Doctoral Thesis (Abridged)

博士論文 （要約）

Municipal Solid Waste Management in rapidly urbanizing cities of the developing world: Exploring pathways to sustainability through a systems-based approach in Santa Cruz de la Sierra

(発展途上国の急速な都市化における固形廃棄物管理:サンタ・クルス・デ・ラ・シエラにおけるシステムベースアプローチを通じた持続可能性の考察)

ロザノ　ラゾ デニース　パトリシア

(LOZANO LAZO DENISE PATRICIA)

Doctoral Thesis (Abridged)

博士論文 （要約）

Municipal Solid Waste Management in rapidly urbanizing cities of the developing world: Exploring pathways to sustainability through a systems-based approach in Santa Cruz de la Sierra

(発展途上国の急速な都市化における固形廃棄物管理:サンタ・クルス・デ・ラ・シエラにおけるシステムベースアプローチを通じた持続可能性の考察)

ロザノ　ラゾ デニース　パトリシア

(LOZANO LAZO DENISE PATRICIA)

Graduate School of Frontier Sciences

The University of Tokyo

Municipal Solid Waste Management in rapidly urbanizing cities of the developing world: Exploring pathways to sustainability through a systems-based approach in Santa Cruz de la Sierra

ABSTRACT

Municipal solid waste management (MSWM) is one of the major public services in cities around the world. For many cities in developing countries, MSWM is still a problematic issue, causing various negative sustainability impacts, especially in rapidly urbanizing cities.

Bolivia, and specifically Santa Cruz de la Sierra, its largest and most economically prosperous city, showcase the struggles of developing countries in improving the performance of their MSWM systems in contexts of rapid urbanization and limited resources. As in other developing countries, it is common for the national and local governments to directly copy solutions designed for industrialized countries, without adapting them to the local conditions, which usually leads to unwanted results. It has been recognized that the characteristics of developing countries increase the complexity of MSWM activities. Moreover, there is a frequent excessive focus on infrastructure elements, neglecting the social dimension of MSWM, which is particularly relevant for cities in the developing world.

The use of transdisciplinary and systemic approaches has gained attention in recent years for the analysis of MSWM systems in developing countries, however few attempts of applying these concepts in specific case studies have been found in the literature. Regarding the transdisciplinary, special relevance has been attributed to the co-design and co-production with non-academic actors across the research process. Regarding the systems approaches, a balance between "hard" systems and "soft" systems techniques has been recommended as a response to uncertainty and lack of data in developing countries context.

This research aims to analyze MSWM in Santa Cruz de la Sierra, a rapidly urbanizing city of Bolivia, from a multi-level and system-based perspective, in order to explore pathways influencing its sustainability. Specific objectives include to:

1) Understand the institutional context at the local and national levels, and unravel the sustainability transitions of MSWM system in the city;

2) Identify the variables and inter-linkages corresponding to the main sustainability impacts of the MSWM system in the city;

3) Determine the mechanisms and assess the main sustainability impacts of the current MSWM practices;

4) Explore the outcomes of the MSWM system under different scenarios of adoption of sustainable practices

Objective 1), analyses primary and secondary data through the lenses of the "Multi-Level Perspective on Sustainability Transitions" (MLP) and the "Integrated and Sustainable Solid Waste Management" framework (ISWM) in order to understand the transition of MSWM systems in the last decades at the national and local level.

Secondary data consists of reports and statistics about solid waste management, sanitation, and urban planning. Primary data consists of 40 expert interviews with representatives of the institutions and organizations mostly involved in the MSWM system at both the national and local level.

Results indicate the unfolding of three overlapping transitions: (a) collection and centralized disposal; (b) environmentally controlled disposal; and (c) integrated solid waste management. These transitions had variable degrees of completion for each of the ISWM dimensions. At the city level, the rapid population and economic growth seem to have created pre-conditions for the third transition (i.e. formal and informal recycling activities). However, due to rapid and unplanned urban development the stabilization of the first and second transitions has been hindered. Major identified challenges include the inability of governments to respond adequately to the roles needed for each transition. This is often driven by issues associated with the incomplete decentralization process at the three government levels in Bolivia, politicians' vested interests, and lack of political will to prioritize waste management issues.

For objective 2), a causal loop diagram of the MSWM system of Santa Cruz de la Sierra is developed. A draft was originally created by the researcher using primary and secondary information (from Objective 1), and the definite one through two participatory modelling sessions with four experts, representing the local government, private sector, and civil society in Santa Cruz de la Sierra. The causal loop diagram elicited the mental models of stakeholders, identifying the main variables impacting the sustainability of the MSWM system, and their influencing mechanisms. At the macro level, stakeholders identified the political will and community awareness as factors influencing policies implementation and resource allocation. On the other side, main unsustainable practices identified related to household waste dumping and burning, while sustainable practices corresponded to household waste source separation, formal recovery, and informal recovery. Most of the issues and connections identified by the stakeholders related to household waste practices, which combined with the fact that household waste constitutes approximately 70% of the waste generated in the city, influenced in the selection of Household Waste as the focus of Objectives (3)-(4).

Objective 3) assessed most relevant practices affecting the sustainability of the MSWM system in Santa Cruz de la Sierra based on the results of Obj. 2: (a) household waste generation, (b) household solid waste management practices; (c) informal waste picking activities

First, the household waste generation determined generation rates, composition and factors influencing rates, through a household waste characterization study with 105 households stratified across income levels. The results indicate a median generation rate of around 0.51 kg/capita for low-income households, 0.59 kg/capita for medium income households, and 0.62 kg/capita for high income households, but the differences are not statistically significant across strata. When it comes to the components' analysis, differences across strata were found to be statistically significant for most of the components (i.e. organic, plastics, fine residue, sanitary waste). Results reflected characteristics of a rapidly developing city with organic waste accounting for around 50–70% for each of the strata, and fine residue accounting for around 10% in the estimation for the whole city and 15% for the low-income strata. For the whole city, the study estimates a median of 0.71 kg/capita and a mean of 0.55 kg/capita. Regarding the factors influencing rates, a multilinear regression analysis using a stepwise selection indicates that the number household members, household head education, presence of a kiosk in the house, and the proportion of children in the family are the most important factors influencing waste generation rates per capita.

Second, the assessment of household solid waste management practices estimated the prevalence of household waste dumping and burning, as well as source separation and recycling, and factors influencing these behaviors. A survey was applied to 305 households, including questions related to socio-demographic aspects, neighborhood characteristics, and questions using Likert scales to reflect different latent constructs for various behaviors related to waste management practices (i.e. awareness, satisfaction, attitudes). The questions were analyzed through a combination of an exploratory factor analysis and structural equation modelling. Results indicate that negative practices (i.e. dumping and burning) are primarily influenced by household location, and in the case of dumping practices, additionally the satisfaction with the collection service, as the most influencing factor. Positive practices (i.e. source separation and recycling) seem to be mainly influenced by latent constructs such as concrete knowledge needed to conduct the separation, the attitude towards the practice, awareness of recycling positive impacts, satisfaction with the service and the knowledge about the local recycling context.

Third, the assessment of informal waste picking activities identified the characteristics (equipment, working hours, association membership), outcomes (i.e. income generation, amount of material recovered), and factors influencing this outcomes. To do that, 95 surveys conducted with informal waste pickers in various points of the city. Results indicate that the amount of material recovered is mainly influenced by the association membership followed by the use of transport equipment, while the income earnings are primarily affected by the use of equipment to prepare the material before selling, followed by the working hours and the association membership.

Objective 4) uses the general structure created in Obj. 2 to create a stocks and flows diagram and the results from Obj. 3 to populate the variables and improve their mechanism definition, in order to explore the future outcomes of the MSWM system in the next ten years under current practices and alternative scenarios based on key variables identified in Obj. 3. To explore the outcomes regarding burning and dumping practices, tested scenarios included the implementation of measures to control the unplanned growth and to increase the service satisfaction, showing that without measures to control this unplanned growth, rates of dumping and burning could double in the next 10 years. Regarding the recovery of recyclable material, results indicate that improving source separation and separate collection would significantly improve the formal recovery but reduce the informal recovery by more than 10% in the next years. Additionally, these improvements would not significantly reduce the amount of waste landfilled in the next 10 years.

The results of the research highlight the importance of: a) Co-design and co-production of knowledge to address the sustainability of municipal solid waste management; b) Understanding and considering the interaction of MSWM activities with broader aspects, particularly societal and political dimensions; c) Considering the input from the community to adequately identify the factors influencing sustainable and unsustainable practices d) the use of a combination of hard and soft systems thinking approaches with participatory techniques for adequate policy design in developing countries.

ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my supervisor, Prof. Alexandros Gasparatos for believing in my potential as a researcher, for his constant encouragement and guidance to make the most of this learning experience, and for his valuable inputs in this research. I learnt so much from working under his mentorship and will forever be grateful for his immense support during my PhD studies.

I thank the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) for the opportunity and trust deposited by providing the scholarship for my studies in Japan. I am also grateful to the GPSS- GLI program for the constant academic, administrative, and financial support during all these years.

I would also like to appreciate and thank my thesis committee members: Assoc. Prof. Hiekata Kazuo, Dr. Hotta Yasuhiko, Assoc. Prof. Sakamoto Maiko, and Assoc. Prof. Tanaka Toshinori for their knowledgeable insights and comments, which allowed me to expand and improve my research outcomes.

I thank the GSFS's, GPSS-GLI's, and Gasparatos Lab's peers, for all the experiences shared and the opportunity to learn from them in so many ways.

Special thanks go to Santa Cruz de la Sierra's Municipal Cleansing Enterprise (EMACRUZ), Universidad Privada de Santa Cruz de la Sierra (UPSA) and Universidad Autonoma Gabriel Rene Moreno (UAGRM) for providing the institutional endorsement required for the research.

This research would have not been possible without the fieldwork collaboration of key actors in the municipal solid waste management system in Santa Cruz de la Sierra: Jorge Soto, Viviana Parada, Heiver Andrade, Raul Paucara; local university representatives: Cynthia Bojanic, Claudia Tinoco; survey collaborator: Leslie Quiroga; friends: Xiomara Zambrana, Angelica Aguilera, Luzia Asin; enumerators; UPSA's undergraduate students; waste pickers associations; stakeholders interviewed; and so many other people who contributed with their time, effort and knowledge for this project.

I want to acknowledge all my family for the enormous support during these years, and very specially my partner, Gen. He witnessed and shared all the ups and downs of this ride with me, and always had the right words to lift me up.

Finally, I thank my familia in Japan: Sakshi Shiradhonkar, Carlota Cubelos and Jairo Vazquez for all the laughs and for being there for each other no matter what. I will treasure our memories forever.

DEDICATION

I want to dedicate this PhD thesis to my mom, Ms. Patricia Lazo Vargas. Her memory accompanied me in the hardest moments of this journey and kept me going through those times. She was the best example of strength, resilience, and perseverance that I could have had. I will forever be amazed and inspired by her passion for knowledge in her field and all aspects of life. She always kept moving forward, always kept learning. I am sure she would have been so proud of this achievement, which is hers as much as mine.

CONTENTS

1. CHAPTER 1 1
INTRODUCTION 1
1.1 Municipal Solid Waste Management 1
1.2 Municipal Solid Waste Management systems in developing cities 2
1.3 Critical aspects of Municipal Solid Waste Management sustainability 7
1.4 Transdisciplinary research approaches to Municipal Solid Waste Management sustainability 9
1.5 Research gaps 10
1.6 Aims and objectives 11
1.7 Originality and academic contribution 12
1.8 Thesis structure 13
2. CHAPTER 2 15
METHODOLOGY 15
2.1 Research approach 15
2.2 Study site 17
2.2.1 General characteristics of Bolivia 17
2.2.2 Characteristics and recent development of Santa Cruz de la Sierra 19
2.2.3 Municipal Solid Waste Management system of Santa Cruz de la Sierra 20
2.3 Data collection and analysis 22
2.3.1 Institutional analysis of Municipal Solid Waste Management System 22
2.3.2 Participatory modeling of MSWM system 28
2.3.3 Assessment of Municipal Solid Waste Management practices 33
2.3.4 System dynamics modeling of Municipal Solid Waste Management system's elements 57
3. CHAPTER 3 63
INSTITUTIONAL ANALYSIS OF MSWM IN SANTA CRUZ DE LA SIERRA 63
3.1 Introduction 63
3.2 Municipal Solid Waste Management Regulations 63
3.2.1 National regulations 63
3.2.2 Local regulations 65
3.3 Main stakeholders and responsibilities within the Municipal Solid Waste Management system 67
3.3.1 National and local government 69
3.3.2 Formal private sector 70
3.3.3 Informal private sector 71
3.3.4 International organizations 73
3.3.5 Civil society and research organizations 74
3.4 Sustainability transitions of the Municipal Solid Waste Management system 75
3.4.1 Transitions characterization 77
3.4.2 ISWM Elements in Municipal Solid Waste Management Systems Sustainability Transitions 82
3.5 Discussion 83
3.5.1 MSWM transitions in Santa Cruz de la Sierra 83

3.5.2 Dynamics within and between government levels ... 84
3.5.3 Dynamics among private sector actors ... 85
3.5.4 Political aspects of MSWM systems' transitions ... 86
3.6 Conclusion ... 87
4. CHAPTER 4 ... 88
PARTICIPATORY MODELING OF THE MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM ... 88
4.1 Introduction ... 88
4.2 Group Model Building with local stakeholders ... 89
4.2.1 General aspects of the sessions ... 89
4.2.2 Participants dynamics ... 90
4.3 Causal Loop Diagram of MSWM system ... 91
4.3.1 Waste generation module ... 91
4.3.2 Common SWM practices module ... 92
4.3.3 Source separation practices and recycling activities module ... 93
4.3.4 Waste disposal module ... 94
4.3.5 Main flows and costs module ... 95
4.4 Discussion ... 95
4.4.1 Representation of the MSWM system in Santa Cruz de la Sierra ... 95
4.4.2 GMB as a tool for MSWM ... 96
4.5 Conclusion ... 97
5. CHAPTER 5 ... 98
ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES ... 98
5.1 Introduction ... 98
5.2 Waste generation and influencing factors ... 99
5.2.1 Household generation rates ... 100
5.2.2 Waste composition ... 102
5.2.3 Factors influencing generation rates ... 103
5.3 Household solid waste management practices ... 106
5.3.1 Latent constructs in solid waste management behaviors ... 108
5.3.2 Factors affecting waste management behaviors ... 112
5.4 Informal waste picking activities ... 114
5.4.1 Characteristics of waste picking activities ... 114
5.4.2 Ethnographic findings of the waste picking activities ... 116
5.4.3 Factors affecting waste picking activities outcomes ... 116
5.5 Discussion ... 118
5.5.1 Waste generation ... 118
5.5.2 Household SWM Practices ... 121
5.5.3 Informal waste picking activities ... 123
5.6 Conclusion ... 125
6. CHAPTER 6 ... 126

SYSTEM DYNAMICS MODELLING 126
6.1 Introduction 126
6.2 Stocks and flows diagram 127
6.2.1 Household waste generation 127
6.2.2 Waste burning and dumping practices 128
6.2.3 Source separation and recycling activities 128
6.2.4 Main flows and costs 129
6.3 Simulation of Municipal Solid Waste Management system 130
6.3.1 Baseline scenario 130
6.3.2 Alternative scenarios 132
6.4 Discussion 134
6.5 Conclusion 135
7. CHAPTER 7 137
SYNTHESIS AND RESEARCH IMPLICATIONS 137
7.1 Synthesis of results 137
7.1.1 Institutional analysis and sustainability transitions of the municipal solid waste management system (Objective 1, Chapter 3) 138
7.1.2 Participatory modeling of the municipal solid waste management system (Objective 2, Chapter 4) 139
7.1.3 Assessment of municipal solid waste management practices (Objective 3, Chapter 5) 140
7.1.4 System dynamics modeling (Objective 4, Chapter 6) 143
7.2 Policy and practice implications and recommendations 146
7.2.1 Physical Dimension 146
7.2.2 Governance Dimension 147
7.3 Limitations and future research 148
REFERENCES 149
APPENDICES 174
Appendix 1: Interview protocol for stakeholders' interviews 174
Appendix 2: Waste characterization questionnaire 176

LIST OF TABLES

Table 2.1 Research methodology.......... 17
Table 2.2: List of respondents and affiliations.......... 23
Table 2.3: CLD main elements and notation.......... 29
Table 2.4: GMB Participants.......... 31
Table 2.5: GMB Agenda.......... 32
Table 2.6 Feedback from GMB session's participants.......... 33
Table 2.7: General house and neighborhood characteristics for each income stratum.......... 37
Table 2.8: Waste categories and sub-categories for characterization.......... 39
Table 2.9: Variables used in multiple linear regression.......... 42
Table 2.10: Items for latent constructs measurement.......... 47
Table 2.11: Observable variables for SEM of Household SWM Practices.......... 52
Table 2.12 Points for waste picking activities' surveys.......... 55
Table 2.13 Variables for path analysis of waste picker activities' outcomes.......... 56
Table 2.14 Stocks and flows diagram elements and notation.......... 58
Table 2.15: Variables included in stocks and flows diagram.......... 60
Table 2.16: Conditions for scenarios' simulation.......... 62
Table 3.1 Main national regulation related to Solid Waste Management.......... 65
Table 3.2: Local Solid Waste Management regulation in Santa Cruz de la Sierra.......... 66
Table 3.3: Main stakeholders in the MSWM system.......... 68
Table 3.4 Multi-level perespective of Municipal Solid Waste Management system transitions in Bolivia.......... 76
Table 3.5 Municipal Solid Waste Management System transitions.......... 76
Table 5.1: Socio-demographic characteristics of household waste generation surveys.......... 99
Table 5.2 Waste generation rates (kg/cap/day).......... 100
Table 5.3: Estimated household waste generation at the city level.......... 102
Table 5.4: Waste components across strata.......... 102
Table 5.5: Correlation analysis for selected variables.......... 105
Table 5.6 Generation rates coefficients and models fit.......... 106
Table 5.7: Socio-demographic characteristics of respondents of household SWM practices' surveys.......... 106
Table 5.8: Constructs for negative behaviors after EFA.......... 109
Table 5.9: Constructs for positive behaviors after EFA.......... 110
Table 5.10: Fit statistics of the measurement models.......... 111
Table 5.11: Composite Reliability and Convergent Validity.......... 111
Table 5.12: Effects in Negative Behaviors Model.......... 112
Table 5.13: Effects in Positive Behaviors Model.......... 113
Table 5.14: Fit statistics of the causal models.......... 113
Table 5.15: Socio-demographic characteristics of respondents of waste picking activities' surveys.......... 114
Table 5.16: Effects of variables on waste picking outcomes.......... 117
Table 5.17: Model fit statistics of path analysis of waste picking activities.......... 118
Table 7.1: Summary of main findings.......... 137

LIST OF FIGURES

Figure 1. 1 Global waste generation 2
Figure 1. 2 Transdisciplinary research process 10
Figure 1. 3 Academic contribution and originality 12
Figure 2.1: Research approach diagram 16
Figure 2.2 Santa Cruz de la Sierra city 20
Figure 2.3 Municipal Solid Waste Collection in Santa Cruz de la Sierra 21
Figure 2.4 Integrated and Sustainable Solid Waste Management Framework 25
Figure 2.5 Multi-level perspective on socio-technical transitions 25
Figure 2.6 Group Model Building Process 33
Figure 2.7: Locations of sampling areas across Santa Cruz de la Sierra 37
Figure 2.8 Procedure of the waste characterization study 40
Figure 2.9 Location of sampling areas for Household SWM Practices surveys 50
Figure 2.10 Sampling areas for waste picking activities' surveys 55
Figure 2.11: System dynamics modeling process 59
Figure 3.1 SVN of stakeholders in the MSWM system 69
Figure 3.2 Timeline of MSWM systems sustainability transitions and ISWM elements 83
Figure 4.1 Participants of the group model building workshop 90
Figure 4.2 SWOT analysis of GMB workshop 91
Figure 4.3 Waste Generation Module 92
Figure 4.4 Common MSWM Practices Module 93
Figure 4.5: Separation practices and recycling behaviors module 94
Figure 4.6 Waste disposal module 95
Figure 4.7: Main flows and costs module 95
Figure 5.1: Prevalence of solid waste management practices across socio-economic strata 100
Figure 5.2: Distribution of waste generation rates per capita for a) pooled sample; b) low income stratum; c) medium-income stratum; d) high-income stratum 101
Figure 5.3: Waste generation rates per capita across socioeconomic strata 101
Figure 5.4: Median waste composition across strata 103
Figure 5.5 Estimated waste composition of the city 103
Figure 5.6: General Neighborhood Characteristics 107
Figure 5.7: Prevalence of behaviors related to SWM practices 108
Figure 5.8: Monthly income in waste picking activities 114
Figure 5.9 Weekly recovered recyclables in waste picking activities 115
Figure 5.10 Weekly average working hours in waste picking activities 115
Figure 6.1: Stocks and Flows diagram of MSWM system 127
Figure 6.2: Household waste generation stocks and flows diagram 128
Figure 6.3Waste burning and dumping stocks and flows diagram 128
Figure 6.4 Separation and recycling stocks and flows diagram 129
Figure 6.5 Main flows and costs stocks and flows diagram 130
Figure 6.6: Baseline Waste generation and landfilling 130
Figure 6.7: Baseline waste burning and dumping 131
Figure 6.8: Baseline recyclable material availability and recovery 132
Figure 6.9: Burning rates under different scenarios 132
Figure 6.10: Dumping rates and additional collection cost under different scenarios 133
Figure 6.11: Recyclables recovery under different scenarios 133
Figure 6.12: Landfilling rate under different scenarios 134

LIST OF ABBREVIATIONS

CLD	Causal Loop Diagram
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
DGIRS	Direccion de Gestion Integral de Residuos Solidos (Integrated Solid Waste Management Direction)
EMACRUZ	Empresa Municipal de Aseo de Santa Cruz de la Sierra (Santa Cruz de la Sierra's Municipal Cleansing Enterprise)
EMDELU	Empresa Municipal de Limpieza Urbana (Municipal Enterprise of Urban Cleansing)
GMB	Group Modeling Building
IDH	Impuesto Directo a los Hidrocarburos (Hydrocarbon exploitation's Direct Tax)
ISWM	Integrated and Sustainable Solid Waste Management
LAC	Latin America and the Caribbean
MCE	Municipal Cleansing Enterprise
MLP	Multilevel Perspective on Sustainability Transitions
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NGO	Non-governmental organization
NIMBY	"Not in my backyard" syndrome
SDM	System Dynamics Modeling
SEM	Structural Equation Modeling
SFD	Stocks and Flows Diagram
SME	Small and Medium Enterprises
SVN	Stakeholder Value Network
SWM	Solid Waste Management

CHAPTER 1

INTRODUCTION

1.1 Municipal Solid Waste Management

Municipal solid waste management (MSWM) is one of the major public services in cities around the world, being the one that deals with the waste generated in the daily activities of the population (Hoornweg & Bhada-tata, 2012). In its broader definition, it includes operational activities at several stages, from the collection, transport, transfer (i.e. between different transportation means), treatment (e.g. incineration, pyrolysis), composting, recycling and disposal of waste (United Nations Environment Programme, 2005). These activities are often a local government's responsibility, representing usually the largest budgetary item, especially in developing countries. MSWM is also regarded as a significant source of employment, considering the number of jobs generated in the formal and informal sectors (Hoornweg & Bhada-tata, 2012).

Sources included in MSWM are not universally defined and depend on the regulations and practices of each city. For instance, some cities include waste generated in industrial activities as part of MSWM while others only include household waste in the definition (Kawai & Tasaki, 2016). In most cases the definition includes waste coming from households (residential waste) as well as other sources with similar characteristics, such as commercial activities and institutions (e.g. schools, offices, public buildings) (Hoornweg & Bhada-tata, 2012). While these differences in definitions make comparisons difficult, it is estimated that household waste constitutes the major source of MSW (Buenrostro, Bocco, & Cram, 2001; Kawai & Tasaki, 2016) with some authors indicating that the residential source represents around 75% of all MSW in the case of developing countries (Welivita, Wattage, & Gunawardena, 2015). On the other side for OECD countries, waste from households is estimated to account for only 24% of all waste generated in cities, with construction waste representing a larger fraction (36%) (Wilson, Rodic, Modak, et al., 2015).

