    f) Dead animals
36. Do you know which types of waste are considered dangerous?
    a) Yes
    b) No
    c) Batteries
    d) Toxic materials
    e) Dead animals
37. Do you know where to take dangerous wastes?
    a) Yes
    b) I know where to take batteries
    c) No
38. Do you know about the recycling centres in the city?
    a) Yes
    b) No
39. If you take materials to them, how often do you take them there?
    a) Once per day
    b) Every other day
    c) 2 times per week
    d) Once per week
    e) Every 2 weeks
    f) Once per month
    g) Every 2 months
    h) Less than every 2 months

40. If you know about the recycling centres but do not use them, why not?
    a) I don't produce very much recyclable material
    b) The centres are too far
    c) I don't have time
    d) I don't believe the centres keep recyclable materials separated (so why should I separate them?)
    e) I don't want to store recyclable materials on my property until I have time to take them
    f) It would be too much of an inconvenience for me
    g) I don't think recycling is important
    h) I use a different method of recycling
    i) No reason
    j) Other (don't know/just moved here)

Informal Waste Collector Survey

For Surveyor:

1. Location of the bin from which the participant was collecting: _____
2. Participant's Gender
   a) Male
   b) Female

To Ask Participant: Possible responses are provided but questions are to be asked unprompted

3. What kinds of waste do you collect and approximately how much of each kind do you collect per week?

Type of Waste	**# Kilograms**
a. Organic (food)	
b. Scrap Metal	
c. Cans and Tins	
d. Glass	
e. Plastic Bottles	
f. Hard Plastic	
g. Other Plastic	
h. Paper	
i. Cardboard	
j. Cement or Brick Scraps	
k. Clothing	
l. Aluminum cans	
m. Other _____	
n. Other _____	

*Note: The sizes of small and large bags will be defined by example bags which will be shown to the respondents when they are asked this question

4. How often do you collect items from the bins?
   a) Daily
   b) Weekly
   c) Occasionally (once per month or less)
   d) Only when I see something of interest
   e) This is my first time collecting from bins

5. How many bins do you collect from?
    a. 1
    b. 2-5
    c. 5-10
    d. 10 or more
6. Do you collect only from bins in this neighbourhood, or from other neighbourhoods as well?
    a. Only this neighbourhood
    b. Yes, 1 other neighbourhood
    c. Yes, more than 1 other neighbourhood
7. Do you live in this neighbourhood?
    a. Yes
    b. No
8. Do you collect from sources other than the waste bins?
    a. Yes, the ground
    b. Yes, dumping areas
    c. Yes, recyclable waste produced in my house
    d. No
9. What precautions do you take while collecting? Multiple responses possible.
    a. Wear gloves
    b. Move waste with a stick
    c. Wear a mask
    d. Other _____
10. Have you ever been hurt while collecting from the bins or become sick as a result of collecting from the bins?
    a. Yes, hurt
    b. Yes, sick
    c. No
11. Do you, or have you ever, asked for, or bought, collectable materials directly from households or businesses?
    a. Yes
    b. No
12. What do you do with the items you collect? Multiple responses possible.
    a. Sell them to a business
    b. Sell them to individuals
    c. Use them myself
    d. Alter, then sell them
    e. Exchange them for goods for the “Municipio Amigo” program
    f. Other _____