Although estimating generation levels at the global scale is complicated due to data unreliability and unavailability, studies have determined a global generation of 1.3 billion ton/year in 2010 with projected amounts ranging from 2.2 to 5.9 billions by 2025 (Hoornweg & Bhada-tata, 2012; UN-Habitat, 2010b), and the generation in low- and lower-middle income countries increasing by more than 100% during that time (Figure 1. 1). When looked at a regional level, the Latin America and Caribbean (LAC) region generated in 2010 approximately 12% of the global waste, with OECD and East Asia and Pacific countries being the largest contributors (Hoornweg & Bhada-tata, 2012). More recent studies in the LAC region estimate an increase from 197 MT/year in 2014 to 244

MT/year in 2050 based solely on the urban population growth, which is considered a conservative estimate for not including the generation per capita increase due to the lack of robust data in the region (Savino, Solorzano, Quispe, & Correal, 2018) . On the other side, trends in high income countries suggest a stabilization in generation rates, which is associated to the start of a decoupling of waste from economic growth, as well as shifts in industrial sectors to emerging economies (Wilson, Rodic, Modak, et al., 2015).

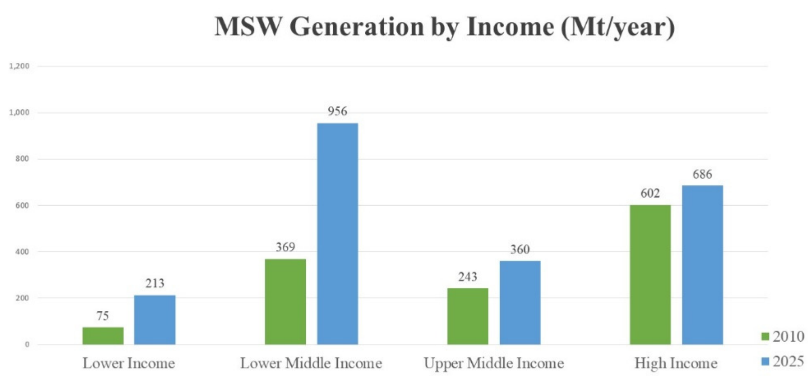


Figure 1. 1 Global waste generation

With the evolution of MSWM in industrialized countries, focus in these contexts has moved from managing waste to managing resources, by putting more emphasis on the upstream part (e.g. waste reduction, product design) as well as "closing the loop" through circular economy approaches (Bartl, 2015; Wilson, Rodic, Modak, et al., 2015). However, this change of paradigm has proven to be difficult for developing countries which are still facing important challenges regarding basic service provision (Schroeder, Anggraeni, & Weber, 2019). In this sense, since the early 21st century, researchers and practitioners have emphasized the need to look at MSWM through more integrated approaches, that consider the different aspects that play important roles in its performance beyond operational aspects (Wilson, Rodic, Modak, et al., 2015). Thus, particularly for developing countries, literature has started to emphasize the view of MSWM as a complex system with various interlinked elements and dimensions working together to perform specific functions, and with interconnected effects on each other (Marshall & Farahbakhsh, 2013; Seadon, 2010).

1.2 Municipal Solid Waste Management systems in developing cities

Although each specific context is different, overall MSWM in developing countries presents common characteristics that can be generalized to some extent. Starting from the generation stage, one of the differences in MSW between industrialized and developing countries relates to generation rates and composition. While high income countries usually present generation rates of more than 1 kg/capita/day, reaching rates around 3.5 kg/capita/day in The Bahamas and 2.3 kg/capita/day in Canada; developing countries are in general under 1 kg/capita/day generation. In this sense, smaller rates are found in Sub-Saharan Africa, as most countries present rates under 0.6 kg/capita/day, with the smallest generation at the global level found in Ghana with 0.09 kg/capita/day (Hoornweg & Bhada-tata, 2012; Kawai & Tasaki, 2016; Mmereki, Baldwin, & Li, 2016). In the case of the LAC region, developing countries present relatively higher rates surrounding 1 kg/capita/day, from cases like Guyana with a generation of 1.53 kg/capita/day to Bolivia generating 0.50 kg/capita/day (Savino et al., 2018). Regarding composition, it is considered that generally, developing countries have much larger amounts of organic fraction in their MSW, which is above 60% in low and lower-middle income countries, compared to less than 30% in high-income countries (Hoornweg & Bhada-tata, 2012; Mmereki et al., 2016).

While in most developed countries MSWM systems reached high levels of performance long before the end of the 20th century after decades of refinement (Herczeg, 2013; Kemp, 2007; Silva, Rosano, Stocker, & Gorissen, 2017), developing countries are still struggling with basic issues related to collection coverage, collection quality, and environmentally safe disposal (Brunner & Fellner, 2007; Guerrero, Maas, & Hogland, 2013; Zohoori & Ghani, 2017). Although this gap is partly related to a later start in the development of MSWM systems in developing countries, compared to industrialized ones, authors also highlight the inherent characteristics that lead to additional complexity in these contexts (Marshall & Farahbakhsh, 2013; Rodić & Wilson, 2017).

In addition to these structural shortcomings, rapidly urbanizing developing cities face additional challenges (Guerrero et al., 2013; UN-Habitat, 2010b). Economic growth and urbanization, which are the major drivers of changes in production and consumption patterns are leading to rapid increases in waste generation rates, as well as changes in its composition (Bai et al., 2017; Y. C. Chen, 2018; Hoornweg & Bhada-tata, 2012), which are surpassing the capacity of local and national governments to react to these rapid changes. While in past decades largest cities were mostly located in developed regions, at the present a majority of megacities (more than 10 million inhabitants) are located in the developing world, with low and lower-middle income countries suffering the most rapid urbanization processes until 2050 (UN-DESA, 2018). Globally, highest urbanization across regions is found in the Americas, with more than 80% of the population living in urban areas, (UN-DESA, 2018), and particularly the South American region where approximately 83% of the population live in cities (Savino et al., 2018). This urban growth, coupled with inadequate planning, has led to uncontrolled and disorganized urban growth, creating additional problems in MSWM service provision in developing cities (Onu, Surendran, & Price, 2014; Owusu, 2010). In the LAC region, these problems have been related to a variety of impacts, particularly in freshwater ecosystems and air quality through dumping and burning activities (America & Caribbean, n.d.; Savino et al., 2018).

Regarding the operational or “hard” elements (i.e. collection, disposal and resource value) of MSWM systems, lack of adequate infrastructure is a critical aspect in developing countries. For instance, poor roads’ quality, inadequate containers, and vehicles, as well as their lack of maintenance contribute to problems in the collection services provision (UN-Habitat, 2010a). Thus, collection coverage in most cases does not reach all areas of cities, and does not capture all the waste that is generated, resulting in the remaining waste being littered, illegally dumped or burned (Brunner & Fellner, 2007; Mmereki et al., 2016). Waste that is not collected influences greatly urban quality of life, as dumping and burning practices have been linked to respiratory, gastroenterological and vector transmitted diseases (Banerjee, Aditya, & Saha, 2013; Boadi & Kuitunen, 2005; Rego, Moraes, & Dourado, 2005; Reyna-Bensusan, Wilson, & Smith, 2018; UN-Habitat, 2010b); increased risk of flooding (Rodić & Wilson, 2017; Wilson, Rodic, Modak, et al., 2015); as well as landscape degradation and increased crime (Anantharaman, 2014; Guo, Hobbs, Lasater, Parker, & Winch, 2016) generating also additional costs for municipalities (Estrellan & Iino, 2010; Reyna-Bensusan et al., 2018).

Lack of adequate infrastructure in disposal activities is also a major issue, with many developing cities still conducting the disposal activities in open dumpsites, which are areas with no control or impact mitigation methods (Mmereki et al., 2016; Wilson, Rodic, Modak, et al., 2015). Moreover, some cities have landfill facilities with basic measures (e.g. leachate collection, waste compacting, regular cover, geomembrane), however due to deficient operation conditions, related impacts are not adequately mitigated (Hoornweg & Bhada-tata, 2012; Mbiba, 2014). For instance, in the LAC region, it is estimated that around 145,000 ton/day are still disposed in open dumpsites, corresponding to the waste generated by 27% of the population (Savino et al., 2018).

Regarding the waste treatment and processing options, the situation is variate. While large developing countries like China and India have implemented numerous projects involving biological (e.g. composting, anaerobic digestion, mechanic biological treatment) and thermal processing (i.e. incineration, pyrolysis, gasification) (Mmereki et al., 2016; Tan et al., 2015; Wilson, Rodic, Modak, et al., 2015), most developing countries have either not attempted to implement these alternatives, or have done it with few success (Hansen & Nygaard, 2014; Narayana, 2009; Shekdar, 2009; Vujic, Stanisavljevic, Batinic, Jurakic, & Ubavin, 2017). This is attributed to various characteristics that would make some of these technologies unsuitable for developing countries such as the high organic content and humidity; amount of waste required for facilities functioning; deficient source separation to assure processing quality; market difficulties for commercialization of recycling/composting products; high investment and operation costs; and lack of technical skills (Brunner & Rechberger, 2015; Cucchiella, D’Adamo, & Gastaldi, 2014; Kumar & Samadder, 2017). In the LAC region, there is no register of thermal processing facilities, with various feasibility studies having found various economic barriers for their implementation. In the case of biological treatments, few projects have been recently implemented in Mexico, Argentina, Brazil and Costa Rica (Savino et al., 2018).

Recycling activities are another aspect that presents significant particularities in low and lower-middle income countries. Overall, recycling rates in these contexts are much lower than in industrialized countries (Mmereki et al., 2016; Wilson, Rodic, Modak, et al., 2015), with recycling rates below 5% in most cases where this information is available (Wilson, Rodic, Modak, et al., 2015). For instance, in the LAC region, this rates have been estimated at approximately 2% of all MSW (IADB, 2015). In this sense, while recycling in developed countries is driven by environmental concerns, and implemented through governmental plans, requiring additional public expenditure and increase responsibility from the waste generators in the source separation (UN-Habitat, 2010a); in developing countries the activity's main driver is the need for income generation for poor segments of society working in the informal sector (Fahmi & Sutton, 2010; Majeed, Batool, & Chaudhry, 2017; Marshall & Farahbakhsh, 2013). This sector, which is in many cases composed mainly by homeless, immigrants, elderly people, and other marginalized groups, are often the main supplier of recyclable material for industries in most of these cities (Wilson, Velis, & Cheeseman, 2006). Moreover, although the advances in this sector have increased recycling activities across some developing countries, achieving recyclable rates up to 20-40% (Wilson, Araba, Chinwah, & Cheeseman, 2009; Wilson, Rodic, Modak, et al., 2015) various conflicts and difficulties in their inclusion in formal MSWM systems have become an important challenge for governments in these contexts (Ezeah, Fazakerley, & Roberts, 2013; Wilson et al., 2009).

Regarding the governance or "soft" components of MSWM (i.e. inclusivity, financial sustainability and sound institutions/policies) various authors consider these aspects critical for sustainability of MSWM in developing regions (Hettiarachchi, Ryu, Caucci, & Silva, 2018; Rodić & Wilson, 2017). In many of these countries, direct regulation about MSWM is inexistent or not adequately implemented, and often "copied" from foreign policies without adapting them to the national/local context (Onibokun, 1999; UN-Habitat, 2010b). Additionally, it is common that most of the responsibilities falling on municipal governments without clear guidelines or budget allocation from national governments (Bhuiyan, 2010). In that sense, governmental power is often too limited for appropriate regulation enforcement, with additional challenges related to corruption and lack of continuity of technical officials due to political involvement in their designation (Hettiarachchi et al., 2018; Hoornweg & Gianelli, 2007). Indeed, political aspects have been found to be of major relevance for MSWM (Bhuiyan, 2010; Ezeah & Roberts, 2014; Marshall & Farahbakhsh, 2013; Mmereki et al., 2016), with the LAC region not being an exemption (Guibrunet, Sanzana Calvet, & Castán Broto, 2017; Lozano Lazo & Gasparatos, 2019; Savino et al., 2018). One of this aspects is related to the governmental structure, which in the LAC region is unitary, with few cases of federal states (i.e. Argentina, Brazil, Mexico and Venezuela). In this regard, while decentralization of power is considered to offer benefits related to more localized MSWM solutions and less institutional bureaucracy for policy implementation and financing decisions; overlapping and voids in competences are a challenging aspect. On the other side, unitary governments seem to provide more consistency in the design of regulations and institutions, but with higher risk of ineffective or uneven implementation due to differences across cities (Savino et al., 2018).

As other major public services, the implementation and operation of MSWM in developing countries requires substantial amounts of funds that are usually not available, or only provided for a limited time by international cooperation programs (Marshall & Farahbakhsh, 2013; Mmereki et al., 2016). While many developed countries have advanced in the implementation of "Extended Producer Responsibility" approaches (Marshall & Farahbakhsh, 2013), aiming to apply the polluter-pays principle to producers for the end of life of their products, in developing countries these duties are still assumed completely by governments (Gupt & Sahay, 2015). In this sense, MSWM often represents the largest budgetary item for local governments, especially in lower income cities, where it is usually heavily subsidized (Besen & Fracalanza, 2016; Hoornweg & Bhada-tata, 2012; Zohoori & Ghani, 2017). Moreover, in rapidly urbanizing cities, communities are not used to pay for the service, or pay small fees that do not cover sufficiently the continuous increase in costs due to progressively larger amounts of waste generation, generating deficits and contributing to the defective quality of services (Hettiarachchi et al., 2018; Lohri, Camenzind, & Zurbrügg, 2014; UN-Habitat, 2010a).

Given the number of stakeholders involved in the MSWM system, with various interests and often conflicting agendas, their inclusion in the system's governance is considered to be critical for sustainability (Rodić & Wilson, 2017; Wilson, Rodic, Modak, et al., 2015). However, developing countries often lack the necessary structures to enable this inclusion (i.e. independent research institutions, public participation mechanisms, transparent information on public activities) (Marshall & Farahbakhsh, 2013; Savino et al., 2018). Moreover, often governments are not interested in promoting these mechanisms in an attempt to control decision-making processes due to political vested interests (Bhuiyan, 2010; Hettiarachchi et al., 2018).

The unawareness of these factors by donors and international organizations has been considered one of the causes for the ineffectiveness of cooperation efforts in the past, which until recently were predominantly focused on the provision of "hard measures" (e.g. machinery, equipment, facilities) or "soft measures" related to organizational and planning aspects. However, this approach has been gradually shifting to a focus on “capacity development” which entails the need of endogenous change in the MSWM system in three levels: individuals, organizations, and society as a whole. According to some international cooperation agencies, this would be achieved through a systematic understanding of the background factors of MSWM issues, and a larger emphasis on the social aspects of the cooperation recipient (JICA, 2005).

1.3 Critical aspects of Municipal Solid Waste Management sustainability

As the impacts of deficient MSWM systems in developing countries have become more evident, MSWM has started to be considered a “basic human right” (Wilson, Rodic, Modak, et al., 2015), creating a growing pressure to improve the quality of the service for cities in the developing world. Being a cross-cutting issue for the achievement of the Sustainable Development Goals (SDGs), MSWM is linked to at least 12 of the 17 SDGs (Rodić & Wilson, 2017; Wilson, Rodic, Modak, et al., 2015). Some of the most pertinent priorities for developing countries relate to SDG6: “Water and Sanitation”, SDG8: “Decent Work and Economic Growth”, SDG11: “Sustainable Cities and Communities” and SDGl2: “Sustainable Production and Consumption” (Besen & Fracalanza, 2016; Elagroudy, Warith, & El Zayat, 2016; Rodić & Wilson, 2017). For instance, for SDG6, the link is direct through Target 6.3 related to the elimination of solid waste dumping (United Nations Statistics Division UNSTATS, 2019). For SDG8, many studies have suggested that circular economy approaches to solid waste management can contribute to the growth of small businesses, the generation of green jobs, and the improvement of working conditions for informal waste pickers (Besen & Fracalanza, 2016; Schroeder et al., 2019; World Business Council for Sustainable Development WBCSD, 2017). The link to SDG11 is through Indicator 11.6.1 regarding waste collection coverage to reduce environmental effects in cities (United Nations Statistics Division UNSTATS, 2019). Likewise, the link to SDG12 is through Targets 12.2–12.5 (United Nations Statistics Division UNSTATS, 2019).

As a response to the challenges of MSWM in developing countries, and the growing global pressure to achieve radical improvements in their sustainability in these contexts, MSWM paradigms have been evolving over time, moving first to “integrated” approaches (Klunder & Anschütz, 2001) and more recently incorporating the sustainability perspective (Agamuthu, Khidzir, & Hamid, 2009; Ezeah & Roberts, 2012; Shekdar, 2009). One of the main focus for the sustainability of MSWM has traditionally been the reduction of amounts of material flows to the environment, and its contribution to the reduction of natural resources consumed in recycling activities (Seadon, 2010; Williams, 2015) through concepts such as 3Rs and Zero Waste (Memon, 2010; Zaman, 2014), and more recently circular economy and green economy (Cobo, Dominguez-Ramos, & Irabien, 2018; Elagroudy et al., 2016).

A dominant paradigm for sustainability in MSWM developed at the end of the 20th century, continues to be the "Integrated and Sustainable Solid Waste Management Framework" (ISWM) (Guerrero et al., 2013; Klunder & Anschütz, 2001). ISWM advocates the focus on two dimensions (i.e. physical and governance) with six main components (i.e. public health; environment; resource value; user and provider inclusivity; financial sustainability; and institutions and policies) as the aspects to look at in order to achieve environmentally sound, economically feasible and socially acceptable waste management (Morrissey & Browne, 2004; Wilson, Rodic, Cowing, et al., 2015).

Despite the popularity of the ISWM framework in establishing certain indicators as the "goals" or "ideal" state regarding sustainability of MSWM systems, a pending issue is in the "how" to achieve these outcomes or how to conduct these processes (Taelman, Tonini, Wandl, & Dewulf, 2018), particularly for the context of developing countries (Marshall & Farahbakhsh, 2013). Some authors claim that reductionist approaches for MSWM have failed and contributed poorly to planning and decision making by focusing, for instance, only on specific stages (e.g. generation, recycling, disposal) or specific waste types (e.g. organic, plastic, e-waste), ignoring the inter-dependencies among these elements (Dijkema, Reuter, & Verhoef, 2000; Marshall & Farahbakhsh, 2013). Other authors have pointed out to the lack of understanding of side effects of interventions, their mechanisms, and long term effects (Seadon, 2010), while others have highlighted the epistemological challenges of assessing and solving problems that involve different dimensions, scales of analysis, and divergent views from the relevant stakeholders (Chifari, Lo Piano, Bukkens, & Giampietro, 2016; Morrissey & Browne, 2004). In this sense, post-normal science, transdisciplinarity, complex adaptive thinking and systems thinking are some of the paradigms that have started to contribute with different perspectives to solid waste management studies (Marshall & Farahbakhsh, 2013; Seadon, 2010). Post-normal science highlights the limitation of traditional approaches in dealing with high levels of uncertainty and conflicting views from stakeholders about "ideal solutions", as well as the need to create localized and context-specific "meta-narratives", considering the historical perspectives from all stakeholders and their changes over time (Marshall & Farahbakhsh, 2013; Ravetz, 2006). Systems thinking conceptualizes problems with a focus on relationships and patterns, which allows to identify the best ways to effect changes in the system, as well as the trade-offs that different solutions would provide (Marshall & Farahbakhsh, 2013; Seadon, 2010). However, "hard" systems thinking has been considered to be more appropriate for "well-defined" problems in physical systems, while "soft" systems thinking is deemed more appropriate for human activities, providing flexibility in the analysis of chaotic contexts where the social and cultural dimensions are relevant (C.T. Agnew, 1984; Featherston & Doolan, 2012; Marshall & Farahbakhsh, 2013). In that sense, approaches such as system dynamics modeling have been considered to be somewhat in the middle of these two extremes in systems thinking (Featherston & Doolan, 2012; Lane, 2000).

Although the importance of holistic and systemic approaches in MSWM research has been recognized, still relatively few attempts to apply these concepts have been found, even in the context of developed countries, with some examples taking place mainly in Europe and Asia (Chang, Pires, & Martinho, 2011; Chong, Teo, & Tang, 2016; Khalili & Duecker, 2013; Marshall & Farahbakhsh, 2013; Taelman et al., 2018; Turnheim et al., 2015). Moreover, in most cases these systemic approaches still focus predominantly in economic and environmental aspects, neglecting the social dimension (Chang et al., 2011; Morrissey & Browne, 2004), which is considered to be essential in the context of developing countries (Rodić & Wilson, 2017; Zohoori & Ghani, 2017).

1.4 Transdisciplinary research approaches to Municipal Solid Waste Management sustainability

As mentioned in the previous section, transdisciplinarity is one of the approaches that has been applied to sustainability research in a variety of fields, including MSWM in recent years. It advocates for a high integration of knowledge across discipline’s boundaries and the involvement of academic and diverse actors in the stages of the research process, in an attempt to solve real-world problems and bridge science and policy (Mauser et al., 2013; Pohl, 2008; van der Hel, 2016). Furthermore, transdisciplinarity specifically addresses the importance to count with the engagement of non-academic actors (Akpo, Crane, Vissoh, & Tossou, 2015; Page et al., 2016) in the different stages of the research process (i.e. co-design, co-production, co-dissemination) in order to capture different perspectives and worldviews about the topic being analyzed (Mauser et al., 2013; Rosenberg Daneri, Trencher, & Petersen, 2015) as a key aspect of sustainability science approaches.

A broadly used depiction of the transdisciplinary research process is the one introduced by Jahn and later complemented by other authors (Bergmann Matthias, Jahn Thomas, Knobloch Tobias, Krohn Wolfgag, Pohl Christian, 2012) (Figure 1. 2). According to it, transdisciplinary approaches aim to combine real-world and science focused research, in a way that the research object is driven by the societal problems and constrained by the scientific issues in the approaches and methodologies that are intended to be used. This problem-framing stage, which in this case is denominated “co-design” is conducted through the involvement and interaction of the academic and non-academic actors. In the process of “co-production” of knowledge, the research is conducted through a continuous interaction and feedback among the researchers and stakeholders, using methodologies from different disciplines and integrating the results which would serve both for societal and scientific practice.

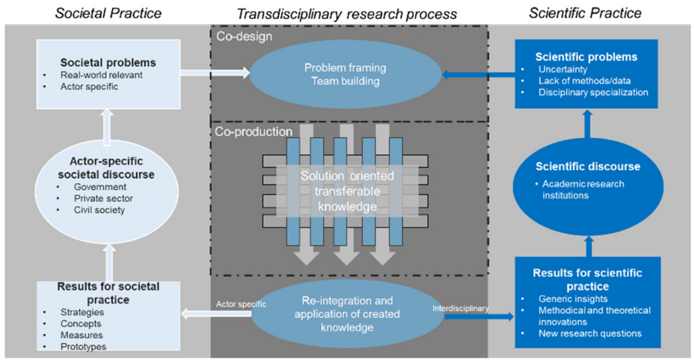


Figure 1. 2 Transdisciplinary research process
Adapted from Lang et al (2012), Bergman et al (2012)

Transdisciplinarity for sustainability is still relatively less used in research about MSWM systems, in comparison to other fields such as built environment and energy systems (Trencher, Bai, Evans, McCormick, & Yarime, 2014). Regarding the few studies using transdisciplinary approaches for MSWM systems, most research has a predominant focus on the co-production aspect (Gonçalves, Gomes, Ezequiel, Moreira, & Loupa-Ramos, 2017; Meylan, Lai, Hensley, Stauffacher, & Krütli, 2018; Pohl, 2008), particularly for the implementation of composting, recycling and energy recovery projects (Danish et al., 2019; Kelly, Mulgan, & Muers, 2002; Seravalli, 2016; Stephanie Von Der Heyde, 2014), or site selection for disposal sites (Lang et al., 2012) . Again, in all cases identified these studies have been conducted in developed countries (Gonçalves et al., 2017; Kelly et al., 2002; Lang et al., 2012; Pohl, 2008; Seravalli, Agger Eriksen, & Hillgren, 2017), or in developing countries by foreign researchers (Meylan et al., 2018; Stephanie Von Der Heyde, 2014), which has been pointed out as a challenging aspect due to issues related to trust building with the communities and lack of understanding of local contexts (Chammas et al., 2020; Goven, Langer, Baker, Ataria, & Leckie, 2015).

1.5 Research gaps

As showed in previous sections, the road to sustainability for MSWM in developing countries faces a variety of barriers, which are essentially different than the current or past conditions in developed countries. While research on specific aspects of MSWM with disciplinary approaches (e.g. engineering, environmental) is extensive, there are still important research gaps from a sustainability science point of view, especially in the context of developing countries.

Particularly, this research aims to touch upon two specific research gaps. The first one is related to the contribution of systems-based approaches in research about MSWM in developing countries, as a mean to grasp the increased complexity in these contexts. The second gap is related to the lack of focus on the social dimension of MSWM, in contexts where the approach towards the topic continues to be predominantly on infrastructure and engineering aspects.

In relation to the first gap, as mentioned in Section 1.3, application of systems approaches for MSWM research in developing countries is still in an incipient stage (Marshall & Farahbakhsh, 2013; Turnheim et al., 2015). Authors have cited the lack of awareness of local stakeholders about the existence of these approaches, as well as lack of reliable data to be used in "hard" systems thinking techniques, as some of the possible causes (Marshall & Farahbakhsh, 2013; Meylan et al., 2018).