13. How much money do you receive sell items for?
    a. _____pesos per _____ amount of _____ (type of item)
14. Is selling collected items your only source of income?
    a. Yes
    b. No, I do other jobs, but it is my primary source of income
    c. No
15. What do you like about the current waste collection system? Multiple responses possible.
    a. Streets are clean
    b. Bins are emptied regularly
    c. Easy to collect items from
    d. Some people leave items I collect (eg food, clothes) on top of or beside the bin so they aren't contaminated with other wastes
    e. Municipal collectors clean up around the bins
    f. Other_____
16. What do you not like about the current waste collection system? Multiple responses possible.
    a. Distances to between bins is too far
    b. Sometimes the bins are completely full and/or overfilled
    c. There are no separate bins for recyclable materials
    d. Bad odour, rats, and/or flies near the bins
    e. Wastes are on the ground near the bin
    f. Bins are not emptied when they are supposed to be
    g. Sometimes the waste in the bins is on fire
    h. Dogs pull waste out of the bins and make a mess around them
    i. People do not use the bins correctly
    j. Other_____
17. What do you think could be improved about the current waste collection system? Multiple responses possible.
    a. Shorter distances between bins
    b. Reduced fees
    c. Bins emptied on schedule (if not already regularly emptied on schedule)
    d. Bins emptied more often
    e. Separate bins for recyclable materials
    f. Shorter bins so they are easier to collect from
    g. More bins in this area
    h. People should use the bins correctly
    i. Other_____

18. If you have a complaint or suggestion about the waste bins, who would you tell?
    a. My local political representative
    b. The municipal waste collectors
    c. Other_____
    d. No one
19. If there were separate bins in a neighbourhood for paper/cardboard and/or metal/glass, how would this affect your collection work? Multiple responses possible.
    a. It would be easier to collect materials
    b. I think there would be more competition to collect materials
    c. The prices of collected materials may decrease if it is easier to collect them
    d. This would benefit me
    e. This would be negative for me
    f. Other _____
20. What is your age? _____
21. Are you a registered collector?
    a. Yes
    b. No

Appendix C

Additional Results

Table C. 1**:** Responses to "Are wastes from this building given to people who ask to collect them?

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference between SE groups (p<0.05)**
No. of responses	*270*	*87*	*90*	*93*	
Yes, regularly	14.44	11.49	15.56	16.13	No, p=0.606
Yes, occasionally	6.67	9.20	6.67	4.30	
No, but we would if asked for them	**61.48**	65.52	57.78	61.29	
No, we haven't and we wouldn't if asked for them	17.04	12.64	20.00	18.28	
Don't know	0.37	1.15	0.00	0.00	

Table C. 2**:** Waste composition as percentage of waste generated for all respondents and each SE group.

	All Respondents	**SE High**	**SE Medium**	**SE Low**	**Significant Difference (p<0.05)**
Number of Respondents	*178*	*68*	*38*	*72*	
%Organic/Food wastes	20.59	28.20	13.25	17.27	Yes, p=0.002
% scrap metal	0.17	0.00	0.00	0.42	Insufficient data to test
% tin cans	2.89	4.51	0.57	2.59	No, p=0.301 for ln transformed data
%glass	0.86	0.92	0.70	0.88	No, p=0.940 for ln transformed data
% plastic bottles	28.68	24.26	31.89	31.16	No, p=0.178
% paper and cardboard	22.22	19.71	27.81	21.64	No, p=0.226
% aluminum	0.23	0.07	0.18	0.42	Insufficient data to test
% toilet paper and diapers	6.95	7.70	7.72	5.83	No, p=0.105 for ln transformed data
%Other Plastics	6.47	6.86	0.79	9.10	No, p=0.056 for ln transformed data
% Tetrapack	3.53	2.99	5.92	2.78	No, p=0.927 for ln transformed data
% yard waste	1.60	1.99	1.58	1.25	No, p=0.955 for ln transformed data
% other waste	0.81	0.00	2.63	0.63	Yes, p=0.019 for ln transformed data)
% Undefined (added by researcher: remaining percent such that the total is 100)	5.00	2.79	6.97	6.04	

Table C. 3**:** Age and sex of person who was normally responsible for taking waste to the container.

	% All	**% SE High**	**% SE Medium**	**% SE Low**
No. of responses	*277*	*90*	*92*	*95*
Male 0-5	0.28	0.00	0.86	0.00
Male 6-12	4.70	2.73	4.31	6.62
Male 13-18	6.08	3.64	6.90	7.35
Male 19-35	9.67	8.18	13.79	7.35
Male 36-55	15.19	13.64	15.52	16.18
Male 56+	10.77	12.73	14.66	5.88
TOTAL MALE	**46.69**	**40.91**	**56.03**	**43.38**
Female 0-5	0.00	0.00	0.00	0.00
Female 6-12	1.38	0.00	0.86	2.94
Female 13-18	3.87	3.64	1.72	5.88
Female 19-35	17.68	21.82	13.79	17.65
Female 36-55	25.14	25.45	20.69	28.68
Female 56 +	5.25	8.18	6.90	1.47
TOTAL FEMALE	**53.31**	**59.09**	**43.97**	**56.62**

(A single household/small business (respondent) could have more than one person responsible for taking the waste out. The percentages of the above table were calculated as total no. of people taking out waste in this age category/total number of people taking out waste. Since there could be multiple people from varying age categories taking out waste for one respondent, a chi-squared test could not be performed on the data corresponding to the above table.)

Table C. 4**:** To whom wastes are sold as percentages of respondents that sell wastes

	% Respondents that sell waste
No. of responses	*27*
Individuals at door	3.70
Companies at door	7.41
Go to companies	88.89

Table C. 5**:** How often wastes are taken to containers

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*275*	*91*	*91*	*93*	
More than once a day	2.55	0.00	4.40	2.15	No, p=0.279 (when results are grouped into fewer categories[47] so chi-squared test is valid)
Once a day	**58.76**	**52.75**	**67.03**	**56.99**	
Every other day	4.38	5.49	7.69	0.00	
Three times a week	4.38	4.40	2.20	6.45	
Twice a week	**20.44**	**21.98**	**15.38**	**23.66**	
Once a week	8.39	13.19	3.30	8.60	
Less than once a week	1.09	1.10	0.00	2.15	
N/A	0.36	1.10	0.00	0.00	

[47] Where the categories are: at least once a day, every other day or three times a week, twice a week, and once a week or less.

Table C. 6**:** Time of day wastes are taken to containers

	% All Respondents	% SE High	% SE Medium	% SE Low	Significant Difference (p<0.05)
No. of responses	*273*	*89*	*91*	*93*	
5-7am	2.96	2.27	0.00	6.52	No, p=0.08 (with results grouped into fewer categories so a chi-squared test is valid)
7am-12pm	12.96	14.77	11.11	13.04	
12-3pm	7.04	15.91	3.33	2.17	
3-7pm	8.15	20.45	2.22	2.17	
7pm-5am	52.22	30.68	70.00	55.43	
Different times but between 7pm and 7am	1.11	0.00	1.11	2.17	
Different times but between 7am and 7pm	4.81	2.27	5.56	6.52	
All different times	10.74	13.64	6.67	11.96	

Table C. 7**:** Methods of taking waste to containers

	% All Respondents	% SE High	% SE Medium	% SE Low
No. of responses	*274*	*91*	*90*	*94*
Walking	**93.82**	86.81	95.56	98.94
Car	1.45	4.40	0.00	0.00
Both	2.55	6.59	1.11	0.00
Other (bike, motorcycle)	1.45	0.00	3.33	1.06
n/a (don't use containers)	0.73	2.20	0.00	0.00
		86.81	95.56	98.94

(Insufficient responses in all other categories aside from walking to perform a chi-squared test).

Table C. 8**:** Responses to the question "Are you concerned about the health of your environment? (Where your environment is your local land, air and water.)

	% All Respondents	% SE High	% SE Medium	% SE Low	Significant Difference (p<0.05)
No. of responses	*273*	*91*	*90*	*92*	
Yes	95.24	94.51	96.67	94.57	No, p=0.239 (with "more or less" removed so a chi-squared test is valid)
No	4.03	5.49	1.11	5.43	
More or Less	0.73	0	2.22	0	