Regarding the second gap, various recent studies have focused on the importance of the social dimension of MSWM systems in developing countries, (J. Ma & Hipel, 2016; Rodić & Wilson, 2017; Zohoori & Ghani, 2017), due to issues such as the ones mentioned in Section 1.2. Despite this importance, the social component has been neglected both for studies with systemic approaches (Section 1.3) as well as for restricted ones. In the latter case, the focus seems to have been predominantly in public participation, with a smaller focus in other aspects such as policies, behaviors and vulnerability. A majority of these studies have taken place in the Asia and Europe regions (J. Ma & Hipel, 2016).

Lastly, while these gaps apply generally for developing countries, they are more marked in the context of low income countries (Zohoori & Ghani, 2017), the Latin American region (J. Ma, Hipel, Hanson, Cai, & Liu, 2018; Vitorino de Souza Melaré, Montenegro González, Faceli, & Casadei, 2017; Wieczorek, 2018) and smaller countries like Bolivia, where research on MSWM systems is practically inexistent.

1.6 Aims and objectives

In order to address the research gaps presented in Section 1.5, this study aims to analyze the MSWM in Santa Cruz de la Sierra, a rapidly urbanizing city of Bolivia, from a transdisciplinary and system-based perspective, in order to explore pathways influencing its sustainability. The specific objectives include to:

1) Understand the institutional context at the local and national levels, and unravel the sustainability transitions of MSWM system in the city;

2) Identify the variables and inter-linkages corresponding to the main sustainability impacts of the MSWM system in the city;

3) Determine the mechanisms and assess the main sustainability impacts of the current MSWM practices;

4) Explore the outcomes of the MSWM system under different scenarios of adoption of sustainable practices

As the aim of the research indicates, the focus of the analysis of this thesis is to understand the current MSWM system in Santa Cruz de la Sierra, rather than designing a specific solution. In that sense, the pathways that will be explored correspond to various aspects/factors that influence the sustainability of the MSWM system at different levels according to the findings of each objective. Therefore, the understanding of the different dimensions of the system represents a first step of a transdisciplinary and iterative process that is expected to allow relevant stakeholders and particularly, the local government, to improve planning and policy design activities.

1.7 Originality and academic contribution

This research aims to contribute to the academic field of sustainability science, through the application of a holistic and transdisciplinary approach to analyze the sustainability in the municipal solid waste management in a rapidly urbanizing city of the developing world. In this sense, the research design has followed the transdisciplinary research process through an early involvement of a variety of stakeholders not only in the co-production of knowledge but more importantly, in the co-design of the research through a variety of participatory tools and mixed-methods (Figure 1. 3). Although all objectives had some elements of co-design and co-production activities, for the research as a whole, Objective 1 and 2 are more related to the co-design aspect, while Objectives 3 and 4 are more related to co-production aspects.

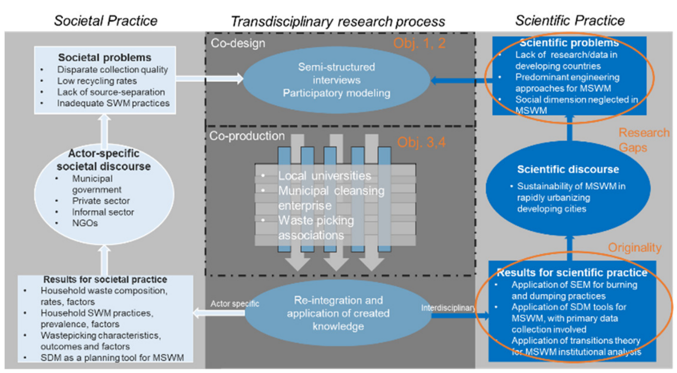


Figure 1. 1 Academic contribution and originality

In this sense, the institutional analysis through the extensive amount of interviews conducted at the local and national level with stakeholders from the formal and informal sectors (Section 2.3.1) provided a comprehensive and broad view of the system (Chapter 3), considering also the spatial and temporal perspectives – which are central elements that have been neglected in other studies (Section 1.3) – with the focus on the "evolution" or transitions in the system (Section 3.4). The choice of the "soft" system based approach, and specifically the participatory modeling of causal loop diagrams (Section 2.3.2, Chapter 4) further contributed to the co-design aspect, by guiding, through the direct input of relevant stakeholders, the selection of specific issues to be included in the assessment of relevant practices.

The co-production of knowledge is achieved through the close involvement of local universities, municipal cleansing enterprise, and informal waste picking associations in the activities conducted for the assessment of MSWM practices (Section 2.3.3, Chapter 5), ass and the future outcomes exploration through the stocks and flows diagram (Section 2.3.4, Chapter 6).

The main originality of the research is in the combination of quantitative and qualitative tools and methods that have been rarely applied for the study of MSWM. In this sense, a first aspect is related to the use of transition theories to discuss the evolution of MSWM in the specific case study, reflecting on factors at a macro-level, stages, and future directions of the different transitions (Section 2.3.1). Regarding the practices' assessment (Section 2.3.3), while SEM is one of the preferred tools for behavioral studies, it has been rarely applied for MSWM and, to the best of our knowledge, has not been applied for behaviors related to burning and dumping practices. Lastly, the use of SDM tools with a participatory approach and primary data collection to improve the outcomes, is another aspect that contributes to the originality of this work.

Nevertheless, it is important to highlight that the research has focused on a rapidly urbanizing city of Bolivia, a small country (in terms of population) in the Latin American region, with particularities regarding its socio-demographic characteristics, politics and history, and socio-economic context. While the global impact of the specific case in a quantitative aspect is not comparable to larger cities in other regions, the combination of characteristics of the local, national and regional (continental) level provides relevance to the case study, with interesting insights in terms of the connections between solid waste management and other elements that are usually overlooked (Section 3.5).

1.8 Thesis structure

The thesis is structured in seven main chapters, including this Introduction. Chapter 1 presented the main general concepts and framed the thesis. As a first step, it highlights the main aspects of MSWM systems and their particular characteristics in developing countries (Sections 1.1, 1.2). Subsequently, it discusses the critical aspects of sustainability in MSWM systems, emphasizing the role of system-based approaches and transdisciplinarity as some of the key elements in the research on MSWM systems in developing countries (Sections 1.3 – 1.5).

Chapter 2 introduces the research approach, the study area and the methods used for the data collection and analysis. More specifically, Section 2.2 explains the main characteristics of Bolivia, Santa Cruz de la Sierra and its recent development, as well as the general aspects of the municipal solid waste management system. Section 2.3 describes in detail the different data collection and analysis methods for the institutional analysis, participatory modeling, waste generation study, household surveys, waste picking activity's surveys and system dynamics modeling. Some of the most relevant methods include qualitative coding, waste characterization, descriptive statistics and statistical tests, multilinear regressions, factor analysis, structural equation modeling, and software simulation.

Chapter 3 presents the institutional analysis, which includes the main national and local municipal solid waste management regulations (Section 3.2), the stakeholders responsibilities and relationships (Section 3.3) and the sustainability transitions in the municipal solid waste management system in the last decades (Section 3.4).

Chapter 4 explains the participatory modeling process conducted to map the main elements of the municipal solid waste management system (Section 4.2) and presents the different parts of the causal loop diagram resulting of this process (Section 4.3).

Chapter 5 assesses the practices identified as the ones with main impacts in the municipal solid waste management system. First, household waste generation is assessed (Section 5.2), by determining the generation rates and waste composition across income strata (Section 5.2.1 - 5.2.2), as well as the factors influencing generation rates (Section 5.2.3). Subsequently, Section 5.3 assess various household solid waste management practices, by exploring factors that could influence in the prevalence of behaviors determining these practices (Section 5.3.1) and estimating the influence of these factors on each of the behaviors (Section 5.3.2). Finally, the informal waste picking activities are assessed (Section 5.4) determining the main socio-demographic characteristics of the respondents and characteristics of the activity (Section 5.4.1) and estimating the influence of key aspects as factors determining the outcomes obtained by the respondents in their activities (Section 5.4.3).

Chapter 6 presents the system dynamics modeling of the main variables of the system. Section 6.2 presents the stocks and flows diagram based on the causal loop diagram created in Chapter 4 and the results of the studies conducted in Chapter 5, and Section 6.3 presents the simulation results for key variables for a baseline scenario and a few alternative scenarios.

Chapter 7 synthesizes the main findings across the different chapters and objectives (Section 7.1). Subsequently, Section 7.2 provides the main policy/practice implications based on the findings. Finally, the chapter finishes by identifying the main the main limitations and suggestions for future research are presented in Section 7.3

CHAPTER 2

METHODOLOGY

2.1 Research approach

Rapidly urbanizing cities in developing countries are experiencing changes that affect various areas of municipal solid waste management systems, putting additional pressure on systems that had an original deficient performance, and various socio-economic-political aspects adding increased complexity. In that sense, in the search for sustainability, there is a need to conduct research with system-based and transdisciplinary approaches that allow to have a holistic understanding of the system, and of its elements' interlinkages, for better policy design and decision making.

The transdisciplinary approach requires the involvement of stakeholders from early stages of the research for the co-design and co-production stages in the research process, which poses the need to choose appropriate methodologies for this involvement. On the other side, lack of official data and uncertainties, which are characteristic of these contexts require approaches that combine "hard science" techniques with the flexibility of social sciences.

The selected case study portraits the sustainability challenges experienced by rapidly urbanizing cities in the developing world, and specifically lower-middle-income countries. As Section 2.2.1 shows, Bolivia displays particular characteristics that are useful to discuss broad socio-political-economic aspects influencing MSWM that are usually overlooked in studies in the field. On the other side, within the context of the country, Santa Cruz de la Sierra is the city that best represents the urbanizing transitions occurring in countries like Bolivia with particularities regarding its geography and urban planning characteristics (Section 2.2.2). Methodologies applied and insights obtained from this case study can be of interest of other cities in the LAC region or countries/cities of similar size and urbanization processes.

Figure 2.1 illustrates the research approach of the thesis, showing the connection among the objectives as well as the stages where main elements related to co-design and co-production can be found. Following a funnel approach, going from broad to specific aspects, the research starts with the institutional and transitions analysis (Obj. 1, providing a broad overview of the main barriers for the sustainability of the MSWM system, the impacts of current practices, and the mechanisms involved was obtained. This objective confirmed the notion of complexity in the MSWM system that was identified in the general literature review about developing countries, posing the need to select a methodology that allowed to identify the main mechanisms of sustainable and unsustainable practices throughout the system. Additionally, it was important that this tool allowed to include both quantitative and qualitative variables; as well as the possibility to explore future outcomes through software simulation, to consider the temporal aspect. Hence, system dynamics modeling tools were chosen to model the variables in the MSWM system in Santa Cruz de la Sierra (Obj. 2), first in a qualitative way through the causal loop diagrams (CLD), and subsequently in a quantitative way through the stocks and flows diagrams and software simulation.

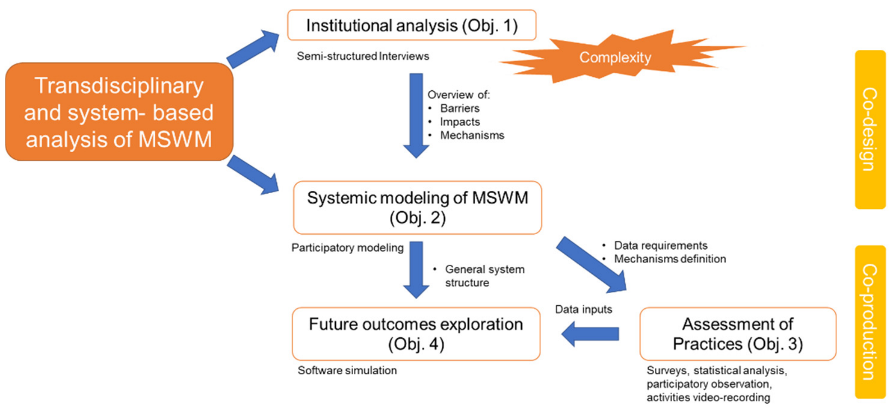


Figure 2.1: Research approach diagram

While originally a first draft of the CLD was built independently, based on the knowledge gained in Obj. 1 and a literature review of the use SDM in the SWM field, a need of more in-depth information from various stakeholders about impact mechanisms was perceived. Moreover, due to the various stakeholders involved, and the somewhat conflicting views that were identified in Obj. 1, a participatory tool which allowed to have all the participants interacting during the creation of the CLD was deemed more appropriate, leading to the selection of the group modeling building (GMB) technique. Objective 2 identified the main variables and inter-linkages involved in MSWM current practices, identifying the main sustainable and unsustainable practices for household solid waste, however, the quantitative modeling (Obj. 4) required more specific data which was not available through secondary sources. Furthermore, having modeled the system only through stakeholders' perceptions, it was important to contrast and complement the mechanisms identified, with information resulting from empirical data. Therefore, three studies to assess specific SWM practices (Obj. 3) were conducted regarding household waste generation, household SWM practices, and informal waste picking activities.

Results from Obj. 3 were used to modify/complement the mechanisms found in Obj. 2 and populate some of the main variables used in the stocks and flows diagram created for Obj. 4. Finally, Obj. 4, was used to explore some of the future outcomes under the current practices and alternative scenarios based on the variables that were identified as influencing factors in Obj. 3.

A summary of the methods used in the research is presented in Table 2.1

Table 2.1 Research methodology

Obj.	Focus	Input	Analysis/Data processing	Output
1	Institutional analysis and sustainability transitions	• Policy documents and statistics review • Stakeholders interviews	• Thematic analysis • Multi-level perspective on socio-technical transitions • Integrated and Sustainable SWM Framework	• Stakeholders' roles and interactions • MSWM transitions, challenges and enablers
2	System elements and interlinkages	• Results Obj. 1 • Lit. review on SDM for MSWM • Workshop with stakeholders	• Group Model Building	• Causal Loop Diagram of MSWM system in Santa Cruz de la Sierra
3	Household waste generation characteristics	• Household waste sampling and separation • Household surveys	• Descriptive statistics • Correlations • Multi-linear regression	• Waste generation rate • Waste components • Factors influencing generation rates
	Household SWM practices	• Participatory observation of collection activities • Household surveys	• Descriptive statistics • Structural Equation Modeling	• Prevalence of positive and negative behaviors • Factors influencing behaviors
	Informal waste picking activities	• Participatory observation of waste picking activities • Self-video-recording of waste picking activities • Surveys with informal waste pickers	• Descriptive statistics • Path analysis	• Characteristics of waste picking activities • Factors influencing informal waste picking outcomes
4	System current and future outcomes	• Results Obj. 2, 3 • Secondary data	• System dynamics modeling techniques	• Stocks and flows diagrams • Simulation for baseline and alternative scenarios

2.2 Study site

2.2.1 General characteristics of Bolivia

Bolivia is a lower middle-income country located in the center of South America. It has a relatively large geographical extent (1 million km^2) and a population of around 11 million people. Society is composed by around 40% of inhabitants who identify themselves as part of one of the indigenous people in the country, and a majority of "mestizo" (mixed race) people, who do not identify with any of these groups (World Bank, 2015). In spite of its abundant natural resources, the country's economic development has been rather slow (Frankel, 2010), having some of the lowest human development indicators in the LAC region (UNDP, 2018) and the lowest GDP per capita in South America, only after Venezuela (World Bank, 2017).

Having a long history of an economy based on extractivist activities since the time of the Spanish colony, in recent decades the country has been shifting from minerals to fossil fuels exploitation and large-scale agricultural production, although still relies mostly on the first two (Kohl & Farthing, 2012). A relatively stable political context and extremely favorable international prices for raw materials exports in the early 2000s resulted in remarkable economic growth, poverty reduction and improvements in health and education services, especially in rural areas (Johnson, 2010; Kohl & Farthing, 2012). These changes influenced consumption and production patterns in the country and contributed to an improvement in people's quality of life (UNDP, 2015) . However, this economic growth is fragile as it still continues to be based on fossil fuel exploitation rather than the industrial or service sectors (Kohl & Farthing, 2012), and an enormous informal sector (around 60% of the GDP) which is considered by the IMF as the largest in the world in relation to national GDP (Medina & Schneider, 2018).

Bolivia consists of nine administrative divisions (departments) divided in 341 municipalities. The country has experienced a massive migration from rural areas to urban centers which peaked in the 1980s, and remains among the highest in Latin America (2% annual urban population growth) (World Bank, 2019b). Approximately 70% of the national population currently lives in cities (World Bank, 2019a), with 40% concentrated in the five larger municipalities (UN-DESA, 2015).

As most countries in Latin America, Bolivia has a unitary political system, with three main levels of government (i.e. national, departmental, and municipal). After having a very centralized government approach for various decades, since 1994 there have been progressive attempts to increase decentralization in the country and provide more autonomy to municipal regions (J. P. Faguet, 2004). While this process is expected to reduce the gap between society and government, by transferring most of decision-making to the lower governmental level, in Bolivia as in the rest of the LAC region, there is evidence of a lack of clearly division of responsibilities across levels (Nijenhuis, 2002). Regarding the financial aspect of decentralization, currently, municipalities receive approximately 20% of the national taxes, plus revenues related to hydrocarbons exploitation, allocated on a population basis and poverty levels. Additionally, municipalities are also entitled to collect municipal taxes on items such as real states, vehicles and related transactions (L. E. Andersen & Jemio, 2016). This has led to large shifts in the distribution and utilization of public resources, allowing local governments to spend more on various sectors such urban development, education and sanitation. (J. P. Faguet, 2004; Nijenhuis, 2002). While the hydrocarbon revenues represent a large share of the increase in municipal funds, due to misinterpretations of the regulation, and fear of legal consequences, many municipalities did not make use of these resources for waste management activities (Ministerio de Medio Ambiente y Agua, 2011a) until 2015 when the "ISWM Law" (Section 3.2.1) indicated this possibility explicitly. Furthermore, these funds are expected to reduce in following years due to the sharp decreases in international oil prices, questioning the availability and reliability of these funds (L. E. Andersen & Jemio, 2016).

Related to the governmental structures is also the political aspect. Political fragility has been a constant throughout Bolivian history, as the country has experienced the most military coups in Latin America (Lehoucq & Pérez-Liñán, 2014). Following popular revolts in 2003 the then president resigned, and the country experienced a period of political stability (Kohl & Bresnahan, 2010). However, this stability was also characterized by the hegemony of the president's political party in the national government (J. Faguet & Faguet, 2018). The scenario of political fragility returned once again to the country after the alleged fraud by the national government party in October 2019 elections, after which the former 15-years government was overthrown by popular revolts and a transitional government established until present days (Crabtree, 2020).

2.2.2 Characteristics and recent development of Santa Cruz de la Sierra

Santa Cruz de la Sierra is located in the eastern side of Bolivia, in an area of tropical lowlands, just around 400 meters above the sea level. Capital of Santa Cruz department, it is the largest and most populous city in the country. It is also the most economically prosperous, and as a consequence, the one with the highest MSW generation in the country (around 1800 ton/day) (INE, 2020). Since the founding of Bolivia, Santa Cruz remained isolated from national development plans, until the 1950s, when the city had an approximately population of 40,000 inhabitants (J. D. Kirshner & Traverso, 2009). From that point due to strategies related to fossil fuels exploitation and commercial agriculture, the city received an important inflow of foreign and domestic migrants, surpassing the 1 million inhabitants before the end of the 90s decade (UNDP, 2015) and having currently an approximate population of 1.7 million inhabitants (INE, 2012) without including the population from other areas in the metropolitan region. Considered as the center of Bolivia's modernization and progress, the city is characterized by a strong role of the private sector, concentrating the major activities in the energy, technology, and business sectors. However, this rapid development and economic flourishment has also posed a variety of urban challenges for the city (Vargas & Apaza, 2015).

Santa Cruz de la Sierra had an original urban plan of concentric rings with specific land uses, based on Howard's garden city model. However, these plans were rapidly outpaced by the uncontrolled growth in the 1980s (Figure 2.2) , creating areas in the outskirts of the city with chaotic landscapes which produced difficult conditions for public services provision in those areas (J. D. Kirshner, 2013). Influenced partly by the geography of the area, and the cultural preferences of the population, the city has had a predominantly horizontal urban development (Green, 1988). While dwelling in vertical housing is increasing in recent years, it is estimated that still less than 3% of the population lives in apartments, being houses the widely preferred option (INE, 2018).

From the start of its urban development, Santa Cruz de la Sierra's local authorities envisioned its potential as an industrial city, hosting the first industrial park in the country. This development attracted national industries, creating an adequate environment for the flourishment of recycling activities. While the city development contributed to the improvement of the quality of life for a large part of the population, many of the recent migrants from other areas of the country have not been able to access to adequate housing, leading to illegal settlements. Moreover, the excessive supply of labor force since the start of the development of the city, has contributed to a lack of formal employment opportunities for many of the newcomers, which ended up dedicating to various informal activities in many cases. (Seleme Antelo, Prado Salmon, Prado Zanini, & Ledo Garcia, 2006).

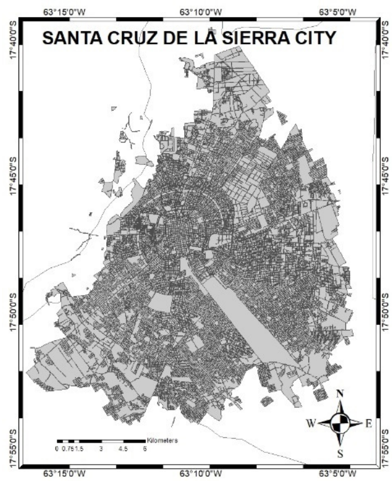


Figure 2.1 Santa Cruz de la Sierra city

2.2.3 Municipal Solid Waste Management system of Santa Cruz de la Sierra

MSWM, as a public service, is provided in Santa Cruz de la Sierra to local residents, in exchange for monthly fees paid to the municipality through the electricity bill since the 1990s decade, based on criteria such as location and electricity consumption (PAHO, 2002). As most of the other large cities in Bolivia (>500,000 inhabitants) Santa Cruz de la Sierra has established a system that delegates MSWM responsibilities to autonomous or semi-autonomous organizations under the municipal government called "Municipal Cleansing Enterprises" (MCE) in charge of planning, contracting, supervising, and monitoring the activities of private cleansing companies. While the MCEs can conduct the operational activities by themselves, they usually subcontract one or more large private companies specialized in solid waste management, to undertake waste collection and landfilling. In the case of Santa Cruz de la Sierra, the MCE, called EMACRUZ, has traditionally had the approach to contract one company for both the collection and landfilling services (Ministerio de Medio Ambiente y Agua, 2011b).

Most of the municipal waste is generated by households, representing more than 70% of the total municipal solid waste (Ministerio de Medio Ambiente y Agua, 2011a). The other 30% is composed by waste coming from commercial activities, offices, hospitals, farmer markets and public spaces. While statistics about waste generation are practically inexistent, aggregated information about collection amounts is publicly available since 2005 (INE, 2017). This data shows a current MSWM collection of approximately 672,341 ton/year for the city in 2019, which represents more than 100% increase since the start of the reporting data (Figure 2.3). The city has an environmentally controlled disposal, constituted by one sanitary landfill with the minimum measures to avoid environmental pollution (e.g., geomembrane liner, methane flaring and leachate treatment processes) (Ministerio de Medio Ambiente y Agua, 2011a). This comes at stark difference with the rest of the country, as according to the only national report of the current state of MSWM (released in 2011), in medium and small municipalities (with less than 100,000 inhabitants) the collection coverage serves only around 60% of the population . Approximately 90% of the municipalities (representing 40% of the waste amount) in the country carry out their disposal in open dumps (Ministerio de Medio Ambiente y Agua, 2011a).

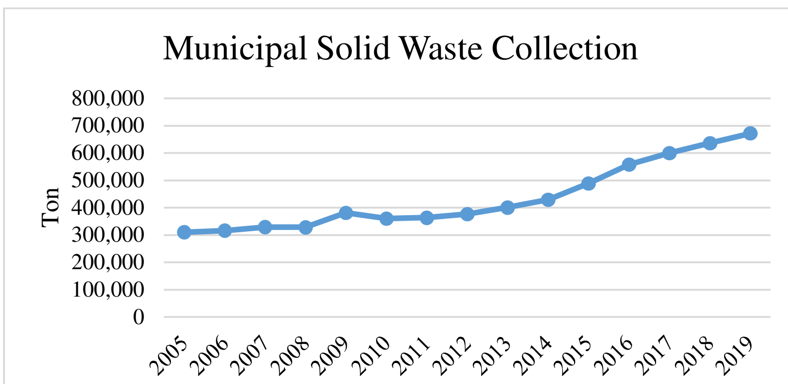


Figure 2.3 Municipal Solid Waste Collection in Santa Cruz de la Sierra

While the city presents a much better MSWM system than the rest of the country, estimating a collection coverage of 95% of the population (Ministerio de Medio Ambiente y Agua, 2011b), both the collection and the disposal elements still present operational and governance issues that result in a questionable quality of these services (Gobierno Autonomo Departamental de Santa Cruz, 2018; Vargas & Apaza, 2015).

The MSWM system in the city does not include any transfer stations, which means that collection trucks that collect the waste are the ones that take it directly to the landfill. Regarding treatment technologies, the current municipal cleansing contract includes services related to the installation of various “eco-points” or “eco-stations” which are recyclables drop-off facilities throughout the city, however at the moment only two have been implemented (Lozano Lazo & Gasparatos, 2019). Formal separate collection is also a pending issue, with it being implemented only in a few areas of the city (Caceres, Prado, & Moreno, 2014), collecting approximately 70 ton/month of recyclable material (pers. commun.: Project Officer, Empresa Municipal de Aseo Urbano Santa Cruz).

The "informal" part of the system is constituted by various stakeholders, among which the waste picker sector is the most relevant (Caceres et al., 2014). There is evidence of waste picking activities in the city since the 1990s decade. At that time waste pickers used to collect materials from the sanitary landfill, before it was enclosed, with many of them settling in the surrounding areas (Casa de la mujer, 1999). In the early 2000s various actions implemented by local NGOs, and municipal government with the support of international cooperation agencies attempted to formalize the waste picking sector, through the creation and strengthening of waste pickers' associations as well as a few local and national networks grouping smaller associations (Caceres et al., 2014). This formalization process peaked in the early 2000s. However, due to various factors such as the cease of external funding, internal conflicts, and the start of formal recycling activities carried out by the municipal and private cleansing companies; the progress in the inclusion of informal waste pickers seem to have decelerated (Caceres et al., 2014; Lozano Lazo & Gasparatos, 2019).

Statistics about the size of the sector have been scarce and uncertain with one NGO study estimating approximately 8.000 waste pickers working in the city, with around 2.500 to 3.000 working permanently and the rest of them working occasionally on the activity (Fundacion PAP, 2010). Recently self-reported numbers by the three networks that congregate smaller associations in the city, estimated around 1750 associated waste pickers (Lozano Lazo & Gasparatos, 2019), while the municipal cleansing company has 450 people from around 30 small associations registered in their records (pers. commun.: Project Officer, Empresa Municipal de Aseo Urbano Santa Cruz). Rough estimations calculate recycling rates of approximately 4% of the total MSWM, attributing the recovery of these materials almost completely to the waste picking sector (pers. commun.: Project Officer, Empresa Municipal de Aseo Urbano Santa Cruz.

2.3 Data collection and analysis

2.3.1 Institutional analysis of Municipal Solid Waste Management System

In order to understand the institutional context and the sustainability transitions in the MSWM system various primary and secondary sources of information were collected and analyzed through the lens of two theoretical frameworks used for the discussion of the results. Secondary data consists of reports, statistics, and policy documents both at the national and local level. At the national level, besides the relevant laws included in the results on Sections 3.2.1 and 3.2.2, some of the most important documents reviewed included the National Report on Solid Waste Management (Ministerio de Medio Ambiente y Agua, 2011a), waste statistics from the National

Statistics Institute (INE, 2017), the National Sanitation Plan 2001–2010 (Ministerio de Vivienda y Servicios Basicos, 2001), and the National Guidelines for Solid Waste Recycling (Ministerio de Medio Ambiente y Agua, 2017). Similarly, at the city level, apart from relevant municipal laws, other secondary sources include urban planning documents such as Santa Cruz Integrated Development's Land Plan (Gobierno Autonomo Municipal de Santa Cruz de la Sierra, 2016) and the municipality's website (Gobierno Autonomo Municipal de Santa Cruz de la Sierra, 2019).

2.3.1.1 Stakeholder interviews

Primary data was collected through 40 expert interviews (Table 2.2), of which 39 were conducted between February 2017 and March 2018, and 1 in February 2019. These stakeholders were identified through an extensive secondary data review (Section 2.3.1) to represent the organizations that are most closely involved in the MSWM system at both national and local levels.

Table 2.2: List of respondents and affiliations

Stakeholder Group	Organization	Affiliation	Reference
National Government	Ministry of Environment and Water	Vice-minister	A1
	Ministry of Environment and Water	Project Officer	A2
Prefectural Government	Santa Cruz Prefectural Government	Environment Control Officer	B1
Municipal Government & Municipal Cleansing Enterprise	La Paz Municipality	Officer	C1
	La Guardia Municipality	Department Leader	C2
	Santa Cruz Municipal Cleansing Enterprise (EMACRUZ)	Projects Officer	C3
	Santa Cruz Municipal Cleansing Enterprise (EMACRUZ)	Director	C4
	Cochabamba Municipal Cleansing Enterprise	Coordinator	C5
	Sacaba Municipal Cleansing Enterprise	Director	C6
	Potosi Municipal Cleansing Enterprise	Communications Officer	C7
International Cooperation Agencies	Japan International Cooperation Agency (JICA)	Program Officer	D1
	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Technical Assistant	D2
Investors/Donors	CAF – Development Bank of Latin America	Environment and Social Risks Executive	E1
Non-governmental/Non-profit Organizations	HELVETAS	Specialist	F1
	FUNDARE La Paz	Executive Director	F2
	FUNDARE Cochabamba	General Manager	F3
	FUNDARE Cochabamba	Technical Advisor	F4
	FUNDARE Santa Cruz	Executive Director	F5
	AVINA	Program Coordinator	F6
	AMIGARSE	Director	F7
	PAP Foundation	President	F8
	SWISSCONTACT Santa Cruz	Project Consultant	F9
	SWISSCONTACT La Paz	Project Consultant	F10
	SWISSCONTACT Cochabamba	Project Consultant	F11
	CIERVA	Coordinator	F12
Formal Recycling Sector	BOLREC	Operations Manager	G1
	CEDARE	Manager	G2
	EMPACAR	Manager	G3
	GRUPO DEL VIDRIO	Owner/Manager	G4
Informal Recycling Sector	RED DE RECOLECTORES	President	H1
	ARECICRUZ	President	H2
	RECICLA BOLIVIA	President	H3
	DEL NORTE	Representative	H4

Private Cleansing Companies	SABENPE	Legal Advisor	I1
	VEGA SOLVI	Head of Department	I2
	TERSA	General Manager	I3
Industry	EMBOL	Solid Waste Officer	J1
	Laboratorios ALFA	Regent	J2
Academia and Research	Environment Engineers Society	President	K1
	Integrated Solid Waste Consultant and Researcher	Consultant	K2

Each interview covered three main topics: (a) evolution of the MSWM systems in Santa Cruz de la Sierra and other cities of Bolivia; (b) role of each stakeholder within the MSWM system and interactions with other stakeholders; (c) key factors (i.e., barriers, enablers) affecting the evolution (transitions) of the MSWM system. The survey was semi-structured and the questions open-ended, allowing respondents to elaborate their answers freely at first. The average interview length was approximately 45–60 min, and all participants (with the exception of 2 respondents) agreed to record the interview for further analysis. The interviews were transcribed verbatim and analyzed using Atlas.ti software to identify emerging patterns through coding based on the conceptual frameworks outlined in Section 2.3.1.2. For the two interviews in which audio recordings were not available, summaries were created based on the notes taken during the interviews.

The main roles and interactions among stakeholders are described verbally and represented graphically through a stakeholder value network (SVN), depicting the main interactions among them, and whether these interactions were perceived to be weak or unstable, contributing to challenges or barriers in the system .

2.3.1.2 Theoretical approach

As mentioned in the previous section, two theoretical frameworks were used to create the discussion regarding the institutional context and the sustainability transitions in the MSWM system. The first framework was briefly introduced in Section 1.3 and refers to the characteristics of sustainable MSWM systems according to Wilson et al. (2015), which are classified in two main dimensions and 6 elements (Figure 2.4). For each element, the framework provides some more specific indicators that allow to estimate the sustainability of the MSWM for that specific element. These definitions were broadly used to find milestones in the secondary data and in the stakeholders' interviews, which allowed to establish the main advances in each of these elements at various points in time.

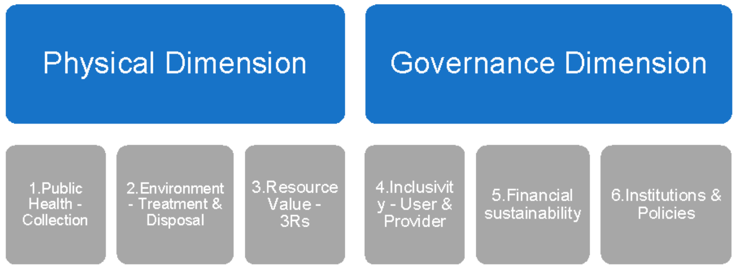


Figure 2.2 Integrated and Sustainable Solid Waste Management Framework (adapted from Wilson et al., 2015)

The other framework refers to the sustainability transitions approach. For this, the Multi-Level Perspective (MLP) on sustainability transitions, which is one of the most utilized such frameworks (Markard, Raven, & Truffer, 2012) was used. MLP conceives transitions as the result of dynamics occurring at (and within) three different levels: (a) niche innovations, (b) socio-technical regimes, and (c) socio-technical landscapes (Figure 2.5).

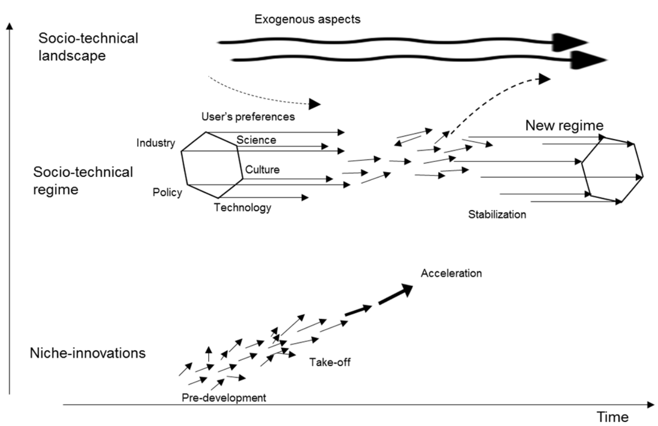


Figure 2.3 Multi-level perspective on socio-technical transitions
Adapted from: (Geels, 2011)

Regimes represent the stablished sets of practices, rules, markets and public policies that dominate a societal context, and niche innovations constantly pushing for mainstreaming new practices/ideas/technologies that take place outside the regime (Markard et al., 2012). The regimes and niche innovations are contained within the landscape, a broader environment characterized by aspects that are stable for longer periods such as "material infrastructure, political culture and coalitions, social values, worldviews and paradigms, the macro economy, demography and the natural environment"(Geels, 2011, p. 019).

The interactions among these three levels, as well as their characteristics and timing, determine whether the pressures originating from different niches and the landscape itself get aligned, and allow a break into the regime. Through this alignment, innovations would reconfigure the regime, then become a part of it, and eventually start a new cycle (Geels, 2002). In this sense, transitions are characterized by four phases, namely (a) pre-development, (b) take-off, (c) breakthrough, and (d) stabilization (Rotmans, Kemp, & Van Asselt, 2001).

During the pre-development stage, small changes might occur that are not necessarily perceived yet in the regime. During take-off, niche innovations and pressures from the landscape can interplay in ways that induce change in the regime, with the transition gradually gaining momentum. Eventually a breakthrough occurs, when visible changes create reinforcing dynamics that continue to strengthen the innovations occurring within the regime. During stabilization, the speed of change decreases, and a new state of equilibrium is established (Grin, Rotmans, & Schot, 2010; Rotmans et al., 2001).

When it comes to solid waste management systems, an institutional change analysis in the Dutch context identified three consecutive transitions during the 20th century (Parto, Loorbach, LansinkAd, & Kemp, 2007). While this study follows a somewhat different type of discussion, a similar lens in establishing a series of MSWM transitions in Bolivia is adopted.

In this sense, the analysis considers that the regime comprises of the interactions occurring both at the national and the local level. The current regime is characterized by recent policy shifts at the national level (Section 3.2.1), with local governments seeking to ensure the safe disposal of municipal waste, even though many issues related to collection services remain unresolved Within this institutional framework, many different actors operate, holding radically different agendas (Section 3.3). In the major cities, the income generation (but also marginalization) of the informal recycling sector is a major aspect of the MSWM system.

The most important niches for MSWM in Bolivia in the current transition include: (a) informal recycling initiatives; (b) formal recycling initiatives; (c) incineration and other “high-technology” alternatives (Section 3.4.1.3). Although there is evidence of other niches (e.g., waste reduction and composting initiatives), they will not be discussed in this study, due to their current minimum role within the MSWM system. Niches from previous transitions are briefly discussed in Sections 3.4.1.1 and 3.4.1.2.

Key landscape factors expected to influence the MSWM transitions in Bolivia are: (a) demographic and urbanization processes; (b) geography, land use and urban planning; (c) socio-economic patterns and development paradigms; (d) political and regional tensions; (e) state-society relations; and (f) global and national narratives on environmental issues (Section 3.4).

As mentioned in Section 2.2.1, a large part of Bolivian population identifies with an indigenous group. Ethnic identities (and their interaction with class issues) have affected practically all domains of Bolivian society throughout its history (Crabtree & Whitehead, 2008; Fabricant & Postero, 2015). Due to the urbanization process, people with indigenous origins settle predominately in the periphery of urban centers, which has created an additional layer of urban conflicts (Arbona & Kohl, 2004; J. D. Kirshner, 2013; Postero, 2007), among which MSWM-related conflicts are not an exception (Caceres et al., 2014; J. D. Kirshner & Traverso, 2009; Rosa & Vespa, 2000).

Geography dictates to a large extent urban planning imperatives, which ultimately affects various aspects of MSWM systems such as waste collection, recycling facilities and, the location of landfills. Despite Bolivia's relatively large geographical extent and low population density, it is not easy to identify suitable areas for landfills, especially in large cities (Otero, 2016).

Regarding the economic aspect, as mentioned in Section 2.2.1, the country has not achieved a transformation of the production system, or major increases in employment generation. The above can have a profound influence on MSWM systems, especially for the recycling industry and the inclusion of actors that are currently working in the informal sector. While at the moment there seems to be room for an increase in recyclable products' supply in national markets, the sector is fragile which is a barrier for the establishment of efficient supply chains (Ministerio de Medio Ambiente y Agua, 2011a).

The political aspect and decentralization process have also been briefly explained in Section 2.2.1. While the regional clashes inside the country have existed throughout its history (Fabricant & Postero, 2015), the hegemony of the party in power in the last fifteen years further contributed to increasing regional clashes over autonomy, and tensions between the national and the subnational governments, especially in areas where local authorities are aligned to other political coalitions (Kohl & Bresnahan, 2010; Regalsky, 2010).

The lack of trust between the state and society also permeates the Bolivian context, as the rule of government is one of the weakest, most unstable and most corrupted in the region (Crabtree & Whitehead, 2008; Transparency International, 2018). Large segments of the society demand solutions to everyday problems through social organizations and grassroots movements. When discontent escalates to conflict, skepticism and doubt are the common attitude towards governmental agencies and public authorities (Salman, 2006). This is a crucial aspect in sectors such as the MSWM, where extensive collaboration is needed from the side of the community for any relevant intervention (Mancilla García, 2017) (Section 3.5.4).

The increasing awareness over environmental issues has provided some short of traction for MSWM issues recently. The former national government promoted an indigenous-environmentalist discourse that advocated values such as “Living Well” and respect for “Mother Earth”, whose symbolism is publicly recognized, although the actual implementation of these principles is questionable (Lalander, 2017). At the same time global environmental issues such as climate change have been increasingly influencing public perceptions and environmental awareness, including those related to solid waste (Zimmerer, 2015).

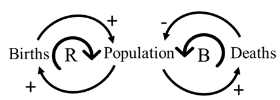
2.3.2 Participatory modeling of MSWM system

As explained in Sections 1.3 and 2.1, the use of system dynamics modeling (SDM) tools in in the study of SWM systems has gained recent attention due to its capacity to deal with complex inter-relationships across SWM stages, including both social and physical processes (Ding, Yi, Tam, & Huang, 2016; Ghisolfi, Diniz Chaves, Ribeiro Siman, & Xavier, 2017; Giannis, Chen, Yin, Tong, & Veksha, 2017; Kubanza & Simatele, 2018). This methodology consists in the use of various tools such as causal loop diagrams (CLD), stocks and flows diagrams (SFD) and software simulation in order to gain knowledge about a complex situation (system) and explore its future behavior (Meadows, 2008; Sterman, 2000). Being a methodology originally created for the supply chain and industrial domains (J. A. Y. W. Forrester, 1968), in the last decades its use has expanded to various fields (Eker, Zimmermann, Carnohan, & Davies, 2018; Yuan & Wang, 2014; Zimmerman et al., 2016). In the SWM field, system dynamic approaches have been used as a planning and discussion tool for municipal solid waste management (MSWM) (Cai & Liu, 2013; Karavezyris, Timpe, & Marzi, 2002; Sudhir, Srinivasan, & Muraleedharan, 1997), to test various scenarios for the management of specific types of waste (Chaerul, Tanaka, & Shekdar, 2008; Ding et al., 2016; Ghisolfi et al., 2017; Marzouk & Azab, 2014; Wäger & Hilty, 2002; Yuan & Wang, 2014), to forecast municipal waste generation (Dyson & Chang, 2005), to analyze effects of recycling and source separation behaviors (Giannis et al., 2017; Sukholthaman & Sharp, 2016; Ulli-beer, 2003), and to estimate various MSWM negative impacts (Kollikkathara, Feng, & Yu, 2010; Oyoo, Leemans, & Mol, 2011) as well as positive ones (Ahmad, 2012) .

2.3.2.1 Causal loop diagrams

Causal loop diagrams (CLD), also called influence diagrams, are the first step for system dynamics modelling, being used to elicit and represent mental models regarding the structure of a system (Table 2.3). A CLD is constituted by variables connected with each other through causal links, with a specific polarity. This polarity can be either positive or negative depending on whether a dependent variable responds to an increase in the independent variable (all other things being equal), with an increase in its own value (positive polarity) or a decrease (negative polarity) (Sterman, 2000). Besides the variables and the causal links, another important element of CLD are the feedback loops. These are constituted by two or more variables with their causal links creating a closed cycle, which can be reinforcing or balancing, depending if all the polarities go in the same direction (reinforcing), or if the positive and negative effects “cancel” each other (balancing) (Meadows, 2008; Sterman, 2000). Feedback loops are important because they allow to have a deeper understanding of variable behaviors, as well as potential leverage points for policy implementation (Eker et al., 2018; Malard et al., 2015).

Table 2.3: CLD main elements and notation

Element	Representation	Description
Variable	Births	Any kind of element (quantitative or qualitative) that takes part of the system, whose value can be measured. Represented by a word or short phrase
Causal link		Effect of one variable on another. Causal links can have positive (+) or negative (-) polarities, representing direct or inverse effects, respectively.
Causal loop		Closed cycles formed by two or more variables influencing each other. Reinforcing loops (R) represent emphasizing effects on one direction. Balancing loops (B) represent counteracting effects attempting to reach balance

Adapted from: (Yearworth, 2014)

While CLDs have received some criticism for a lack of detail about the modeled variables and in consequence, providing limited potential for a deeper understanding of the system (Featherston & Doolan, 2012; Richardson, 1986) they are considered an advantageous tool to outline systems’ structure and provide a reflection of people’s mental models (Featherston & Doolan, 2012). In this sense, CLDs have been recommended as the first step in modeling processes, having even more relevance in the case of participatory approaches (Binder, Vox, Belyazid, Haraldsson, & Svensson, 2004; Malard et al., 2015; K. A. Stave & Dwyer, 2005).

As mentioned in Section 2.1, for this study, a first draft of the CLD was created by the researcher including general flows across the MSWM stages, as well as some of the main impacts according to the literature review. However, in order guarantee that the main impacts and mechanisms of the current MSWM practices are identified in the model, a participatory approach was deemed necessary.

2.3.2.2 Group modeling building

After being originally used for the business consulting field, participatory approaches for the development of CLDs and other system dynamics tools have started to be applied in the public and academic spheres for a variety of topics, from smallholder agriculture (Malard et al., 2015), to health programs (Ansah et al., 2019), community water management (Beall, Fiedler, Boll, & Cosens, 2011) and environmental management (K. A. Stave & Dwyer, 2005). The purpose of these approaches is not only to improve the depth and quality of the modeling data through the knowledge and experience of participants, but also to serve as a tool for dialogue among relevant stakeholders involved in the thematic being analyzed (Ansah et al., 2019; Newell & Proust, 2009). This is especially relevant in complex urban issues where representatives of different stakeholder groups usually have uncomplete information about parts of the system in which they are not directly involved, or where points of view about the same issue clash due to the inherent role of each stakeholder (Eker et al., 2018; Malard et al., 2015; Newell & Proust, 2009).

The technique for participatory modeling in system dynamics has been denominated Group Model Building (GMB) (Richardson & Andersen, 1995). Having been considered a craft as much as a science (D. F. Andersen, Richardson, & Vennix, 1997; Beall et al., 2011) it provides general guidelines for the conduction of participatory modeling process, while stressing the need for flexibility depending on the specific case study (D. F. Andersen & Richardson, 1997; Sadia, 2014b). Three elements are considered to be of upmost importance for the design of group model building techniques: i) Participants selection; ii) session preparation; iii) session facilitation (Sadia, 2014b). Section 2.3.2.3 will explain the three elements in more detail.

2.3.2.3 Conduction of the study

While the number of stakeholder groups in the MSWM system is numerous, as mentioned in Section 3.3, stakeholders with the major roles are at the local level. Among those, the ones with the most involvement in current practices are the municipal cleansing enterprise, the private cleansing company and informal recycling sector. Additionally, although NGOs have decreased their involvement in the system at the moment, they had a pivotal role at the start of the 3rd transition in the system, related to the beginning of recycling initiatives in the city (Section 3.4.1.3). In this regard, these were the stakeholder groups selected for the GMB workshop. Regarding the specific participants' selection, both number and diversity are considered to be important criteria to take into account (Eker et al., 2018; Sadia, 2014b). A number of five participants has been recommended as ideal (Sadia, 2014b), however numbers in other studies have variated from 3 to 20 (Beall et al., 2011; Eker et al., 2018; K. a Stave & Ph, 2008). The important consideration for a larger number of participants is the need to have more structured sessions and more people taking the necessary roles to conduct the study (See below in this section) (Sadia, 2014a). For the present study, four participants (three men and one woman) from the main stakeholders' groups involved in MSWM in the city were selected, each of them belonging to a specific organization (Table 2.4). Despite the number of stakeholders involved, size of each organization is relatively small, resulting in a few people within each organization working on MSWM. In this sense, as explained below, the participants of the workshop were either the only representatives working on the topic for the organization, or the most relevant ones in terms of involvement, knowledge, and experience. Originally it was expected that one representative from the informal recycling sector could be able to participate, however due to difficulties in their location and working conditions, this was not possible. Nevertheless, it was expected that the participation of one of the NGOs, which works in close relationship with the sector, could represent their views to some extent.

The representative from the municipal cleansing enterprise (MCE) is the main person in charge of developing projects related to the integrated MSWM in the city at the time. The representative from the private cleansing enterprise is the leader of the area in charge of monitoring the quality, environmental and occupational health indicators in the company's activities. NGO1 is an international NGO that dedicates to inclusive development projects in various countries. In Bolivia, NGO1 has had one of the pivotal roles in the implementation of recycling programs in the last two decades. The representative is the person in charge of all the activities for the city. NGO2 is a small local foundation that deals mainly with corporate social responsibility projects, which in the case of MSWM relate to providing various types of support to waste pickers' associations, through direct capital provision through the establishment of partnerships with private companies that can donate their recyclable materials to these associations. The representative that participated in the GMB session is the foundation's director.

Table 2.4: GMB Participants

N°	Stakeholder	Organization	Organizations' activities	Participant's role
1	Government	Municipal cleansing	MSWM Planning	Projects Officer
2	Private sector	Private cleansing enterprise	MSWM Execution	Integrated Systems
3	NGOs/NPOs	NGO1 (foreign)	Inclusive development projects	Project Consultant
4	NGOs/NPOs	NGO2 (local)	Corporate social responsibility	Director

The sessions' preparation consisted in the logistic aspects and the content development. The logistic was planned for two sessions of approximately 4 hours each, carried out in a classroom at a local university, in order to have a neutral place for all the participants to feel equally comfortable, and to have access to the necessary material and equipment (blackboard, markers, projector, internet). Guidelines refer to five roles for GMB sessions conduction, which could be taken by one or more people: facilitator, modeler/reflector, process coach, recorder, gatekeeper (Richardson & Andersen, 1995). While all these roles were taken by the main researcher, two volunteer university students who were recruited in advance, aided with logistic aspects and with some responsibilities of the modeler/reflector and recorder roles, by taking notes of the most relevant discussion point during the sessions.