Table C. 9**:** Percentage of respondents by **methods** of recovering wastes

Recovery Category	Recovery Method	% All Respondents	% SE High	% SE Medium	% SE Low	Significant Difference (p<0.05)
	No. of responses	*279*	*92*	*92*	*95*	
Reuse	Plastic or metal containers reused for storage	22.14	20.43	27.17	18.95	No, p=0.331
	Paper reused (back)	4.29	7.53	5.43	0.00	i.r.t.
	Any form of Reuse	26.16	27.96	31.87	18.95	No, p=0.120
Organics Recovery	Food fed to animals	9.64	0.00	3.26	25.26	i.r.t.
	Compost Organics	5.71	8.60	7.61	1.05	No, p=0.052
	Food waste given away	3.57	1.08	2.17	7.37	i.r.t
	Any form of Organic Recovery	18.21	9.68	11.96	32.63	Yes, p<0.001
Recycling	Recyclable materials given away	15.00	13.98	22.83	8.42	Yes, p=0.016
	Recyclable Materials Sold	14.64	8.60	3.26	31.58	Yes, p<0.001
	Recyclable Materials to Children's' School	14.64	12.90	9.78	21.05	No, p=0.083
	Recyclable Materials to Municipal Recycling Depots	13.93	24.73	15.22	2.11	Yes, p<0.001
	Recyclable materials taken to non-municipal recycling depot	7.50	8.60	9.78	4.21	No, p=0.303
	Recyclable material taken to recycle bin in neighbourhood	0.71	0.00	2.17	0.00	i,r,t
	Any form of Recycling – including sometimes	57.14	58.06	53.26	60.00	No,p=0.633
	Any form of Recycling – not including sometimes	44.29	49.46	50	33.68	Yes, p=0.038;
Other	Recyclable materials separated but thrown into bins	10.00	19.35	4.35	6.32	Yes, p=0.001
	Other Method of Reuse/Recycling	6.79	9.68	7.61	3.16	i.r.t
None	Do not use any form of recycling or organic recovery (but may reuse)	25.71	30.11	21.74	25.26	No, p=0.521

Table C. 10**:** Recovery rates by type of waste.

	Total % Recovered	**% Recovered in SE High**	**% Recovered in SE Medium**	**% Recovered in SE Low**
No. of responses	*278*	*92*	*92*	*94*
Organics	10.64	2.83	13.18	28.06
Scrap Metal	56.52	100.00	none generated	0.00
Tin Cans	58.49	54.30	0.00	69.74
Glass	92.88	83.36	0.00	98.00
Plastic Bottles	39.92	40.58	35.66	41.66
Paper and Cardboard	45.40	71.36	27.23	25.22
Aluminum	67.00	67.53	0.00	70.44
Other Plastic	2.99	5.51	0.00	0.00
Tetrapak Cartons	0.15	0.00	0.00	0.28
Yardwaste	0.00	0.00	0.00	0.00

(Could not analyze the above for differences by SE status because the percents given are derived from the total resource recovery rate for all respondents in each group, rather than being the mean of the respondent's individual recovery rates.)

Table C. 11**:** Percentages of respondents that reuse, recycle or sell by **type** of waste

Type of Waste	**% Respondents**
No. of responses	*279*
Feed Organics to animals and/or Compost	16.13
Feed Organics to animals, Compost and/or Give food scraps away	18
Reuse, Recycle or Sell Scrap Metal	2.51
Reuse, Recycle or Sell Tins and/or Cans and/or Aluminum	**19.35**
Reuse, Recycle or Sell Glass	9.68
Reuse, Recycle or Sell Plastic Bottles	**44.09**
Reuse, Recycle or Sell Paper and/or Cardboard	**34.77**
Reuse, Recycle or Sell Cement and Construction Waste	0.36
Reuse, Recycle or Sell Other Plastic	2.51
Reuse, Recycle or Sell Tetrapak Cartons	6.09
Reuse, Recycle or Sell other wastes reused, recycled or sold	1.43

Table C. 12**:** Respondents that know about municipal recycling centres, and that know about and use them

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*259*	*91*	*87*	*81*	
Know about the municipal recycling centres	55.98	76.92	57.47	30.86	Yes, p<0.001
No. of responses	*78*	*48*	*23*	*7*	
Know about the municipal recycling centres and **have used them at least once**	30.12	47.25	32.18	8.64	Yes, p<0.001

Table C. 13**:** How often wastes are taken to recycling centres by percent of respondents that take wastes to centres out of those that use the centres.

	% Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*83*	*44*	*28*	*11*	
Once a day	1.30	0.00	0.00	16.67	i.r.t (even when grouped into smaller categories)
Every other day	1.30	2.33	0.00	0.00	
Twice a week	3.90	4.65	3.57	0.00	
Once a week	**15.58**	18.60	14.29	0.00	
Every 2 weeks	**24.68**	27.91	21.43	16.67	
Once a month	**19.48**	9.30	35.71	16.67	
Every two months	7.79	13.95	0.00	0.00	
Less than every two months	**19.48**	16.28	17.86	50.00	
Didn't know	3.90	6.98	0.00	0.00	
only been once	2.60	0.00	7.14	0.00	

Table C. 14**:** Responses by percent to the question "If you have a complaint or suggestion about the containers, who would you tell?

	% All Respondents	**% SE High**	**% SE Medium**	**% SE Low**	**Significant Difference (p<0.05)**
No. of responses	*273*	*91*	*90*	*92*	
My local political representative	1.46	1.10	1.11	2.17	Yes, p=0.04 when local political rep. and neighbourhood board grouped together and other and collectors removed.
The municipal waste collectors	0.73	0.00	1.11	1.09	
The Municipality	**43.59**	**46.15**	**54.44**	**30.43**	
My neighbourhood board	9.157	13.19	6.67	7.61	
Other	2.56	6.59	0.00	1.09	
No one	**33.33**	**16.48**	**35.56**	**47.83**	
Don't know	9.16	16.48	1.11	9.78	

List C.1: Other stated likes and their frequencies.
Related to Containers:

- That there are containers x 4
- Container is close by x4
- Lots of containers in an area
- Containers are not full
- Waste isn't left on ground for collection x 2
- Containers prevent littered streets compared to leaving waste on street for collection
- Waste not on ground
- Other cities don't have containers

Related to Municipal Service:

- Workers do their job
- Municipal collectors know how to collect and clean
- Municipal collectors separate some materials
- Truck beeps horn while driving by so people can bring out their waste
- collect in the night x2 (which reduces spread of odour)
- Truck comes in the morning x2
- Punctual Collection x 2
- The schedule x3
- [Schedule allows for] lots of time to throw waste
- Informal collectors are allowed to collect

In General:

- Good x36
- Everything x3
- okay
- Nothingx2
- Efficient x3
- practical
- No bugs or rats
- animals can't reach container to make a mess
- can't smell it
- doesn't smell bad
- Really good compared to Guadalajara

List C.2: Other stated dislikes and their frequencies.
Related to Peoples' Use of the Containers:

- Litter x3
- People don't always sweep outside their homes like they are supposed to
- There is garbage in empty lots
- People throw waste in empty lots - he owns lots and has to clean them
- People leave furniture x2
- Dead animals in containers
- People don't put waste in bags before throwing it in containers
- Yard waste in yellow containers
- Informal collectors make a mess and/or open bags(mix separated wastes) x 7, for this reason they are smelly
- Informal collectors
- Kids make a mess

Related to the Municipal Service:

- Sometimes truck doesn't come x2
- [Municipality] took away container in park for yardwaste. Now park manager doesn't know where to put yardwaste.
- Municipality doesn't take as good care of containers here as in more residential neighbourhoods
- Trucks are dirty, bottles on backs of trucks are ugly
- Trucks are old and breaking down, uniforms are ugly
- [Municipal] collectors don't clean well around the containers x7
- Trucks drive really fast and sometimes go wrong way down streets
- Location of the container - poor lighting and they are supposed to throw out waste at night time
- No containers in some areas x3, municipality hasn't kept promise to put containers here
- Container is too close to house x3
- Container is too small
- Truck comes late (3am) the noise wakes them
- Truck doesn't come till afternoon
- Recycling centres are not easy to access and are driven by $ not concern for environment
- Have asked municipality to remove container because of smell (it is near their house) but they didn't. There have been crashes since it's on the corner
- Used to be a container closer but they took it away. They [municipality] said they would put another one closer but they didn't

Issues arising from both the service and use of the system:

- Streets are dirty x5
- Containers are dirty
- Graffiti on containers

- Smells when hot
- Bad odour because nearby restaurant throws oil and meat in container
- Container overflows once a week after the market on Monday
- Lots of trash after market on Sunday on street outside this building - people who live there have to clean it up.