Regarding the content, for the first session, the first 30 minutes were planned to be dedicated to the explanation of the general objectives of the research, the objectives of the GMB sessions, system dynamics approach and specific CLD tool that would be used during the session. Subsequently a brainstorming session was planned in order to be able to capture as much ideas as possible for the start of the exercise, followed by the drawing of the CLD in the blackboard using the inputs from the participants. Considering the small size of the group, relatively less structured sessions were planned, however a tentative agenda was created (Table 2.5).

Table 2.5: GMB Agenda

Day	Time	Agenda
1	8:00 am – 8:20 am	Introduction, Research Objectives, System Dynamics
	8:20 am – 8:30 am	CLD technique
	8:30 am – 8:45 am	Brainstorming session
	8:45 am – 9:45 am	CLD Drawing
	9:45 am – 10:00 am	Break
	10:00 am – 12:00 pm	CLD Drawing
2	8:00 am – 8:10 am	Recapitulation of previous session
	8:10 am – 9:45 am	CLD Drawing
	9:45 am – 10:00 am	Break
	10:00 am – 11:50 am	CLD Drawing
	11:50 am – 12:00 pm	Wrap up

As mentioned above, the facilitation as well as other roles were conducted by the main researcher. An important activity that was conducted before the implementation of the exercise, was to create a preliminary CLD only constructed by the researcher, based on literature review and knowledge of the local context. While the GMB session did not use the previous CLD in order to avoid bias in the process, it was an important reference that allowed to provide additional guidance and ideas to the participants, whenever needed.

For the start of the session, literature suggests to consider conducting ice-breaker exercises to make the participants more comfortable (D. F. Andersen & Richardson, 1997), however due to the size of the group and the fact that all the participants knew each other as well as the researcher, only a brief introduction was conducted at the beginning of the session. After the introductory part, the brainstorming session was conducted using post-it notes, requiring participants to first individually write down as many variables as they could, that they considered to be positive or negative outcomes (impacts) of MSWM activities in the city, as well as the variables that they thought could influence these outcomes. After collecting the ideas, each of them was discussed and the CLD drawing process in the blackboard started (Figure 2.6). During the CLD creation process, equal participation of all the members was encouraged as much as possible, addressing questions about their perception to specific participants whenever needed. Whenever different or somewhat contradictory points of view were raised, it was attempted to reach consensus, or otherwise include all the ideas in the CLD, unless it affected the logic of the diagram. However, this last situation did not occur during the sessions.

Figure 2.4 Group Model Building Process

The second session followed a structure similar to the first, with the difference that the advance in the drawing for the first session was modeled in the Vensim software in order to have a cleaner version for the recapitulation at the start of session two. At the end of the second day a brief time for discussion was allocated at the end of the session. Additionally, a short survey (Eker et al., 2018) with four 5-likert scale questions was circulated and filled anonymously by the participants in order to get their feedback about the exercise (Table 2.6). Afterwards, once the whole model was represented in Vensim, it was sent by email to all the participants.

Table 2.6 Feedback from GMB session's participants

N°	Aspect	Average
1	Good variables definition and easy understanding from people involved in the activities	3.25
2	Good problem representation through the structure of the model	4.5
3	Most relevant problems have been included	4.25
4	Usefulness of the exercise to better understand problems, causes and effects	5

2.3.3 Assessment of Municipal Solid Waste Management practices

After conducting the participatory modeling in order to map the variables and inter-linkages corresponding to the main sustainability impacts of the MSWM system in the city, the major data sources and mechanisms definition needs for the stocks and flows diagram (SFD) were identified. This led to the decision to focus on household waste practices, through three specific studies related to the main upstream and downstream stages of the MSWM process in the city: generation, collection and recycling. The results of these studies were expected to cover most of the data needs to create basic SFD of the system and simulations to explore some of the future outcomes of the system under different scenarios.

2.3.3.1 Household waste generation

The first study relates to the household waste generation stage, with the purpose to identify the generation rates, composition, and influencing factors. While the municipality has conducted a couple of characterization studies before, through consultant companies, the results have been limited to descriptive statistics. In that sense, to the best of our knowledge, there is not previous research in the country that attempted to identify factors influencing generation rates, which resulted in the need to conduct the study to generate the data for the SFD in Obj. 4.

In order to conduct the study and guarantee the quality of results, a thorough planning was required, involving various actors. On one side, the support of a local university was obtained, in order to encourage households' participation, involve a team of volunteer students to assist with the activities as well as the main equipment and facilities. Also, the study counted with the support of the municipal cleansing enterprise, which shared some additional data about previous studies, and contributed with the trucks for samples collection and disposal during the period of the study. Some of the waste pickers associations contributed in the students training, through a general explanation of their activities, and providing practical recommendations for the identification of the different materials during the separation activities. Finally, through the municipality, the consulting team that conducted one of the previous studies in the city was contacted to collaborate with their experience regarding logistics, risks and challenges of the study in the local context.

The waste characterization study was carried out in September 2018 for a total of 105 households from 3 socioeconomic strata divided across income. For each socio-economic stratum (i.e. low-income, middle-income, and high-income) 35 households were selected and surveyed for a period of 7 days. Existing literature on waste characterization suggests that some of the most relevant aspects to ensure the accuracy of the waste generation process include the proper selection of i) sampling location, ii) sample size, iii) stratification, and iv) type and number of waste components (Dahlén & Lagerkvist, 2008). Sections 2.3.3.1.1 – 2.3.3.1.2 outlines the criteria influencing these decisions, and Section 2.3.3.1.3 the characterization protocol.

2.3.3.1.1 Sampling

Sampling location refers to the area where waste sample collection takes place. In contexts with a clear differentiation between the collection activities for each source (e.g. households and commerce) it is possible to collect samples directly from the waste collection trucks at transfer stations or landfills. However, this method introduces errors in relation to the estimation of the number of people involved in the generation of the waste that is sampled and overall provides less detailed results (Dahlén & Lagerkvist, 2008; Runfola & Gallardo, 2009).

Based on in depth discussions with the municipal cleansing enterprise, (pers. commun.: Project Officer, Empresa Municipal de Aseo Urbano Santa Cruz) and the private cleansing enterprise (pers. commun: Head of integrated systems department, Vega Solvi Bolivia) it was identified that household and commercial waste is collected through the same process for most areas of the city. In this sense, and in order to obtain a good understanding of waste generation patterns, the waste sampling was conducted directly from individual households.

Regarding the sample size, there is no standardized or uniform approach for sample size determination for waste characterization studies (Dahlén & Lagerkvist, 2008). One of the methods used in developed countries establishes a minimum of 100-200 households for component analysis and 1.3% of the population for rate determination (Nordtest, 1995). Other studies have established minimum sample size based on total sample weights, establishing a minimum of 91kg of waste as a minimum sample for accurate components determination (Tchobanoglous, Theisen, & Vigil, 1993). Most studies in developing countries have based the sampling size on feasibility aspects, or following the approach of the central limit theorem (Abu Qdais, Hamoda, and Newham, 1997).

In this study the central limit theorem is used to establish sample size, by calculating the minimal sample size for a 95% confidence interval (Z=1.96), a sampling error of 10% of the estimated mean (0.058), and an estimated standard deviation of 0.75 kg/capita/day based on data obtained from a characterization study conducted by the municipality in 2013 (EMACRUZ, 2016). Based on this a total of 642 samples is estimated, which represents 91 households for a period of 7 days, which is the minimum amount of days recommended by the literature (Dahlén & Lagerkvist, 2008). To incorporate a security margin, a total of 105 households were included in the study.

Stratification in waste characterization studies seeks to ensure that groups with different characteristics within a population are adequately included in the sample. In the case of household waste characterization, various studies recommend separating the population in different strata according to income levels (Bernache-Pérez, Sánchez-Colón, Garmendia, Dávila-Villarreal, & Sánchez-Salazar, 2001; Parizeau, Maclaren, & Chanthy, 2006; Sahimaa, Hupponen, Horttanainen, & Sorvari, 2015). This is because income is considered a good proxy to consumption levels and patterns (Khan, Kumar, & Samadder, 2016), which influence directly the amounts and composition of generated waste (Bandara, Hettiaratchi, Wirasinghe, & Pilapiiya, 2007; Dennison, Dodd, & Whelan, 1996; Suthar & Singh, 2015).

In this study, three strata are selected based on income levels (i.e. High, Medium, and Low). The stratification and household selection were conducted according to the geographical location and general characteristics of the households and neighborhoods. As mentioned in Section 2.2.2, while the city had an original orderly development plan, the rapid growth, particularly in the 1980s surpassed the original design (J. D. Kirshner, 2013), creating an urban setting where lower-income segments of the population are usually located outside the 4th and 5th rings, and middle-income households inside these borders. Upper-income households are usually located in closed condominiums and a few specific neighborhoods across the city, most of them also inside the 5th ring.

Having no available government data about these patterns, to reflect this situation the identification of the households corresponding to each income stratum was based on a 2018 Real State Report conducted by the real state sector and various universities (Pando & Morales, 2018), which established geographic quartiles according to housing prices. For the waste characterization, it was assumed that the "High Income" strata corresponded to the 1st quartile area, the 2nd-3rd quartiles corresponded to the "Middle Income" strata, and the 4th quartile corresponded to the "Low Income" strata. This rough classification coincides with the general urban setting mentioned in the previous paragraph, having been discussed in city development reports and academic research (J. Kirshner, 2011; Vargas & Apaza, 2015).

Once the areas for each stratum were delineated geographically, seven random starting points per strata were generated through ArcGIS's function "Create Random Points". For each random point, five households were selected following a systematic rule, for a total of 35 households per stratum (Figure 2.7). In stratified sampling, while allocation of sample size among strata can be done using equal, proportional or Neyman's criteria, literature indicates that if variances within strata are expected to be similar, either of the first two can be used (Keskintürk & Er, 2007). In that sense, while both the equal and proportional procedures have been used in characterization studies, the most common approach is to select approximately equal sample sizes for each stratum and then, at a later stage, calculate weighted averages based on the proportion of the strata in the population (Dahlén & Lagerkvist, 2008; Gomez, Meneses, Ballinas, & Castells, 2008; Ojeda-Benítez, Vega, & Marquez-Montenegro, 2008; Villalba, Donalisio, Cisneros Basualdo, & Noriega, 2020; Zia, Batool, Chauhdry, & Munir, 2017). For this study, equal sub-sample sizes were selected to assure that results obtained within each stratum have the same level of accuracy, even more considering the relatively small size of the full sample.

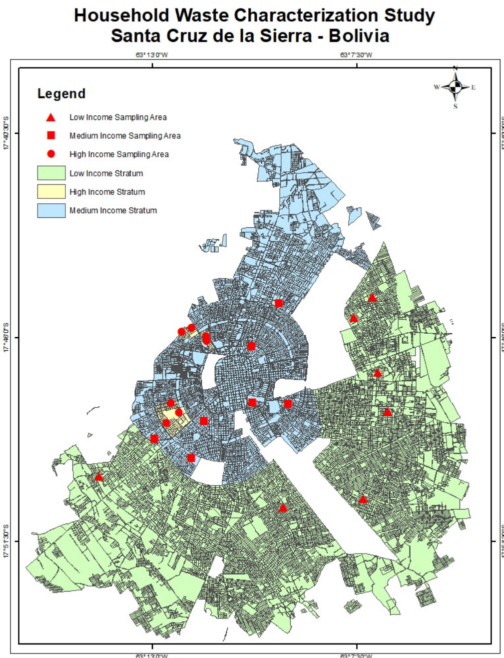
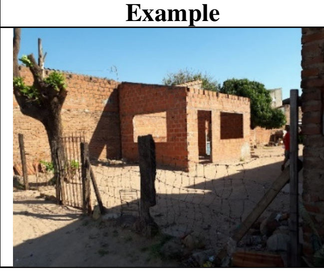


Figure 2.5: Locations of sampling areas across Santa Cruz de la Sierra

Prior to the beginning of sampling, the identified starting points were visited to verify the general characteristics of each neighborhood and whether it complies with the characteristics of the respective stratum (Table 2.7). No major discrepancy was observed, so all of the originally identified sampling points were used in the study. Similarly, during the selection of individual households, the enumerators were instructed to perform a quick qualitative validation of the household income level on site, based on the general characteristics of the house. Enumerators were instructed to avoid the households indicated by the systematic selection process, only if there was evidence of great discrepancy with the expected income level, i.e. houses with "high income" characteristics in a "low income" neighborhood or vice versa (Table 2.7**Error! Reference source not found.**), however, enumerators did not report the need to conduct major changes in household selection.

Table 2.7: General house and neighborhood characteristics for each income stratum

Strata	Household	Neighborhood	Example
Low-income	- No external walls -Frail fences - Unfinished construction - Alternative construction materials (e.g. wood, clay)	- Unpaved roads - No sidewalks - High prevalence of stray animals - High prevalence of waste dumping and waste burning.	

Middle-income	- One-story houses - Neglected facades - Neglected sidewalks	- Some paved roads - Medium prevalence of stray animals	
High-income	- Two-story houses - Fully covered gates	- Paved and clean roads and sidewalks - No stray animals	

Source: All photos taken by the author

2.3.3.1.2 Type and number of waste components

When selecting the number of waste components/categories in waste characterization studies there should be effort to achieve a balance between detail and accuracy (Dahlén & Lagerkvist, 2008; Krause & Townsend, 2014; Sahimaa et al., 2015) . A larger number of waste components increases the detail of the waste characterization exercise but decreases the accuracy of the results and requires more samples (Sfeir, Reinhart, & McCauley-Bell, 1999). Furthermore, the type of waste categories must correspond to the context and objectives of the study (e.g. recycling potential, energy potential, composting potential, hazardous waste determination).

For the current study, the component separation aims to obtain a general outlook of the composition, as well as recovery potential of organic and recyclable materials. Currently, it is estimated that recycling rates in the city barely reach a 4% of all the municipal solid waste generated, most of it through the activities of the informal waste picking sector. Composting initiatives are incipient, with only a few municipal projects implemented in farmer markets (pers. commun.: Project Officer, Empresa Municipal de Aseo Urbano Santa Cruz). In this sense, it is important to determine the potential recovery options for household waste. For this reason, a typology consisting of a total of 8 waste categories and 34 sub-categories was established prior to the start of the study (Table 2.8). This typology was based on Bolivian standards used in this study (Section 2.3.3.1.3), which include the sub-categories displayed in Table 2.8. However, some of these subcategories were merged based on the relevance for the objectives of the study (e.g. sanitary pads and diapers originally in separated categories, were grouped in only one). Furthermore, the grouping in the 8 main categories was influenced by studies conducted in Denmark and guidelines from the European Commission (Edjabou et al., 2015; European Commission, 2004). Training and proper guidelines for their identification were provided to the enumerators involved in the waste characterization exercise (Section 2.3.3.1.3).

Table 2.8: Waste categories and sub-categories for characterization

Category	Subcategory
1 – Organic Waste	1.1 Raw food waste and garden waste
	1.2 Cooked food waste
2 – Paper and Cardboard	2.1 White paper
	2.2 Color paper
	2.3 Newspaper
	2.4 Cardboard
	2.5 Other papers
3 – Plastics	3.1 Polyethylene terephthalate (PET)
	3.3 Polyvinyl-chloride (PVC)
	3.4 Low density polyethylene (LDPE)
	3.5 Polypropylene (PP)
	3.6 Polystyrene (PS)
	3.7 Other plastics
4 – Metals	4.1 Aluminium
	4.2 Ferrous metals
	4.3 Other non ferrous metals
5 – Glass	5.1 Transparent glass
	5.2 Amber glass
	5.3 Green glass
	5.4 Other glass
6 – Sanitary Waste	6.1 Sanitary waste
7 – Fine residue	7.1 Fine residue
8 – Others	8.1 Tetrabrik
	8.2 Textiles
	8.3 Waste of Electric and Electronic Equipments
	8.4 Rubber and leather
	8.5 Batteries
	8.6 Medicines
	8.7 Pesticide containers
	8.8 Styrofoam
	8.9 Ceramic
	8.10 Wood
	8.11 Others

2.3.3.1.3 Characterization study

The overall waste characterization protocol in terms of duration and calculations was based on guidelines from the Panamerican Health Organization (PAHO) and Bolivian standard NB-743 (IBNORCA, 1996). However, the detailed methodology was decided following a literature review on characterization studies in other countries (Dahlén & Lagerkvist, 2008; Edjabou et al., 2015; European Commission, 2004; Gomez et al., 2008). Additionally, a small survey questionnaire was included alongside the characterization in order to collect information about the socio-demographic household characteristics, consumption patterns and solid waste management practices. Considering the possible reluctance from respondents to offer information about income, service expenditure in basic services (e.g. water, electricity, phone, internet, cable tv) was used as a proxy indicator. Being a common challenging aspect, particularly in developing countries, other studies have used similar approaches, considering housing rental, monthly expenditure, dwelling size and property values as alternatives to income (Abu Qdais et al., 1997; Jadoon, Batool, & Chaudhry, 2014; Parizeau et al., 2006).

Figure 2.8 outlines the basic procedures of the waste characterization protocol. After identifying target households (Section 2.3.3.1.1), the consent of the household head or other adult decision-maker was sought after explaining the purpose and characteristics of the study. During this time, the household general information was registered through the survey, a unique code was assigned, and a sticker was put on the front door for easier identification at later stages. Different color-coded trash bags were assigned to each stratum for easier identification during the components' separation stage.

During Day 0 (denominated "cleaning day"), the selected households were visited again, and their waste was collected and taken to the sorting facilities, but immediately discarded. This was done with the objective of avoiding any waste corresponding to prior days affecting the results (Bernache-Pérez et al., 2001; IBNORCA, 1996; Villalba et al., 2020).

From Day 1 to 7, waste from each household was collected and immediately weighted in the premises with handheld scales. Subsequently, all samples were transported to the sorting facility and grouped according to the strata. Components separation was done manually in a sorting table, with the weights of each category registered for the determination of their proportion for each stratum.

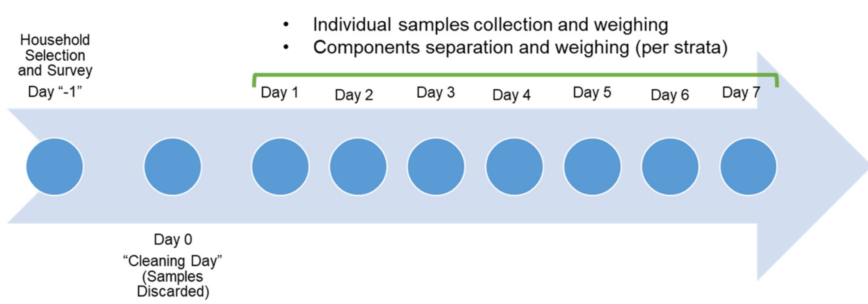


Figure 2.6 Procedure of the waste characterization study

Waste generation rate per capita was calculated for each household for each day of the study, by dividing the total waste generated in the household during that day by the number of members reported in the survey. Subsequently, a simple average waste generation was estimated for all days in order to determine the generation rate per capita for each household. Similarly, for the composition analysis, the fraction of each waste component in the total sample was calculated for each stratum for each day of the study. Subsequently, mean and median values were estimated for both the generation rate and each component fraction, for all strata.

Finally, the waste generation rates and composition for the whole city were estimated through weighted averages based on the fraction of the population in each economic stratum. Due to the lack of official statistics, a 2017 study was used, which established that approximately 56% of the city's population fell into the low-income stratum, 37% to the medium-income stratum, and 7% to the high income-stratum (Captura Consulting, 2017).

2.3.3.1.4 Data analysis

Various statistical analysis were used to (a) identify the main characteristics of the strata (descriptive statistics), (b) determine the statistical significance of the differences across strata (Kruska Wallis test); (c) identify the correlation between the main variables obtained through the surveys and the estimated waste generation rate (Spearman correlation analysis); and (d) identify the main variables that could explain the variations in the waste generation rates through multiple linear regression analysis.

Initially, the dataset was screened to identify abnormalities such as missing data, outliers, and other sources of bias. During this procedure, the sample size was reduced to 101 households, as four households were removed for delivering the waste sample for only three days (or less) out of the seven days of study. Additionally, one daily sample of more than 6 kg per capita (~10 times the estimated sample average) was removed from three other households. It is suspected that these abnormal samples were caused by exceptional activities in the households (e.g. social gatherings or periodic deep cleaning).

Subsequently, the sample distribution was explored in order to determine the type of appropriate statistical tests. As the samples do not follow a completely normal distribution, non-parametrical tests, such as Kruskall-Wallis tests, are used to establish the differences across strata, and Spearman correlation analysis.

Finally, for the multiple linear regression, a stepwise procedure was adopted using the main variables expected to influence the generation rates based on the correlation analysis. According to this procedure, initially a relatively large number of variables that could influence the rates were included, but only variables that were found to be statistically significant and explain most of the variability in the sample were kept (Barr, Gilg, & Ford, 2001; Lebersorger & Beigl, 2011; Shamshiry, Bin Mokhtar, & Abdulai, 2014). Table 2.9 outlines the initial set of variables and the expected effect for waste generation rates.

Table 2.9: Variables used in multiple linear regression

Variable	Description	Expected effect on dependent variable	
		Direction	Reference
Waste generation rate (dependent variable)	Average daily per capita household waste generation (in kg/capita/day)	Non applicable	
Household members	Number of family members living in the household	Negative	(Bandara et al., 2007; Buenrostro, Bocco, & Vence, 2001; Hoang, Fujiwara, Pham Phu, & Thi, 2017; Lebersorger & Beigl, 2011; Ojeda-Benítez, Lozano-Olvera, Morelos, & Vega, 2008; Qu et al., 2009)
Livelihood activity	Small additional livelihood activity in the household expected to contribute to waste generation such as an office, small kiosk, or eatery. No additional activity = 0; Additional activity = 1	Positive	(Hoang et al., 2017)
Eatery	Small eatery in the household. No eatery = 0; Eatery = 1	Positive	Original. Based on (Hoang et al., 2017)
Kiosk	Small kiosk in the household. No kiosk = 0; Kiosk = 1	Positive	Original. Based on (Hoang et al., 2017)
Proportion of children	Fraction of people younger than 18 years in the family	Negative/No effect	(Hoang et al., 2017; Lebersorger & Beigl, 2011)
Education of the Household Head	Number of years of education of the household head	Negative/No effect	(Buenrostro, Bocco, & Vence, 2001; Ojeda-Benítez, Lozano-Olvera, et al., 2008)
Socioeconomic stratum	Low Income=1; Medium Income=2; High Income=3	Positive/No effect	(Hoang et al., 2017)
Cooking at home	Cooking at home as main type of meal preparation for 4 or more days a week; No cooking at home = 0; Cooking at home = 1	Positive	Original
Dwelling ownership	Type of ownership level of dwelling. Borrowed=1; Rented=2; Leased=3; Owned=4	Positive/No effect	(Adedibu, 1988)
Service expenditure	Monthly per capita expenditure for household basic services such as water, sanitation, electricity, phone, internet, cable service (in BOB/capita)	Positive	Original. Based on (Abu Qdais et al., 1997)
Garden waste recovery	Separation and recovery of garden waste for composting purposes. No recovery = 0; Recovery = 1	Negative	Original
Food waste recovery	Separation and recovery of garden waste for composting or animal feeding purposes. No recovery = 0; Recovery = 1	Negative	Original
Waste separation	Source separation of waste for recyclables donations, composting, handcrafts or other purposes. No separation = 0; Separation = 1	Negative	Original

2.3.3.2 Household solid waste management practices

The CLD corresponding to Objective 2 (Chapter 4) established connections between household practices and positive and negative impacts in the system. At the same time, it mapped the mechanisms influencing these household practices, based on the mental models of stakeholders participating in the GMB workshop (Section 2.3.2). In this sense, without any existing study at the country level that provides the necessary information to populate these variables and validate the mechanisms established to create the SFD, it was deemed necessary to conduct an empirical study to gather the relevant data.

The study focused on positive and negative behaviors related to SWM practices at the household level, which are in between the generation and collection stages in the MSWM process. In this sense, in order to have the sufficient knowledge of the local context for the questionnaire design and results interpretation, a participant observation of the collection process was conducted for three days during the planning of the study. This activity consisted in visiting the collection facilities, conducting informal interviews with some of the collection workers and supervisors, and accompanying them during their day and night shifts across the different areas of the cities supervising the collection activities. Through this method, it was possible to observe and better understand the characteristics of different areas of the city, characteristics of the collection activity, challenging aspects and problems identified by the supervisors regarding household practices. Additionally, in order to promote household participation, the institutional support of a local university was obtained through a letter that was shown to the household members when approaching them to conduct the survey, and three recent graduates of the university with experience conducting surveys were involved in the project as enumerators.