Other:

- When the streets are being fixed the trucks can't get through
- Queretaro [other city in Mexico] has better system for recycling - organics and inorganics separated

List C.3: Other stated dislikes and their frequencies.

Suggestions Directed to the Municipality:

For Improved Collection:

- Truck [should] come more often x3
- more trucks x3
- newer trucksx2
- Door to door collection x2 (so people can't throw things that aren't permitted in containers x1)
- Trucks come earlier
- Trucks come when needed
- If trucks need to come twice [in a day] they should. (If container is full)
- Trucks come 2x per day
- make containers so that people can't get waste back out of it
- larger containers
- larger containers in areas with small ones
- New containers
- put container in this area [Los Pericos]
- should paint a picture of what wastes are permitted and how to throw them (in bags) on containers
- Sign on container "close lid"

To encourage the public to use the containers properly:

Through Increased Fines:

- More fines for people who don't use it [containers] right x2
- Fines for littering
- More rules/fines - i.e. distributing flyers to everyone should be illegal- stores should ask homeowners who wants it [them]

Through Increased Monitoring

- Should inspect streets x3
- Send supervisor to monitor how people use the containers x2
- more inspectors to monitor that the schedule is respected x2
- should have someone to check containers lids- closed [or exist]
- put person in charge of checking containers - [to see] if [they] need paint/lids x2
- Municipality should take care of containers
- Supervisor check for burning
- Check for commercial/industrial waste in containers
- government should pay more attention to this community - inspect it, clean it [Los Pericos]

Suggestions for Improved Cleanliness:

- Clean the containers x3
- Clean around container x2
- Clean more often around dirty containers
- Should clean empty lots
- Clean trucks
- [Municipal] Collectors should clean everything
- Collectors should clean ground
- Cleaner Streets
- No flyers/ litter in the street
- fumigate containers to kill bugs

Collection Strategies to Improve Recycling:

- [Separate] organic and inorganic x6
- More containers for yard waste x2
- Different trucks, different days for different types of materials x2
- Truck drive by [specifically] for recyclables
- Trucks come to every house to pick up recyclables
- Trucks come every other day to pick up recyclables like in Queretaro
- Separate container for food waste
- Organic- collected daily, Recycling-once per week
- Different coloured bags for different types of waste thrown into container
- More, and closer, recycling centresx2 and containers
- Containers for recyclables should be close

Other Suggestions to Improve Recycling:

- Develop a culture of recycling
- Educate about composting
- Very important to send people into this neighbourhood to educate about recycling
- Programs to encourage recycling, Give an incentive for recycling
- Don't just bury/landfill, but recycle

Other Suggestions:

- Education x2
- Educate people to use [containers] right x2
- Municipality should encourage proper use of containers
- More $ and government involvement
- Improve public health policy
- Have honest people in all levels [of government (and it's employees)]
- Trucks shouldn't go wrong way down streets
- Containers for gated communities should be inside them
- Disposal schedule would be better in the day time because kids take out waste
- Lighting [improved near containers]
- All waste should be incinerated and ashes used for construction

Suggestions Directed towards the Public:

- People should respect the schedule x4
- Keep containers closed always x2
- Don't send kids to throw out waste x2
- Homeowners should give people money to collect waste from houses
- Keep dogs in house [to reduce feces on streets]
- People shouldn't litter
- People shouldn't leave furniture [by the containers]

N.B. *It is interesting that there were several suggestions about increased collection (more trucks or more frequent collection) when the dislike "Sometimes the containers are completely full or overflowing" did not have a high response rate. It is possible that this response was given just for the sake of contributing a suggestion.*

Table C. 15**:** Number of informal collectors by gender and age.