Household backyard burning and illegal dumping are still prevalent in many developing cities (Karija & Lukaw, 2013; Tadesse, Ruijs, & Hagos, 2008). They cause impacts for the environment, health and generate additional costs for municipalities (Estrellan & Iino, 2010; Reyna-Bensusan et al., 2018).

Factors influencing solid waste management behaviors have been investigated through different approaches. Theoretical frameworks such as List of Value (LOV) (McCarty & Shrum, 1994), Theory of Reasoned Action (Amini, Ahmad, & Ambali, 2014; Park, Levine, & Sharkey, 1998) Theory of Planned Behavior (TPB) (Oztekin, Teksöz, Pamuk, Sahin, & Kilic, 2017; Pakpour, Zeidi, Emamjomeh, Asefzadeh, & Pearson, 2014; Ramayah, Lee, & Lim, 2012), and "Knowledge, Attitudes, Practices" (KAP) (Babaei et al., 2015; Mamady, 2016; Tatlonghari & Jamias, 2010) have been directly applied, or expanded with additional elements, to formulate hypothesis regarding the possible latent constructs (non-observable variables) influencing recycling or source separation behaviors. To the best of our knowledge, no study about backyard burning and household's illegal dumping practices has used any of these theoretical frameworks.

Other approach in the study of factors influencing practices has been to focus solely on observable variables including socio-economic characteristics such as household education, income, size and distance to facilities, to name a few (Padilla & Trujillo, 2018; Tadesse et al., 2008). Regarding the data analysis, descriptive statistics and correlations (Sekito, Prayogo, Dote, Yoshitake, & Bagus, 2013), regression analysis (Padilla & Trujillo, 2018; Tadesse et al., 2008; Wang, Cheng, Reisner, & Liu, 2018) and Structural Equation Modelling (SEM) (Loan, Nomura, Takahashi, & Yabe, 2017; Mosler, Tamas, Tobias, Rodríguez, & Miranda, 2008; Ramayah et al., 2012; Wu, Yu, & Shen, 2017) have been some of the most common methodologies used.

TPB is one of the most utilized frameworks in behavioral studies (S. Zhang, Zhang, Yu, & Ren, 2016). It assumes that there are three main abstract constructs influencing behavioral intentions: attitudes (degree of positive or negative opinion about the behavior), subjective norms (perceived social pressure to engage or not in the behavior), and perceived behavioral control (ease or difficulty in engaging in the behavior), with the latter having an additional effect in the materialization of the intention into the actual behavior (Ajzen, 1991). Various studies applying the TPB framework have been able to successfully identify relevant factors influencing source separation and recycling practices at households (Oztekin et al., 2017; Pakpour et al., 2014; Wang, Guo, & Wang, 2016; Lin Xu, Ling, Lu, & Shen, 2017). However, in other cases, the connections assumed by the framework could not be established (Wu et al., 2017) or showed a weak influence (Knussen, Yule, MacKenzie, & Wells, 2004; Tonglet, Phillips, & Read, 2004). The limitations of TPB have been addressed in some studies suggesting possible reasons for the failure of some of its constructs to show significant influences, and the need to consider additional variables in the behaviors explanation (Armitage & Conner, 2010; Bagozzi, 1992; Knussen et al., 2004; Ramayah et al., 2012; Stoeva & Alriksson, 2017).

When dealing with abstract constructs, Structural Equation Modelling (SEM) is one of the preferred analytical techniques, due to its capacity of modelling complex interactions between multiple dependent and independent variables in more powerful ways than common regression analysis (Rahman, Siwar, & Begum, 2017; D. Zhang, Huang, Yin, & Gong, 2015). SEM consists in two stages: a measurement model, and a structural model. The measurement model, which is also denominated Confirmatory Factor Analysis (CFA) consists in testing the validity of the indicators (items/questions) that are expected to reflect a latent abstract construct. After the measurement model, the structural model is used to estimate the effects of constructs and observed variables on the dependent variables of the model in a similar way to multivariate analysis techniques (Schumacker & Lomax, 2016; Wu et al., 2017).

In factor analysis studies using SEM, various sources suggest the importance of testing the measurement validity of newly created instruments (questionnaires), or even existent instruments applied in new types of contexts (Fabrigar, MacCallum, Wegener, & Strahan, 1999; Mardani et al., 2017). This validation can be performed through an Exploratory Factor Analysis (EFA), which is carried out previously to the SEM (Rahman et al., 2017; Wang et al., 2016). The idea behind EFA is to identify latent structures by "grouping" similar items through iterative statistical processes, which would become the groups that are subsequently included in SEM. During this step, items that are considered to not be sufficiently related to the various latent constructs, are discarded in order to have a "cleaner" dataset for the SEM stage (Nikolaou, Basbas, & Politis, 2020).

For this study, the TPB framework was used as the base for the research design, which then was validated and analyzed through an EFA-SEM approach. The behaviors investigated occur at the household level, which is considered the unit for the study.

In the context of this study, backyard burning behavior refers to the act of burning any type of waste generated by the household, whether it occurs inside the dwelling property or outside in the house's curbside. Illegal dumping behavior refers to the act of taking any type of household waste to any place that is not the household curbside's floor or waste deposit, where it is collected by the public collection service. Common types of illegal dumping include taking the waste to other neighbors' waste containers, abandoned fields, green spaces, and water canals.

Regarding the positive behaviors, "source separation" refers to the act of separating at least some types of materials from the waste, independently of the posterior use of this material. In this case households can engage in the behavior to use the materials themselves, to deliver the recyclable materials to the separate collection service, to donate the material to actors who can process the material themselves (informal waste pickers) or just to deliver the waste in separate bags to the regular collection service. In this sense, "recyclables donation" refers to purposely give away the recyclables material to any actor that dedicates to recovery activities. "Recyclables selling" refers to households that separate recyclables from their waste as a way to generate income for themselves. "Use of drop-off station" refers to people giving away their recyclables in any of the drop-off stations existing in the city.

2.3.3.2.1 Data collection

The questionnaire, applied through tablets, was designed based on a literature review of similar studies, the TPB framework, and the researchers' knowledge of the local context. Due to the possible limitations of TPB (Section 2.3.3.2), items for measuring additional constructs related to knowledge, satisfaction and habits were included, as well as observable variables related to socio-economic aspects of the household and characteristics of the neighborhood. Variables related to the latent constructs were measured through a 6-point Likert type scale, from 1 = “Strongly disagree” to 6 = “Strongly agree” with exception to 6 items related to knowledge and attitude, in which case it was more coherent to use a dichotomous scale (Yes/No). Although enumerators were instructed to avoid its use as much as possible, an option of “No Response/Non applicable” was contemplated in case it was needed during the application of the questionnaire.

It was expected that the factors for positive (separation, recycling and use of the drop-off facilities) and negative behaviors (dumping and burning) would have common factors affecting them, which is why the analysis was done separately for these two groups. Table 2.10 shows all the items used for the latent constructs' measurement, for each of the groups: Group 1(Negative Behaviors) and Group 2 (Positive Behaviors).

Table 2.10: Items for latent constructs measurement

Const.	Question	Group 1	Group 2	Reference
S	I am satisfied with the collection service frequency	✓	✓	Adapt. (Babaei et al., 2015; Isa, Asaari, Ramli, Ahmad, & Siew, 2005)
S	I am satisfied with the collection service infrastructure (collection trucks/containers)	✓	✓	Adapt. (Babaei et al., 2015; Isa et al., 2005)
S	I am satisfied with the collection service quality (cleanliness, schedule compliance)	✓	✓	Adapt. (Babaei et al., 2015; Isa et al., 2005)
S	In general, I am satisfied with the solid waste management in the city	✓	✓	Adapt. (Sekito et al., 2013)
S	I am satisfied with the communication activities of the collection services (delays info, call center)	✓	✓	Adapt. (Babaei et al., 2015; Chung & Lo, 2004)
S	I am satisfied with the education I receive about solid waste management	✓	✓	Original
S	The collection service takes care of all the types of waste that my household generates	✓	✓	Original
A	It is important to take out the garbage only in the designated days and times	✓		Adapt. (Knussen et al., 2004)
A	Would you be willing to pay more for the solid waste management service?	✓		(Babaei et al., 2015)
A	I do not care about what happens with my household waste after I take it out to the street (R)	✓		Adapt. (Lin Xu et al., 2017)
AK	Inadequate SWM practices cause health problems	✓		(Bhawal Mukherji, Sekiyama, Mino, & Chaturvedi, 2016)
AK	Inadequate SWM practices cause pollution	✓		(Bhawal Mukherji et al., 2016)
CK	Did you know that there is a law that requires all households to have a waste container in their curbside?	✓		Original
CK	I know there is a collection service call center	✓		Adapt. (Chung & Lo, 2004)
CK	I have a good knowledge of the collection service schedule	✓		Original
CK	I know the guidelines for waste delivery for the collection service	✓		Adapt. (Strydom, 2018)
CK	I know the adequate procedure to dispose all the types of waste that my household generates	✓		Adapt. (Strydom, 2018)
PBC	It is difficult to take out the garbage only in the designated days and times	✓		Adapt. (Nguyen, Zhu, & Le, 2015; Lin Xu et al., 2017)
PBC	I sometimes do not know what to do with some types of waste generated in my home	✓		Adapt. (Strydom, 2018)
SN	My family thinks it is important to follow good SWM practices in the household	✓		Adapt. (Knussen et al., 2004)
SN	My neighbors do not care about good SWM practices (R)	✓		Adapt. (Knussen et al., 2004)
A	I like burning waste	✓		Original
A	I feel bad when I burn waste or when I see my neighbors burning waste (R)	✓		Adapt. (Nguyen et al., 2015)
AK	Backyard burning can cause health problems	✓		(Bhawal Mukherji et al., 2016)
AK	Backyard burning contributes to pollution	✓		(Bhawal Mukherji et al., 2016)
B	My household burns waste	✓		Adapt. (Chung & Lo, 2004)

B	My household has burnt waste frequently in this year (once a week)	✓		Adapt. (Knussen et al., 2004)
H	My household has always burnt our waste	✓		Adapt. (Knussen et al., 2004)
I	I intend to keep burning waste in the future	✓		Adapt. (Stoeva & Alriksson, 2017)
I	I will try to dispose my household waste without burning it in the future (R)	✓		Adapt. (Stoeva & Alriksson, 2017)
PBC	I do not get any benefit from burning waste (R)	✓		Adapt. (D. Zhang et al., 2015)
PBC	It is easy to dispose my household waste without having to burn it (R)	✓		Adapt. (Knussen et al., 2004; D. Zhang et al., 2015)
SN	My neighbors do not think backyard burning is wrong	✓		Adapt. (Knussen et al., 2004)
SN	My friends think burning waste is not ok (R)	✓		Adapt. (Knussen et al., 2004)
A	I feel bad when I dump waste or when I see my neighbors dumping waste (R)	✓		Adapt. (Nguyen et al., 2015)
A	I do not think illegal dumping is wrong	✓		Original
AK	Illegal dumping practices contributes to pollution	✓		Adapt. (Bhawal Mukherji et al., 2016)
AK	Illegal dumping practices affects neighborhood's aesthetics	✓		Adapt. (Bhawal Mukherji et al., 2016)
AK	Illegal dumping practices contribute to urban floodings	✓		Adapt. (Bhawal Mukherji et al., 2016)
B	My household dumps waste in unauthorized places	✓		Adapt. (Chung & Lo, 2004)
B	My household has dumped waste in unauthorized places frequently this year (once a week)	✓		Adapt. (Knussen et al., 2004)
H	My household has always dumped our waste	✓		Adapt. (Knussen et al., 2004)
I	I intend to keep dumping waste in the future	✓		Adapt. (Stoeva & Alriksson, 2017)
I	I want to stop dumping waste in the future (R)	✓		Adapt. (Stoeva & Alriksson, 2017)
PBC	It is damaging for my household not to dump waste	✓		Adapt. (D. Zhang et al., 2015)
PBC	It is easy to dispose my household waste without having to dump it (R)	✓		Adapt. (Knussen et al., 2004)
SN	My family thinks illegal dumping is wrong (R)	✓		Adapt. (Knussen et al., 2004)
SN	My neighbors think that illegal dumping waste is ok	✓		Adapt. (Knussen et al., 2004)
A	I think recycling is important		✓	Adapt. (Lin Xu et al., 2017)
A	I like to separate my household waste		✓	(Lin Xu et al., 2017)
A	I think source separation is a waste of time (R)		✓	Adapt. (Lin Xu et al., 2017)
A	I think donating recyclable material is good		✓	Adapt. (Lin Xu et al., 2017)
AK	Waste separation improves the working conditions of wastepickers		✓	Adapt. (Bhawal Mukherji et al., 2016)
AK	Recycling activities contribute to pollution reduction		✓	Adapt. (Bhawal Mukherji et al., 2016)
AK	Recycling activities reduce the amount of waste landfilled		✓	Adapt. (Bhawal Mukherji et al., 2016)
AK	I know there is a sector of informal wastepickers that gains their livelihoods by selling recyclables materials to industries		✓	(Bhawal Mukherji et al. 2016
AK	I know there is a recycling industry in the city that uses recyclable material recovered from waste		✓	(Bhawal Mukherji et al. 2016
AK	Did you know that there are drop-off facilities in the city where you can take your recyclable material?		✓	Original
AK	Did you know there is a separate collection service in some areas of the city?		✓	Original

CK	Do you know where the drop-off facilities are located and which materials you can bring?	✓	Original
CK	I know the difference between organic and inorganic waste	✓	(Bhawal Mukherji et al. 2016
CK	I know which materials can be recycled	✓	(Babaei et al., 2015)
PBC	It is difficult for me to donate or sell recyclable material from my household waste (R)	✓	Adapt. (Nguyen et al., 2015)
PBC	Conducting the waste separation at home takes too much time (R)	✓	Adapt. (Lin Xu et al., 2017)
PBC	It is/it would be easy to separate the waste at home	✓	Adapt. (Lin Xu et al., 2017)
PBC	It is/it would be difficult for me to take recyclables to the drop-off facilities (R)	✓	Adapt. (Stoeva & Alriksson, 2017)
S	I am satisfied with the amount and location of dropping facilities in the city	✓	Adapt. (Stoeva & Alriksson, 2017)
S	I am satisfied with informal recycling activities	✓	Adapt. (Chung & Lo, 2004)
S	Im am satisfied with the level of recycling activities in the city	✓	Adapt. (Stoeva & Alriksson, 2017)
SN	My family needs source separation is not necessary (R)	✓	Adapt. (Lin Xu et al., 2017)
SN	My family does not care about recycling (R)	✓	Adapt. (Lin Xu et al., 2017)
SN	My friends/colleagues think recycling is good	✓	Adapt. (Lin Xu et al., 2017)
SN	My friends/colleagues think separating waste at the source is good	✓	(Lin Xu et al., 2017)
B	I usually separate at least some recyclables materials from my household waste	✓	(Stoeva & Alriksson, 2017)
B	I have never separated my household waste (R)	✓	
I	I intend to separate my household waste in the future	✓	Adapt. (Stoeva & Alriksson, 2017)
I	I want to separate at least some materials from my waste in the future	✓	Adapt. (Stoeva & Alriksson, 2017)
B	I usually give away recyclable material	✓	Adapt. (Nguyen et al., 2015)
I	I will try to take some recyclable materials to the drop-off facilities	✓	Adapt. (Stoeva & Alriksson, 2017; Strydom, 2018)
B	I usually sell recyclable material	✓	Adapt. (Nguyen et al., 2015)
B	I usually take recyclable material to the drop-off facilities	✓	Adapt. (Nguyen et al., 2015)
I	I will try to donate/keep donating my recyclables materials in the future	✓	Adapt. (Nguyen et al., 2015)

Note: S= Satisfaction; A= Attitude; SN= Subjective Norm; PBC=Perceived Behavioral Control; H=Habit; AK= Abstract Knowledge; CK=Concrete Knowledge; I=Intention; B=Behavior; L=Likert; D=Dichotomous; (R) = Scale reversed

Regarding the sampling, it was expected that besides the latent constructs, the behaviors would be influenced by observable factors such as socio-economic (e.g. education, income) and geographical characteristics (e.g. household location, neighborhood characteristics). This hypothesis determined the sampling method selection, which took a different approach than the one in the previous study (Section 2.3.3.1.1). While generation rates are expected to be influenced primarily by consumption habits related to income and other socio-economic characteristics, leading to a sampling based on income areas, for the household practices assessment it was important to use a sampling approach that allowed as much geographical variety as possible to observe possible differences related to the geographical aspect. Therefore, it was decided to use a systematic sampling consisting in 30 random points throughout the city generated with ArcGIS and the selection of around 10 households per point through a systematic rule previously established (Figure 2.9). A total of 348 households were surveyed between August and September 2019, among which, 38 respondents did not accept to participate in the survey or argued not having enough knowledge about the household solid waste management practices. After the data screening process, 5 households were discarded for having high levels of unanswered questions, resulting in a final sample of 305 households with valid answers.

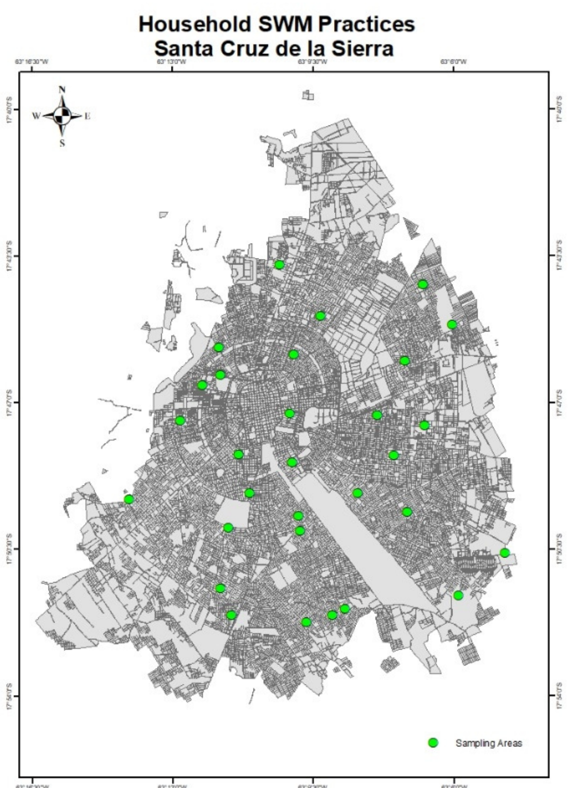


Figure 2.7 Location of sampling areas for Household SWM Practices surveys

2.3.3.2.2 Data analysis

During the data screening, items were revised in order to confirm the level of missing data, which for more than 90% of the items was under 5%. For the other 10% of the items, missing data was under 30%, which is considered common in behavioral studies (Dong & Peng, 2013). For factor analysis, studies have found that below 30% of missing data there use advanced imputation methods such as linear trends is not necessary (S. F. Chen, Wang, & Chen, 2012; Dong & Peng, 2013; Enders, 2003). Therefore, this study followed a simpler approach, substituting missing values in the dataset with the sample mean for continuous variables and sample median for categorical and dichotomous variables (Huang & Zhu, 2002; Jönsson & Wohlin, 2006).

As mentioned in Section 2.3.3.2.1, EFA was used to confirm the validity of the measurement instrument and, if necessary, discard the items that might not be adequately reflecting the latent constructs. In order to do that, the items for each group of behaviors were analyzed separately in SPSS, using factor analysis tool. The extraction method was Principal Axis Factoring, which is one of the most widely used methods (Hinkin, 1998), due its flexibility of application for any type of sample distribution, and the smaller probability of producing distorted results in case of non-normality (Fabrigar et al., 1999). Rotation method used was Varimax, which is also the preferred type of rotation in applied social sciences research, due to the simplicity in the interpretation of solutions (Brown, 2015; Fabrigar et al., 1999).

The factors' determination process is iterative in nature. Every time it is run, it provides a number of factors (latent constructs), classifying each item ideally in only one factor. Each item presents a "loading factor" which according to most literature should be > 0.4, representing the "correlation strength" with the factor (Brown, 2015; Watkins, 2018). Additionally, overall indicators of adequacy such as KMO>0.5 suggest that the factor analysis is suitable for all the items included (Nikolaou et al., 2020). Variables which are under the cut-off value should be removed from the analysis, and factors' number adjusted accordingly before starting a new iteration. The procedure is continued until all the variables included in each factor are above the cut-off value (Brown, 2015; Hinkin, 1998). Once the final factor structure is achieved, internal reliability is validated, which in this study was done through Cronbach's Alpha test, which according to literature should result in values ideally >0.7 (Bonett & Wright, 2015; Stoeva & Alriksson, 2017). Dependent variables such as intention and behavior were analyzed separately due to the possibility of results distortion, considering the expected strong relation between items measuring these variables with influencing factors (Brown, 2015).

During EFA analysis, it was found that the measurement instrument did not reflect completely adequately all the TPB constructs for either of the 2 groups of behaviors, having to modify the original approach in order to use factors that reflect more appropriately the empirical outcome of the EFA. Additionally, considering that recyclables donation, recyclables selling, and use of dropp-off facilities behaviors were detached from the separation behavior, and that each of them is only measured by one item, they were not considered for the first stage of SEM, and just included directly in the second part.

Once the constructs measurements were validated through the EFA, the next stage was the SEM analysis. The first part of SEM, consisting in the measurement model (Section 2.3.3.2.1) served to confirm the results obtained in the previous step, through more advanced tools. In this sense, the data from SPSS was directly imported in its added module, AMOS. During this stage, a variety of indexes were verified to confirm the model fit, convergent validity, and composite reliability for both groups.

For the second part of the SEM, a causal model including the latent variables and the observable variables was created in order to test possible influences in the behavior variables previously mentioned. Table 2.11 shows the observable variables included in this last step. For each of them, the hypothesized influences were established in the model, which was then run in order to estimate the standardized coefficients for each of them and verify the model fitness indexes. As long as acceptable fitness were not achieved, paths that are not significant were deleted, and ultimately variables that did not have any significant path (Gallagher, Ting, & Palmer, 2008; Weston & Gore, 2006).

Table 2.11: Observable variables for SEM of Household SWM Practices

Variable	Description	Negative Behaviors	Positive Behaviors
Income per capita	Monthly per capita income in BOB/person	✓	✓
Household head education	Number of years of education of the household head	✓	✓
Distance to the city center	Concentric ring where the household is located. Values from 1 to 9	✓	✓
Stray animals prevalence	Prevalence of stray animals seen in the neighborhood. 1= No stray animals, 2 = Some stray animals (1 to 3 daily); 3= Many stray animals (More than 3 daily)	✓	
Collection frequency	Number of days per week that the collection truck passes by the neighborhood	✓	
Household collection service	Door to door collection in the household. Waste collected from the door = 1; Waste collected from other place=0	✓	
Separate Collection	Separate collection service in the neighborhood. Separate collection = 1; No separate collection = 0		✓
Waste pickers frequency	Frequency of wastepickers passing by the neighborhood. 1 = Never; 2 = Every 2 months; 3 = Once a month; 4 = Once a week; 5=Few times a week; 6=Many times a week		✓

2.3.3.3 Informal waste picking activities

The last practice assessed for Obj. 3 corresponded to the informal waste picking activities in the city. As mentioned in Sections 2.2.3 and 3.3.3, these activities represent the starting point of the recycling chain, being responsible for almost all the recyclable material recovered in the city.

In this regard, informal waste picking activities were mapped in the CLD created in Objective 2 (Chapter 4) as one of the main practices contributing to the sustainability of the local MSWM system. These activities depend partly on the household SWM practices (Section 2.3.3.2) and directly influence the amount of recyclable material collected and disposed in the local landfill. Furthermore, they contribute to the subsistence and income generation of underprivileged sectors of the population, which represents an important positive social impact.

Research on waste picking activities has increased in the last decades due to the predominant role of the sector in the developing world, and the need to implement circular economy approaches appropriate for the context, which could benefit from their inclusion (Rojas C., Yabar, Mizunoya, & Higano, 2018; Wilson et al., 2009). However, the informal sector in general, and specifically for the waste picking activities has been difficult to approach with research purposes (Linzner & Lange, 2013), requiring a deep understanding of the context and a careful planning of research activities. On one side, the stigma that has traditionally surrounded occupations related to waste management, particularly in the informal sector, has contributed to feelings of shame and mistrust from potential respondents, leading to the need of ethnographic approaches that allow to build trust with participants and gain a better understand of their practices. On the other side, the precarious estate of the activity, regarding the working locations, schedules, lack of registry of commercial operations, to name a few, has difficulted the collection of quantitative data, resulting in a predominance of studies using qualitative methods (Schenck, Blaauw, & Viljoen, 2016).

Regarding studies using quantitative methods, many of them have focused on descriptive statistics (Andrianisa, Brou, & Séhi bi, 2016; Kawai & Osako, 2013; Majeed et al., 2017; Steuer, Ramusch, Part, & Salhofer, 2017), while a few others have focused on statistical tests such as ANOVA , or regression analysis (Navarrete-Hernandez & Navarrete-Hernandez, 2018; Sembiring & Nitivattananon, 2010; Singh & Chokhandre, 2015).

The present study uses path analysis as a way to identify factors influencing main outcomes of waste picking activity. While to the best of our knowledge no study has used path analysis for the study of waste picking activities, it has been used in researches with similar approaches in the solid waste management field (Dai & Shan, 2020; J. Ma et al., 2018; Lilai Xu et al., 2016)

For the present study, previous contact was made with some of the leaders of the main networks and smaller associations in the city (Section 3.3.3), to inform them about the intention to conduct the study and obtain their "approval". In this sense, in case of approaching a waste picker that belonged to any of these networks they were reassured that the information provided would be used only with academic purposes, and that their leaders did not have any objection with the data collection. Additionally, before the questionnaire design, some associations accepted to show their facilities and allowed to observe their activities. In order to avoid any disturbance during the collection of the recyclable materials, a few waste pickers were asked to self-video-record their activities for a few hours during one day through action cameras attached to their bodies. These video-recordings allowed to further understand the characteristics of the activity to improve the questionnaire design, sampling, and results interpretation.

2.3.3.3.1 Data collection

The study was carried out for approximately one week in September 2019 with a total of 95 waste pickers in different points of the city (Figure 2.10). Similarly to other studies about waste picking activities (Andrianisa et al., 2016; Steuer et al., 2017; Tremblay, Gutberlet, & Peredo, 2010) sampling locations were selected with the objective to obtain as much variety as possible in the sample regarding the respondents' socio-demographic profile, types of material collected and working routines. In this sense, tablet-based surveys were conducted in a total of 22 points in the city, consisting in: a) collecting areas (6 farmers' markets, 1 public waste container); b) selling areas (11 middlemen shops); c) storing areas (3 associations headquarters); d) municipal separation plant, where many of the workers also dedicate to the waste picking activity. Surveys were administered randomly to all the respondents encountered at the sampling location, that would agree to participate in the survey. Additionally, a few surveys were conducted in public areas of the city if a person dedicating to the activity was spotted by an enumerator during the period of the study.

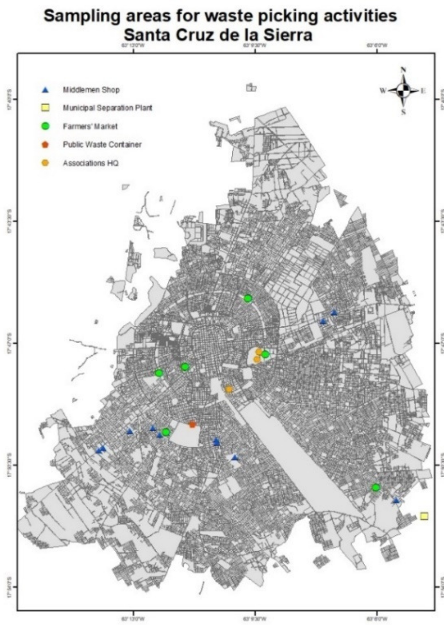


Figure 2.8 Sampling areas for waste picking activities' surveys

The sampling points were identified through the researcher's knowledge of the local context, with the support of some of the leaders of some of the local waste pickers' networks; information from municipal government; private cleansing company and NGO officers; as well as snowball method, by asking about possible new points during the survey implementation. The surveys were conducted at different times of the day and night, and in different days of the week. Great effort was put in the enumerators' selection and training, in order to make sure that the approach to the respondents at the moment of the survey made them feel comfortable. Additionally, in order to assure their participation, and considering that most of them were involved in working activities at the moment of the survey, a small incentive for the participation was offered, consisting in a phone prepaid card for a value of 1.5 USD. Table 2.12 shows the number of surveys obtained per point.

Table 2.12 Points for waste picking activities' surveys

Survey Point	Surveys
Association Storage	8
Waste Container	3
Market	20
Municipal Recycling Plant	7
Selling Point	49
Street	8
Total	**95**

The questionnaire included questions about the respondents and their household general socio-demographic characteristics, waste picking activities, association membership, material recovered and commercialized, equipment used, support received, and health impacts related to the waste picking activity.

2.3.3.3.2 Data analysis

Initially, the data set was screened to identify possible missing data and outliers which could interfere with the analysis. During this process, four surveys were discarded for representing the largest outliers for the monthly income and/or the amount of material recovered in the activity. Two of them corresponded to the first day of the study, which could have resulted in an incorrect input from the enumerator, while no clear reason was identified for the other two.

Subsequently, a path analysis was conducted, using AMOS module for SPSS software in order to identify the factors influencing waste picking activities' outcomes. A causal model including the dependent and independent variables with the hypothesized paths influencing each variable was created, and then run in order to estimate the standardized coefficients for each of them as well as the model fitness. As long as acceptable fitness indexes were not achieved, not significant paths were deleted, and ultimately variables that did not have any significant path. The main dependent variables that were tested were the monthly income generated through the waste picking activity, the amount of material recovered, and the existence of chronic pain due to the activity. Table 2.13 includes the variables that were included in the analysis.

Table 2.13 Variables for path analysis of waste picker activities' outcomes

Variable	Description
Income earned	Monthly income earned in the waste picking activity in BOB (bolivian pesos)/month
Material recovered	Amount of material in kg. recovered per month
Storage	Storage process before selling. 1=Does not store the material; 2 = Stores the material
Transport Equipment	Weighted sum of all the transportation equipment used during the activity. Each transportation equipment was assigned the following weights: 1= Pushing Cart, Bike, TrolleyCart , Wheelcart; 2 = Motorcart, horsecart; 3 = Small truck, car
Working Hours	Number of working hours per week
Association	Association membership. 1=Does not belong to association; 2=Belongs to association
Education	Number of years of education of the respondent
Dwelling ownership	Type of ownership level of dwelling. Homeless=1; Borrowed=2; Rented=3; Leased=4; Owned=5

Preparation Equipment	Use of equipment for the material preparation before selling (e.g. press, grinder) 1=No equipment use; 2=Equipment use
Cooperation storage	Cooperation during the storage activity (e.g. sharing storage facility, help in the storing activities) from family, friends or association. 1=No cooperation; 2=Cooperation
Cooperation material preparation	Cooperation during the material preparation activity (e.g. cleaning, cutting, packing the material) from family, friends or association. 1=No cooperation; 2=Cooperation
Chronic pain	Number of body areas with chronic pain from the following: a) Neck; b) Shoulders; c) Hands; d)Upper back; e) Lower back; f) Knees; g) Thighs; h) Calfs; i) Ankles; j) Feet;

2.3.4 System dynamics modeling of Municipal Solid Waste Management system's elements

The system dynamics modeling conducted in this study is based on the results of the study explained in Section 2.3.2, which was conducted previously through a Group Model Building (GMB) technique with representatives of the main stakeholder groups involved in the MSWM activities in the city. That process resulted in the creation of a Causal Loop Diagram (CLD), which was divided in five modules: waste generation, common SWM practices, separation practices and recycling activities, waste disposal and main flows and costs.

The CLD was a first step for the use of a system dynamics modeling approach to explore the impacts of MSWM in the city. Subsequently, due to the lack of reliable secondary data for the simulation stage and in order to validate the main causal relationships established by stakeholders in the CLD, the three empirical studies that were explained in Section 2.3.3 were conducted.

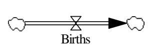
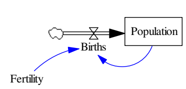
The waste characterization study (Study 1) (Section 2.3.3.1) was conducted in households in order to determine the waste generation per capita, waste composition and factors influencing waste generation. Data from this study was used for the estimation of waste generation and the potential recyclable material in the model. Study 2 consisted in determining the prevalence of various solid waste management practices at households in the city (Section 2.3.3.2). Data from this study was used for the estimation of backyard burning, illegal dumping, and separating rates in the city, as well as other aspects related to the collection service. Study 3 was conducted in order to investigate the characteristics of informal waste picking activities, their outcomes and determine the main factors influencing these outcomes (Section 2.3.3.3). Data obtained from this study was used in the model for the estimation of the informal recyclables recovery rates, and income generation for waste pickers. Finally, it is important to mention that these results not only served to generate data inputs for the model and estimate the equations for causal relationships, but also to validate and improve the causal relationships that were originally established in the CLD through the participatory model building technique. In this sense, modifications to the original CLD were directly included in the stocks and flow diagram presented in the results section.

The model also uses secondary data as the source for some of the variables included, or to validate the results of calculations carried out in the simulations. For the variables related to population, household numbers and proportion of children, secondary data was gathered from National Census (INE, 2012) and National Households Survey (INE, 2018) reports. Secondary data related to the formal MSWM system was obtained from national and local governmental reports (Ministerio de Medio Ambiente y Agua, 2011a, 2011b). Secondary data related to waste pickers activities was obtained from one of the few studies conducted in the city (Caceres et al., 2014).

2.3.4.1 Stocks and flows diagram

Stocks and flows diagrams (SFDs) are the following stage in system dynamics modeling, after the creation of CLDs (Yearworth, 2014). These graphs describe the system structure by establishing additional types of variables depending on the information they represent. These variables can be represented as "flows" when they contain information about elements changing their value through time, and which are usually intended to increase or decrease the value of a cumulative variables with are represented by "stocks". Stocks are variables intended to cumulate values over time, which are affected by incoming or outgoing flows (Meadows, 2008; Sterman, 2000). Table 2.14 displays the most important elements of stock and flows diagrams.

Table 2.14 Stocks and flows diagram elements and notation

Element	Representation	Description
Variable	Fertility	Any kind of element (quantitative or qualitative) that takes part of the system, whose value can increase or decrease over time. Represented by a word or short phrase
Flows		Also called "rate" variables. Represent change over time. Used to increase (inflow) or decrease (outflow) the value of stocks.
Stocks	Population	Also called "level" variables. Integrates or cummulates inflows and outflows over time.
Feedback		Effect from a stock on its inflows, outflows or the stock itself.

Adapted from Yearworth, 2014

The transformation process from CLDs to SFDs is not a simple one. While both types of diagrams have benefits, CLDs are often criticized for their lack of detail about the variables and links behavior (Richardson, 1986), while SFDs are considered to have an excessive complexity, making them only accessible to experts (Binder et al., 2004). In this sense, although CLDs are often used as the start of the modeling process, particularly in the case of participatory approaches (Malard et al., 2015; K. A. Stave & Dwyer, 2005), the transformation to SFDs requires the inclusion of additional variables, revision of causal links, and definition of the element typology (i.e. variable, stock or flow) (Binder et al., 2004). This process is iterative by nature and requires constant revision of previous steps (Sterman, 2000; Wolstenholme, 1999) (Figure 2.11), being highly recommended to start simulation process as early as possible (Sterman, 2000).

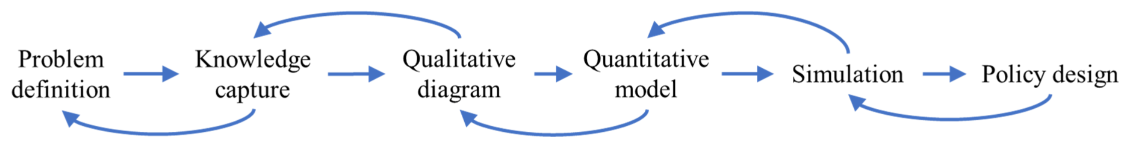


Figure 2.9: System dynamics modeling process. Adapted from (J. W. Forrester, 1994; Wolstenholme, 1999)

In the case of system dynamics modeling applied to the solid waste management field, the aim is usually to estimate dynamic effects from diverse variables (influencing factors) on waste amounts or effects of waste amounts in other variables (impacts) in different parts of the system (e.g. generation, collection, recycling, disposal). Therefore, waste amounts are usually modeled as stocks (Ding et al., 2016; Kollikkathara et al., 2010; Sukholthaman & Sharp, 2016). Other variables that are also frequently modeled as stocks are the ones related to costs, incomes, budgets or other monetary values that need to be integrated over time (Giannis et al., 2017; Karavezyris et al., 2002; Sukholthaman & Sharp, 2016). This is the approach that was followed in the present study, having all variables related to population, waste amounts, costs, and waste pickers capital modeled as stocks. Variables affecting directly the stocks were modeled as flows.

Table 2.15 shows a list of the variables included in the model, their units, input data sources and validation data sources when it is applicable. As mentioned in Section 2.3.4, key variables values and calculation procedures were obtained from empirical studies conducted after the qualitative diagram stage, while other variables values were obtained from secondary data. For some variables currently there is not a primary or secondary data source available, in which case assumptions about their possible values were made for the data input. When possible, these assumptions were made with approximations to existing data and in the rest of cases conservative approaches were taken for the value assignment, in order to avoid oversizing their possible effects. Additionally, in cases were a variable value resulted from the simulation process in the model and available secondary data existed, this was used as a way to validate the results obtained for the start of the simulation period.

Table 2.15: Variables included in stocks and flows diagram

N°	Abbrev.	Variable	Unit	Input Data	Validation Data
1	AA	Additional activity	%	Study 1	
2	AC	Additional collection	Kg/day	Modeled	
3	ACC	Additional collection capacity	%	Assumption	
4	ACSC	Additional collection service cost	USD/day	Modeled	
5	AM	Association membership	Dimensionless	Study 3/Secondary	
6	AR	Acceptance rate	%	Assumption	
7	ARM	Available recyclable material	Ton/day	Modeled	
8	AT	Attitude	Dimensionless	Study 2	
9	BBR	Burning behavior ratio	%	Modeled	
10	BI	Burning incidence	Household	Modeled	
11	BINT	Burning interval	/day	Modeled	
12	BR	Burning rate	%	Modeled	
13	C	Capital	BOB	Modeled	
14	CC	Collection coverage	%	Secondary data	
15	CH	Percentage of children per household	%	Secondary data	
16	CK	Concrete knowledge	Dimensionless	Study 2	
17	CP	Commercialization profit	BOB/day	Modeled	Study 3, secondary data
18	CR	Collection rate	%	Modeled	Secondary data
19	CSC	Collection Service Cost	USD/day	Modeled	Secondary data
20	CSP	Collection Service Price	USD/ton	Secondary data	
21	DBR	Dumping behavior ratio	%	Modeled	
22	DC	Daily commercialization	Kg/day	Modeled	Secondary data
23	DI	Dumping incidence	Household	Modeled	
24	DINT	Dumping interval	/day	Assumption	
25	DR	Dumping rate	%	Modeled	
26	EI	Equipment investment	BOB	Assumption	
27	FR	Formal recovery	Ton	Modeled	Secondary data
28	FRR	Formal recovery rate	Ton/day	Modeled	Secondary data
29	GD	Generation per day	Ton/day	Modeled	Secondary data
30	GPCD	Generation per capita day	Kg/day	Modeled	Secondary data
31	GSS	General service satisfaction	%	Study 2	
32	HH	Number of households	Household	Secondary data	
33	ICR	Informally commercialized recyclables	Ton	Modeled	
34	ICRR	Informally commercialized recyclables	Ton/day	Modeled	
35	IR	Informal recovery	Ton	Modeled	Secondary data
36	IRR	Informal recovery rate	Ton/day	Modeled	Secondary data
37	LC	Landfilling cost	USD/day	Modeled	Secondary data
38	LK	Local context knowledge	Dimensionless	Study 2	
39	LR	Landfilling rate	Ton/day	Modeled	Secondary data
40	LSP	Landfilling service price	USD/ton	Secondary data	
41	MH	Members per household	Capita	Study 2,	
42	MPE	Material preparation equipment	Dimensionless	Assumption	
43	P	Price	BOB/Kg	Secondary data	
44	PBHH	Potential burning per household	Kg/day	Modeled	
45	PDHH	Potential dumping per household	Kg/day	Modeled	
46	PG	Population growth	Capita	Modeled	Secondary data
47	PGR	Population growth rate	%	Secondary data	
48	POP	Population	Capita	Secondary data	
49	PSHH	Potential separation per household	Kg/day	Modeled	
50	PWB	Percentage of waste burned	%	Assumption	
51	PWD	Percentage of waste dumped	%	Assumption	
52	PWS	Potential waste separation	%	Study 1, Study 2	
53	RE	Recovery efficiency	Dimensionless	Modeled	
54	RS	Recyclables separated	Ton	Modeled	
55	SB	Separation behavior	Dimensionless	Modeled	
56	SC	Separate collection	%	Study 2	
57	SCQ	Separate collection quality	Dimensionless	Study 2	
58	SI	Separation incidence	Household	Modeled	
59	SR	Separation rate	Ton/day	Modeled	
60	TCC	Total collection cost	USD/day	Modeled	Secondary data
61	TE	Transport Equipment	Dimensionless	Study 3	

62	UG	Unplanned growth	Dimensionless	Assumption	
63	WB	Waste burned	Ton	Modeled	
64	WC	Waste collected	Ton	Modeled	Secondary data
65	WD	Waste dumped	Ton	Modeled	
66	WG	Waste generated	Ton	Modeled	Secondary data
67	WL	Waste landfilled	Ton	Modeled	Secondary data
68	WME	Waste management expenditure	USD	Modeled	Secondary data
69	WP	Number of waste pickers	Capita	Secondary data	
70	WPP	Waste picking productivity	Kg/day	Secondary data	
71	WSR	Waste picker saving rate	%	Assumption	

2.3.4.2 Software simulation

The SFD creation and the software simulation were done through Vensim software. The software facilitates the visual programming through the creation of the different types of variables and the manual definition of equations to determine their dynamics. In the present study, equations were primarily constituted by basic mathematical operations, with few others being graphically defined. The default variable "time" was used to determine the dynamics of some variables over time such as the ones related to socio-demographic changes. A minimum period of 8-10 years is usual in MSWM studies (Dyson & Chang, 2005; Karavezyris et al., 2002; Kollikkathara et al., 2010; Sukholthaman & Sharp, 2016), with some cases conducting simulations over 15, 20, 30 or 50 years (Cai & Liu, 2013; Ghisolfi et al., 2017; Oyoo et al., 2011; Wäger & Hilty, 2002), depending on the specific purposes of the simulation. For the present study, considering the exploratory purpose, the simulation process was carried out for a period of 10 years with a time-step of 1 month. The monthly time-step was determined as a way to facilitate the revision and results validation according to the secondary data available.

Major assumptions used in the model are the following:

1. Population growth rate (PGR) is assumed to be constant. Members per household (MH) and percentage of children (CH) are assumed to decrease based on trends from previous years.
2. Recyclables materials are modeled at an aggregate level (i.e. no differentiation between plastics, metals, etc.) and their proportion in waste is assumed to increase over time.
3. Sufficient demand for recyclable materials during the whole period of the simulation is assumed.
4. Waste picker sector is modeled at the aggregated level for the estimation of the informal recovery amounts, and at the individual level for the estimation of their income. No differentiation among waste pickers was done (e.g. associated, non-associated, part-time, full-time)
5. Waste generated at each step is processed within the same step.
6. Additional collection services will capture at least 30% of all the waste dumped daily

The model was run for a baseline scenario representing the current conditions. Additionally, scenarios were created in relation to two types of interventions: on one side, interventions in order to reduce the effects of backyard burning and illegal dumping practices, and on the other side interventions to support informal waste picking activities vs improving formal recyclables recovery. The scenarios are classified in "Baseline", reflecting the outcomes under no change over time in the leverage variables, "High" when these variables are assumed to progressively increase over time, and "Low" when these variables are assumed to progressively decrease over time. Table 2.16 shows the values used for the leverage variables in the simulation of each scenario. The scales for each variable are not comparable as they are modeled using different scales

Table 2.16: Conditions for scenarios' simulation

Variable	**Baseline**	**High**		**Low**	
		5th year	**10th year**	**5th year**	**10th year**
UG	0.6	0.7	0.77	0.5	0.45
GSS	0.1	0.13	0.15	---	---
CK	0.66	0.71	0.75	---	---
SC	0.18	0.28	0.38	---	---
SCQ	0.33	0.4	0.45	---	---

CHAPTER 3

INSTITUTIONAL ANALYSIS OF MSWM IN SANTA CRUZ DE LA SIERRA

3.1 Introduction

The importance of institutional and governance aspects in the study of MSWM systems in developing countries has been highlighted since the early 2000s, through approaches such as the ISWM framework (Section 1.2). More recently, paradigms such as the multi-level perspective on socio-technical transitions (MLP) have started to be applied in order to discuss the influence and interactions of factors across different levels, allowing to also include the temporal perspective into these debates. Moreover, in the case of the MLP framework, it has been suggested to use it in combination with modeling techniques as a way to bridge the gap between analytical approaches and governance challenges (Turnheim et al., 2015), although the application of these methods for MSWM systems has been scarce (Sections 1.3 – 1.5).

Santa Cruz de la Sierra is a city that has experienced a rapid economic growth in the last decades, leading to an urban demographic and territorial transition, impacting also MSWM systems (Section 2.2.2). These technological and organizational changes in MSWM across time are not disconnected from the broader context of the city and Bolivia as a whole.

For the present study, the institutional analysis constitutes the first step in the analysis of the MSWM system in Santa Cruz de la Sierra, providing a broad view of the system and its complexity, with a focus on the governance aspect but also allowing to understand the general material flows in the system; the most important impacts and general mechanisms; as well as changes across time and possible future directions (Section 2.1). It also served as the starting point for the co-design aspect of the thesis, by establishing the first contact with the numerous stakeholders taking part in the system.

This chapter presents the results of Objective 1, displaying: a) the main regulations relevant for MSWM at the national and local level; b) the main stakeholders involved, their roles and interactions; c) the transitions experienced by the system, as well as their barriers and enablers. Discussion and conclusions (Sections 3.5, 3.6) highlight the changes across the different transitions, the importance of various aspects related to the social dimension of MSWM regarding the broader aspects in the societal and political dimensions, for governmental actors, private sector actors and community as a whole.

3.2 Municipal Solid Waste Management Regulations

3.2.1 National regulations

The first attempt to establish policies related to the sustainability of MSWM systems can be traced to the early 1990s, with the ratification of the first comprehensive environmental law, the "Law of Environment". Despite its broad scope and lack of specificity for the solid waste sector (personal comm: C1; F3), it brought the topic to the public agenda and catalyzed the creation of a dedicated governmental office, the "Integrated Solid Waste management Direction (DGIRS) (Caceres et al., 2014) (personal comm: I3; C3; F1). The Law of Mother Earth, raised the importance of adopting sustainable production and consumption practices to protect "mother Earth" (personal comm: A1; D1).

A majority of interviewees indicate that one of the most important milestones in the transition to a more sustainable MSWM was Law 755 on Integrated Solid Waste Management (ISWM Law) in 2015. This was the first legal instrument specifically dedicated to establishing a solid waste management agenda in the country. It represents a paradigm shift from a focus on "cleaning" and disposing waste, to managing resources and include all relevant dimensions and actors (Estado Plurinacional de Bolivia, 2015) (personal comm: K1; F11; A1; A2; D1; K2; I1).

According to most respondents, the most pertinent aspects of the law on sustainability are: (i) the plan to cease operation of all open dumps in the country until 2020; (ii) the recognition of waste pickers activities; (iii) the introduction of Extended Producer Responsibility (EPR) obligations, an approach that extends a producer's operative or financial responsibility beyond the consumption stage (Tong & Yan, 2013); and (iv) the introduction of "authorized operators" schemes. The new law also mentions explicitly the possibility for departmental and local governments to use resources from hydrocarbons exploitation revenues to activities related to ISWM, which was mentioned as an additional positive aspect by some of the interviewees (personal comm: C3; I2).

However, despite the general recognition of the symbolic aspect of the law, there were rather conflicting perceptions among interviewees regarding its actual implementation outcomes. In particular, while most actors believe that the law will have tangible positive impacts (personal comm: C2; G3; C3; C4; F4; I2; B1;A1; I3; F5; D2; F10; C6; C1; D1; C7; A2; I1; F7; H3; H1; H2), others are more pessimistic and consider that the success will heavily depend on the actual implementation and monitoring aspects (personal comm: G2; G3; F6; K1; G1; F12; E1; J1; F8). Some actors even consider that there might be unwanted effects if implementation mechanisms are not adequately planned (e.g., closure of open dumps before new disposal sites are available; more dumping to avoid collection fees payment; decrease in business opportunities for SMEs and informal sector due to excessive requirements; unfair competition due to uneven law enforcement among various private actors) (personal comm: F12; G2; F3).