Gender	**Male**	**Female**
Ages of Collectors	31	35
	52	52
	38	
	18	
	58	
	unknown	
	64	
	70	
	75	
	39	
	30	
	75	
Total	12	2

Table C. 16**:** Number of informal collector questionnaire respondents by neighbourhood they were collecting in.

Neighbourhood	Los Pericos	La Herradura	Libertad	Trabajo	Benito Palomino Dena	Vicente Guerrero	Bosques del Prado Norte
Number of informal collectors questionnaireed	4 (2 couples)	1	1	3	3	1	1

Table C. 17**:** Types and amounts of materials collected.

Type of Material	**Number of Collectors**	**Average Amount Collected kg/week**	**Max. Amount Collected kg/week**	**Min. Amount Collected kg/week**
scrap metal	5	99	210	69.5
tin cans	3	5	10	2
Glass	1	2.1	2.1	2.1
plastic bottles	4	8	15	5
hard plastic	3	15	28	2
paper	4	212	420	5.25
cardboard	8	145	420	4.2
aluminum cans	7	20	140	1
other waste	3			

Other types of wastes collected mentioned were toys, clothes, laminated cardboard, anything sellable items.

Table C. 18**:** Types of materials, the range of buying and selling prices and amounts bought and sold for 3 small buy/sell businesses.

Material	**Buying Price Range (Pesos/kg)**	**Selling Price Range (Pesos/kg)**	**Range of Amount Bought&Sold (kg/week)**
Copper	60-65	70	5-50
Bronze	30-37	40-45	5-50
Iron	2	2.25-2.5	1000-2000+
Aluminum	12-13	13-15	10-100
Paper	1	1.1	500
Cardboard	0.7-1	1.1	100-500
Plastic Bottles	1.2-1.5	1.5-1.7	100-500
Hard Plastic	1.5	1.7	500
Glass Bottles	1/bottle	1.8-2/bottle	30-240

Table C. 19**:** Percents of respondents that know where to take old batteries.

	% All Respondents	**% SE High Respondents**	**% SE Medium Respondents**	**% SE Low Respondents**
Know where to take old batteries	21.61	24.18	22.47	12.90

Appendix D
Waste Characterization

The average amount of waste generated in the city of Aguascalientes was found to be 5L/capita/day based on respondent estimates.[48] This result falls into a worldwide generation range by volume of 0.5-10 L/capita/day derived from Flintoff's (1984) generation by mass and waste density reports, and so is thought to be valid. Comparing this value to waste quantities of other developing countries is difficult because most waste quantity data is in mass rather than volume. However, comparisons of differences in waste generation by SE group can be made to other developing countries.

By socio-economic status, waste generation was not linear as the SE High group produced the most waste while the SE Medium group produced the least. The result that the SE High group produced the most waste by volume is consistent with findings in the literature that generation rate by mass increases and density of waste decreases with increased SE status, such that generation rate by volume increases with increased SE status (Cointreau, 1984; Flintoff, 1984; Blight & Mbande, 1996). However, the result that the SE Low group produces more waste than the SE Medium group disagrees with their findings. The high generation rate of the SE Low group may be because in Aguascalientes, those with low income tend to buy provisions daily (as they cannot afford to stock up), so they tend to generate more plastic bags and packaging waste.

The top three types of waste generated by respondents were plastics, organics and paper, with organic waste being 22% of waste generated by volume. If the results were by mass, the proportion of organic waste would be greater than 22% because organic matter is denser than non-compacted paper products and plastic. The waste produced by the entire state, was reported by the landfill manager to be 50% organic by mass. The high organic content of the waste generated in Aguascalientes is similar to the average organic content of developing countries reported by Troschinetz and Mihelcic (19 countries, 55% organic, 2009), but is not in the range of the high proportions seen in some developing countries (up to 75% organic, Flintoff, 1984)

Flintoff (1984) identified income as a factor of waste composition with the proportions of paper, glass and metal generated increasing with income, and the proportion of organics decreasing. The results of this study contradicted Flintoff's finding that the proportion of organics generated decreases with increased income because the SE High group generated the highest proportion of organics. A plausible

[48] It should be noted that the results are based on estimates by the participants, so the margin of error is high, and the accuracy may vary with SE status as those with more education may be able to estimate more accurately.

explanation for this result is that the SE High group could perhaps afford to be more wasteful with food scraps.

Appendix E

Probability Proportional to Size Sampling Method

RHRC CONSORTIUM MONITORING AND EVALUATION TOOLKIT

SURVEY SAMPLING TECHNIQUE EXAMPLE

Instructions for

Probability Proportional to Size Sampling Technique

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Probability proportional to size (PPS) is a sampling technique for use with surveys or mini-surveys in which the probability of selecting a sampling unit (e.g., village, zone, district, health center) is proportional to the size of its population. It gives a probability (i.e., random, representative) sample.

It is most useful when the sampling units vary considerably in size because it assures that those in larger sites have the same probability of getting into the sample as those in smaller sites, and vice verse. This method also facilitates planning for field work because a pre-determined number of respondents is interviewed in each unit selected, and staff can be allocated accordingly.

Steps in Applying Probability Proportional to Size Sampling

1. List all villages in the project area (Column A in the following example) and their populations (Column B). You can use the total population or the population of the group you are sampling, for example, married women aged 15-44 or men 15-60. In a pinch, the number of households can be used.

2. Calculate the running cumulative population (Column C). The last number in this column is the total population of the project area. In the sample, the total population is 17,619.

3. Determine the number of sites which will be visited and the total sample size desired. For a mini-survey, from which only basic frequencies are desired, expect to visit 10-15 villages for a total sample size of 100-200. For a full scale survey, the sample size will be determined by the level and type of analysis planned; you should probably expect to visit 15-30 sites, although the final number will be determined by the complexity of the area and the purpose of the study.

   In this example, we will visit 10 sites to conduct a mini-survey with a desired sample size of 150 women aged 15-44. Thus, 15 women will be interviewed in each of the 10 sites selected.

4. Divide the total population of the project area (17,619, the final figure in Column C) by 10, the number of sites we decide to visit. The result, 1,762, is called *the Sampling Interval (SI).*

5. Choose a number between 1 and the SI at random. This is the *Random Start* (RS). In this sample, the RS is 1321.

6. Calculate the following series: RS; RS + SI; RS + 2SI; RS + 3SI; RS + 4SI; RS + 5SI; RS + 6SI; RS + 7SI; RS + 8SI; RS + 9SI.
   Example: RS + 2SI is to be calculated as 2 times the sampling interval added to the random start. In this case, 1321 + 2(1762) = 4845.

7. Each of these 10 numbers corresponds to a site on the list of villages. The villages selected are those for which Column C, the cumulative population, contains the numbers in the series we calculated.

   For example, the first number in the series, 1,321, is contained in village 3, which holds numbers 788 to 1,819. The second number in the series (3,083) is contained in village 6, which holds numbers 2,943 to 3,294.

   Continuing in this manner, the desired number of sites will be selected. In this example, the selected villages are numbers 3, 6, 9, 11, 15, 18, 21, 22, 25 and 29 (Column D).

8. As planned, 15 interviews will be conducted in each of the 10 villages selected. Selection of respondents within the village should also be done randomly, preferably from a list of eligible names or a map of households. If these are not available, estimate the number of households in the village from the population figures, then divide that number by 15, the number of respondents desired. This is the interval, *n*. Starting from a random household, count every n*th* household and interview all eligible respondents in that household. For example, in village 3 there are 1,032 people. If other information suggests that an average of 6 people make up a household, then we estimate that there are 172 household in the village (1032/6=172). To get 15 respondents, we need to sample every 11^{th} household (172/15=11.5).