Many of the interviewees raised the need to create specific regulation for the main topics of the law: (e.g., EPR, waste pickers activities, authorized operators, collection fees) (personal comm: I1; F3; G1; A2; F6; F9). More importantly, many respondents pointed to the need to create mechanisms for the successful implementation at the municipal level (personal comm: C5; C1; F4; F12; I3; A1). It is expected that under the mandate of the national law each prefecture and municipality should create and implement their specific regulations that reflect their local context and particular needs. However, even some years after the enactment of the ISWM law, there are still just a handful of municipalities that have developed new local regulations (personal comm: K2; C1; A1, A2; F12). The lack of local regulations under the umbrella of the ISWM Law was seen as a major challenge that was repeatedly mentioned. Representatives of the national government recognize that the ISWM Law requires specific regulation, for the municipalities to have better means to draft their own statutes (personal comm: A2). This is a task that is still in progress due the limited resources of the DGIRS division (Section 3.3.1) and the need of inter-ministerial consultations (personal comm: A2, A1). On the other side, local representatives, while acknowledging that local regulation is a responsibility of each municipality, insist in the need to wait for clearer guidelines from the national level (personal comm: C3; C2; I1; F5). The main contributions to national regulations for MSWM are summarized in Table 3.1.

Table 3.1 Main national regulation related to Solid Waste Management (Estado Plurinacional de Bolivia, 1992, 2012, 2015)

Policy Document	Main Contribution	Government Division in Charge	Year
Law 1333—Law of the Environment	- Responsibility related to solid waste management for each government level (national, regional and local) - Creation of the department of Integrated Solid Waste Management (Caceres et al., 2014)	Ministry of Sustainable Development and Environment	1992
Law 300—Law of the Mother Earth	- Obligation of the state to promote sustainable consumption habits and to develop mechanisms for an integrated solid waste management	Ministry of Environment and Water	2012
Law 755—Law of Integrated Solid Waste Management and its specific regulation	- First national law specifically dedicated to the regulation of Solid Waste Management. - Mandates the cease of operation of all open dumps in the country until 2020. - Establishes the Extended Producer Responsibility for producers and distributors for specific sectors (e.g., PET bottles, tires, batteries and pesticides, electric and electronic waste) - Recognizes waste pickers activities and mandates authorities to support and promote training and formalization programs. - Raises the need to evaluate and register private actors as “authorized operators” for solid waste management - Allows explicitly the use of the hydrocarbons revenues (IDH) for MSWM projects	Ministry of Environment and Water	2015/ 2016

3.2.2 Local regulations

Tracing the origins of solid waste management regulations in Santa Cruz de la Sierra is difficult due to the lack of publicly available historical information. The first approaches towards MSWM focused only on the city “cleansing” and the collection aspect (personal comm: C3; I1; F1). It is thus possible to assume that the first relevant policies related to the establishment of the organizational aspects of the collection service.

The first autonomous municipal cleansing company, called EMDELU, was created sometime in the 1980s, with the mandate to operate the cleansing services in the city, either on its own or through subcontracting schemes (Ministerio de Vivienda y Servicios Basicos, 2001). EMDELU was terminated in 1999 and substituted by another cleansing company (EMACRUZ) (Rosa & Vespa, 2000), which remains up to now the organization in charge of the MSWM system in Santa Cruz.

Table 3.2 summarizes the main local regulation in the city. Regarding this aspect, several respondents mentioned the 2006 Municipal Law 043/2006 “Basura Cero” (Zero Waste) as a landmark for the sustainability transition of MSWM system in the city (personal comm: C3; C4; F7; H1; K2). According to this law, by 2017 the city should reach a state where there will be no disposal of valuable materials that could be recycled or reused. This is the first municipal law in Bolivia to envision a future where all the recoverable waste would be adequately treated and re-incorporated in productive value chains (personal comm: F7; H1; H3). The law is also visionary in the sense that it recognizes waste pickers labor and mandates the municipality’s financial and technical assistance for waste picker-related projects (Caceres et al., 2014)(personal comm: F7). However, despite its positive aspects, the law was repealed a few years ago, and has been considered a failure by some interviewees (personal comm: C3; C4). Different respondents attributed this to diverse factors: (a) the law was a copy of a foreign law not well-adapted to the local context (personal comm: C3), (b) not receiving the necessary financial resources for implementation (personal comm: C4) or (c) political rivalries within the local government that led to the blocking of funding for the related projects (personal com: F8).

Table 3.2: Local Solid Waste Management regulation in Santa Cruz de la Sierra (Gobierno Autonomo Municipal de Santa Cruz de la Sierra, 2019)

Year	Policy Document	Relevance to MSWM system	Comment
2000	Law 160-A/2000	Creates the Municipal Cleansing Company “EMACRUZ”, to which the Municipal Government delegates the responsibilities for regulating, planning, and supervising solid waste management in the city	Solid waste management is carried out by an autonomous and decentralized entity
2001	Law 030/01—Solid Waste Management	Focuses mainly on cleansing aspects and hazardous waste.	First municipal law to regulate solid waste management
2006	Law 043/06—“Zero Waste”	Aims to reach “zero waste” from recyclable or compostable waste by 2017	First municipal law adopting an integrated and sustainable approach for solid waste management
2016	Law N° 295/16—Urban Cleansing	Establishes the rights and obligations, compliance and sanctions to urban cleansing, aligned with the national Law 755 (Table 3)	Substitutes Law “Zero Waste”. Focus on “cleansing activities”. No reference to integrated or sustainable solid waste management

Currently, Municipal Law 295/16—"Urban Cleansing" is the main legal instrument for MSWM systems, which, at the time of the interviews, is the only municipal law in Bolivia under ISWM Law umbrella (personal comm: A1). While this could be considered as a sign of a strength in terms of regulation, the opinions of some of the interviewees regarding the content of the law (personal comm: A1; F2), and a comparison between the regulation found for each city, point at the idea that this aspect may actually be a weakness in Santa Cruz de la Sierra (personal comm: F2; C3; K1). For instance, the "Urban Cleansing" law mostly focuses on "rights and obligations" of the community and the correspondent sanctions (personal comm: A1) and returns to a "public cleansing" approach, which had already evolved to an integrated and sustainable approach in previous decades, with the "Zero Waste" law.

3.3 Main stakeholders and responsibilities within the Municipal Solid Waste Management system

One of the reasons behind the complexity of MSWM systems and the difficulty of devising and implementing appropriate policies is the wealth of relevant stakeholders. Table 3.3 outlines the stakeholders in the MSWM systems in Bolivia, the main institutions involved and major roles. These stakeholders operate either directly within the MSWM system or at the intersection with other sectors. The radically different roles and agendas of these actors within the MSWM system can facilitate or hinder sustainability transitions as discussed below. Additionally, the main types of flows amongst stakeholders are represented through the SVN displayed in Figure 3.1. Through this graph it is possible to identify the most relevant stakeholders in the system at the moment (i.e. municipal cleansing enterprise, private cleansing company, informal private sector), as well as the main issues identified regarding deficient or unclear involvement in terms of regulations, contractual agreements, and support, to mention some of the most relevant.

Table 3.3: Main stakeholders in the MSWM system

Stakeholder Group	Stakeholder	Main Institutions	Dimension (Physical/Governance)	Element (Collection/Disposal/ 3Rs)	Main Role
Government	National Government	Ministry of Environment and Water	Governance	All	- Formulates the national ISWM policy framework and implementation strategies. - Facilitates access to funding from internal and external sources - Performs capacity building for municipalities
	Prefectural Government	Secretary of Sustainable Development and Environment	Governance	All	- Formulates the prefectural ISWM regulation - Oversees the implementation of ISWM Law in its jurisdiction - Mediates and coordinates joint projects with various municipalities
	Municipal Governments	Municipal Cleansing Enterprise (EMACRUZ)	Physical Governance	All	- Formulate the municipal MSWM regulation - Plan and execute MSWM activities - Monitor and control the negative impacts of MSWM activities
Formal Private Sector	Private Cleansing Companies	VEGA SOLVI	Physical	Collection/Disposal/3Rs	- Execute operational activities according to the specific conditions of municipal contracts
	Recycling Industry (Procesors)	EMPACAR (Plastics), COPELME (Paper/Cardboard), Scrap metal exporters	Physical	3Rs	- Re-introduce the recovered materials into productive value chains
	Consummer Goods' Producers	Drinks industry, electronics Importers, tires Importers	Physical	3Rs	- Implement Extended Producer Responsibility (EPR) measures
Informal Private Sector	Waste pickers	RED DE RECOLECTORES, RECICLA BOLIVIA, ARECICRUZ	Physical	3Rs	- Collect recyclable material and sell it to middlemen and recycling industries.
	Middlemen	Small enterprises	Physical	3Rs	- Accumulate recyclable material collected by waste pickers and improve its quality before selling to industries.
International Organizations	Investors/Donors	Interamerican Development Bank, World Bank, CAF Development Bank of the Americas	Physical	All	- Provide funding for large projects, mainly related to infrastructure provision
	International Cooperation Agencies	JICA (Japan), GIZ (Germany), SDC (Switzerland), KOICA (Korea)	Physical Governance	All	- Facilitate access to external funding - Perform capacity building activities for various actors - Develop and execute joint projects through NGOs and other actors
Civil society and research organizations	NGOs/NPOs	SWISSCONTACT, FUNDARE, AMIGARSE, FUNDACION PAP AVINA	Physical Governance	3Rs	- Develop and execute small/medium projects - Foster collaboration among different actors in the MSWM sector
	Universities	UAGRM, UNE	Physical Governance	All	- Undertake research and knowledge dissemination related to the MSWM sector
	Professionals Associations	Society of Engineers	Physical Governance	All	- Provide advice on issues related to technological development
	Chambers of Industry and Commerce	CAINCO	Physical Governance	3Rs	- Promote MSWM initiatives that benefit the private sector and broader economic development

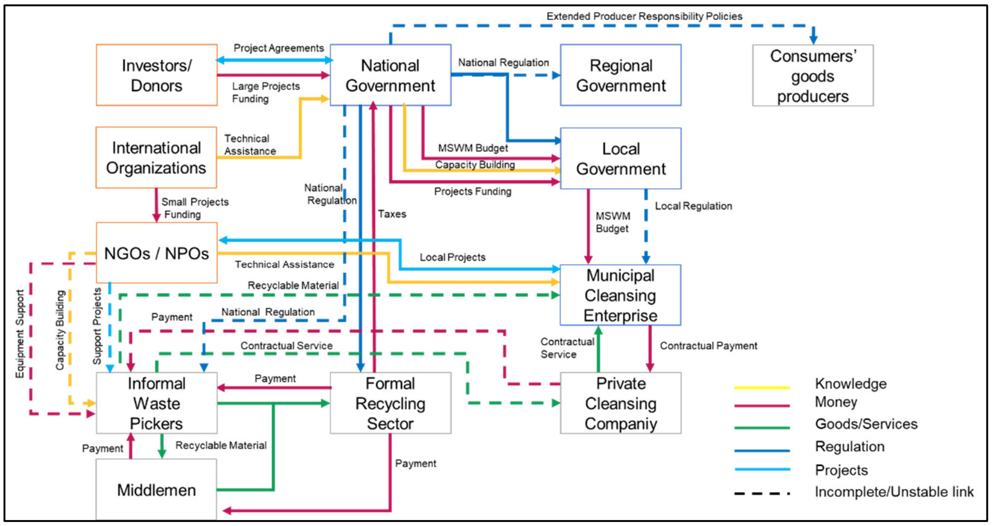


Figure 3.1 SVN of stakeholders in the MSWM system

3.3.1 National and local government

The Bolivian political administration has three levels of government: national, regional (prefectural), and municipal. Each of these levels plays a specific role in the provision of public services such as MSWM according to the various laws and policies discussed in Section 3.2.

At the national level, the Ministry of Environment is the main institution involved in the MSWM sector, leading any major relevant project or program through a dedicated division: The Direction of Integrated Solid Waste Management (DGIRS). The DGIRS has been identified as one of the enablers in the sustainability transition of the sector (personal comm: F10; F1; D1; D2). Despite the limited human resources in the division (personal comm: C4; F9; F6; A1; K2), many respondents highlight the commitment and leadership of the unit to promote sustainability within the sector (personal comm: D1; C4; D2). Other ministries such as the Ministry of Planning and Finance, the Ministry of Health, and the Ministry of Productive Development are briefly mentioned, with most respondents, however, perceiving the considerable lack of involvement and coordination between ministries on municipal waste management (personal comm: C1; C7; F9; I1; F4; H1; F3; D1; K2). Various of the respondents attributed this to rivalries among different ministries (personal comm: K2); lack of mechanisms for inter-ministerial coordination (personal comm: F2); or bureaucracy (personal comm: G1).

Despite some apparent legal ambiguities on municipal waste management, most respondents agree that a major role of the national government (beyond policy formulation) is to facilitate access to internal and external funding to enable municipalities implement MSWM projects and support them through capacity building and training (Caceres et al., 2014; Ministerio de Medio Ambiente y Agua, 2011a) (personal comm: A2; A1; F5; F7; D2; E1). In fact the role of municipal governments is recognized as particularly important in the MSWM system, as they are in charge of planning and executing all necessary activities for adequate MSWM operation and implementation (Caceres et al., 2014; Ministerio de Medio Ambiente y Agua, 2011a) (personal comm: B1; I2; F9; K1; F5; F7; F8; J1; F2; E1).

At the municipal level, the responsibility regarding MSWM is completely on the municipal cleansing enterprise (MCE) (Section 2.2.2). While MCEs are supposed to be completely autonomous and independent institutions, functioning almost like private enterprises, in Santa Cruz de la Sierra there seems to be a blurred boundary with the municipality, with a large dependency both in terms of financial support and political influence (Ministerio de Vivienda y Servicios Basicos, 2001) (personal comm: F2; F8). Additionally, the fact that the MCE focus mostly on operational aspects, but at the same it is considered the main responsible organizations for MSWM activities, creates a grey zone in that policy, regulation and governance responsibilities are not undertaken by any of the municipal government divisions (personal comm: F8; F2; I2; C3).

Finally, the functionality of prefectural governments is neither clear and nor fully implemented in the MSWM system. One of their main clear responsibilities is to implement hazardous solid waste management schemes (personal comm: C3; I1; C1). Other respondents indicate that they can help small municipalities or metropolitan regions to implement joint MSWM projects, allowing them tackle issues related to the high costs of facilities (personal comm: F12; A2; D1; E1; F11). In any case, most actors either consider that regional governments are currently irrelevant in the MSWM system (pers comm: C3; H3; D2; F8), or even forget to mention it when identifying the relevant actors in the system.

3.3.2 Formal private sector

Formal private sector actors include enterprises that are formally constituted under Bolivian law and are engaged in different aspects of the MSWM systems. This mainly includes: (a) private cleansing companies, (b) recycling companies, (c) consumer goods' producers.

Currently, private cleansing companies tend to be large companies, sometimes funded through foreign capital, that have enough financial capacity to invest in the machinery and equipment necessary to undertake waste collection and/or final disposal (personal comm: I1; A2; F2). These companies participate in public bidding processes announced by the municipality, and following the necessary evaluation, the winner is awarded a cleansing contract that lasts usually at least 5 years (Caceres et al., 2014). In Santa Cruz, the private cleansing company is Vega Solvi, a company funded from the Brazilian transnational Vega. Vega Solvi is in charge of 13 services related to public cleansing in the city, with the MSW collection and final disposal being the most important (personal comm: C3; I2).

Recycling/exporting companies are enterprises that either transform the recyclable materials into new products or productive inputs; or sell the materials (e.g., scrap metal) to foreign buyers in the global markets, in cases where no local industries can process them. These companies buy recyclable material from middlemen or waste pickers according to their requirements in terms of quantity, quality and price (personal comm: G2; F2; H1; H3); playing an important role in the activity of these stakeholders (Section 3.3.3).

Consumer goods' producers do not play a major role in the Bolivian MSWM system at the moment. This category includes manufacturers and importers of consumption goods (e.g., companies from the drinks sector). While currently they are barely aware of their role, the Extended Producer Responsibility (EPR) under the new ISWM law requires them to be responsible for the adequate recovery/disposal of the waste from commercialized products (personal comm: A2; I3; F3; C5; C1; F7). These actors should consider important issues such as products design and the material selection, which ideally should reflect the recycling alternatives that exist in the country. Currently, EMBOL, which owns the Coca-Cola franchise in Bolivia, is one of the few companies that has started complying with some EPR requirements, e.g., by using bottles manufactured with 30% of recycled PET (personal comm: J1; DSIW; I2; G2; F8; G3).

3.3.3 Informal private sector

As in many other developing countries, material recovery from waste is undertaken almost completely by informal private actors who collect, select, prepare and commercialize the recyclable material obtained from waste (Agamuthu, 2010; Botello-Álvarez, Rivas-García, Fausto-Castro, Estrada-Baltazar, & Gomez-Gonzalez, 2018; Wilson et al., 2009). These actors recover the recyclable materials and sell them either to recycling companies or exporting companies, usually focusing on metal scrap recycling (personal comment: G2; F5).

Waste pickers are considered to be the most important actors in the recyclable material value chain in Bolivia. "Urban mining" activities performed by these actors are essentially the starting point for the recycling industry (personal comm: K2; F6; I3; F7; F3; F12). However, the distinction between the formal and informal sector is not always clear. In Bolivia this ranges from waste pickers who work completely independently, outside municipalities' registries, in situations of extreme poverty, risky working conditions and sometimes alcohol-drug abuse; to waste pickers who belong to associations that are legally recognized as non-profit organizations, and often form alliances with the municipal government, companies or NGOs (personal comm: F6; G3; H2; K2; H1; H3).

Santa Cruz de la Sierra has the largest number of waste pickers, being estimated a total of 8000 people involved in the activity (Ministerio de Medio Ambiente y Agua, 2017). The formalization process is more advanced in this city, with various small associations grouped in three large networks: “Red de Recolectores”, “Recicla Bolivia” and “ARECICRUZ”. Although there are no reliable statistics about the number of associated waste pickers in the city, some sources report around 2500-3000 people with waste picking as their main occupation (Caceres et al., 2014). The self-reported number of members by each network leader are: 600 members for “Red de Recolectores”, 1000 members for “ARECICRUZ” and 150 members for “Recicla Bolivia (personal comm: H1; H2; H3). ”Red de Recolectores” and “Recicla Bolivia” originally belonged to the same network, which split due to internal conflicts, while “Arecicruz” was more recently created but not recognized by some actors who refer to them as “not real waste pickers”, indicating that this network is in reality a small enterprise with a relationship employer-employee between leaders and members, often buying the recyclable material instead of collecting it by themselves (personal comm: H1). Each network is composed by various small associations with variate number of members, usually around 10-15 people. These people are usually family members, friends, neighbors, which in many cases have dedicated to the activity since the beginning of the formalization attempts by NGOs in the city in the early 2000s. The associations' structure is also varied and not well-defined, with some of the associations indicating to have leadership roles (e.g. president, vice-president, secretary) but not being able to explain their functions clearly. Some of the members are also not capable of differentiating the two levels of organization (i.e. association, network) or clearly identify the association to which they belong (Lozano Lazo, 2015). Since 2013 the private sanitation company and some waste picker associations have worked together for the recovery of recyclable materials, through a service that is part of the new cleansing contract operating in the city, consisting in the separate collection of recyclable material in some neighborhoods of the city (See Section 3.3.3).

Middlemen or intermediaries are micro and small enterprises that buy recyclable materials for resale to recycling industries, which often require larger amounts of recyclable materials and higher quality. Middlemen have usually greater human and financial capital compared to waste pickers, and thus have a competitive advantage for recyclable material storage and processing (personal comm: F8; I3; F3; G3). For instance, middlemen usually operate warehouses with better infrastructure, and essential machinery to wash, press and pack the recyclable materials. The perceptions regarding middlemen are varied. Some actors consider they are detrimental to the recycling value chain due to their impact on waste pickers' activities (personal comm: F3; F2). On the other side, other respondents think there is a place for all the actors if the adequate collaboration, regulation, and monitoring are implemented (personal comm: K2; F12).

3.3.4 International organizations

International organizations are important actors to the MSWM system in Bolivia. They have often influenced the development of MSWM initiatives, and/or affected the evolution of existing one through financing and/or technical cooperation (personal comm: F1; D1; A2; F10; I2; C6; C1; C3). The main categories included are investors/donors and international cooperation agencies.

The donors are usually multilateral organizations and development banks that provide the funding for MSWM projects, often related to infrastructure that requires large initial capital investments (see below). The main institutions carrying out that role have been the Inter-American Development Bank (IADB), CAF Development Bank of Latin America, and the World Bank. Several of the interviewees mentioned that the provided financing is an important enabler in the sustainability transition of MSWM systems in the country (personal comm: F12; A2; D1; E1; F1). The funding is usually utilized to conduct large projects, from the feasibility study until the project implementation, such as the construction of sanitary landfills. For instance, CAF provides the funding for the new sanitary landfill in Santa Cruz de la Sierra (which is supposed to be finished in 2019) (personal comm: A2).

International cooperation agencies contribute smaller amounts of funding, and mainly through technical cooperation and project implementation activities. The cooperation agencies with the largest presence in the country are the SDC (Switzerland), JICA (Japan), GIZ (Germany) and more recently KOICA (South Korea). Despite the smaller size of funding, they have large impacts at the national level through community education/awareness campaigns, capacity building for municipality officers, and creation of networks with different stakeholders' groups, particularly in smaller municipalities (personal comm: C3; C1; C6; D2; F2; F1; A2; D1; F11; K2). Similar to donors, many stakeholders indicate that the support of international cooperation agencies is one of the main enablers for sustainability transitions in the sector (personal comm: C1; D2; D1; K2). In this sense, many interviewees note that the decrease in international cooperation that is occurring at the moment could influence negatively in many aspects of the transition (personal comm: K2; F7; F8; D1; F6). Another challenge that was identified by a few actors, including international organizations themselves, is a "paternalist" approach from international cooperation and NGOs (personal comm: D1; C4), which is slowly shifting to provide more autonomy to cooperation targets (personal comm: D1). This aspect could hinder the capacity development of local actors by not allowing them to take proper ownership of their activities and make them dependent of external assistance, such as the case of the formalization process of waste pickers (Section 3.4.1.3)

External actors have a considerable influence at the national level. However, as most of their offices in La Paz, the capital of the country, their contribution is not so visible in the local context of Santa Cruz de la Sierra (personal comm: K2; C1).

3.3.5 Civil society and research organizations

The main actors in this group include NGOs and NPOs that undertake relevant activities at the local level. Some NGOs are closely related to cooperation agencies and work as the main counterparts in local projects/programs related to source separation activities, community education, awareness raising, and capacity building for small enterprises, to name a few (personal comm: D1; F11; F10; H1; F8; F1; K2). SWISSCONTACT is one of the NGOs that has had a major presence in the country as a whole, through its projects funded from the Swiss cooperation agency (personal comm: K2; D1; C3; F9; F10; F11; F5; G2; G1; F7; F2). FUNDARE is another NPO that is quite relevant, working under the umbrella of the Industry and Commerce chamber, which explains its rather business-like mindset, compared to other NGOs (personal comm: F2; F5; I3; F3; F10; J2).

It is important to note that the "golden" period of NPO/NGO influence in the MSWM sector was the early 2000s (personal comm: H1; F8; F7;H3), when Santa Cruz de la Sierra attempted the first waste picker formalization process (Section 3.3.3). At the time 6 NGOs formed a council that established a coordination scheme through which significant steps were taken towards what was branded as "inclusive businesses" in the recycling value chain (personal comm: F7; F8; H3).

Universities could also potentially play an active role in the MSWM system (and its sustainability) through academic research and training programs geared towards the local needs in each city. However, most of the interviewees acknowledge that this is not yet done in Santa Cruz de la Sierra, with the role of the universities being mor relevant in other main cities of the country (personal comm: J2; F12; F8; A2; D1; F11; C1). Associations of professionals can play a similar positive role, and especially the society of environmental engineers (personal comm: F8; K1; I2).

Chambers of commerce and industry have also recently appeared in the MSWM discourses, through their efforts to promote circular economy approaches, which contributed to the strengthening of the recycling industry (personal comm: D1; F12; F5; F11; F7). However, as some of the interviewees commented, their interventions have at times drawn criticism or distrust, due the perceived self-interests (personal comm: H2; I3; F2).

Finally, while neighbors associations could represent an important stakeholder in this group, there is no clear structures or mechanisms for their participation in public decisions, and no evidence of their involvement in MSWM activities, except in few occasions, in cases where the neighborhood is opposed to facilities in the area.

3.4 Sustainability transitions of the Municipal Solid Waste Management system

Based on the primary and secondary data analysis we identify three different transitions in the MSWM systems of the two cities: (a) Collection and centralized disposal; (b) Environmentally controlled disposal; (c) Integrated solid waste management. Each of the three transitions has been characterized by a specific type of regime shift, which allowed for the mainstreaming of relevant niche innovations at specific points in time (Table 6). Regarding the landscape factors (Section 2.1.2), while most of them have been present in all three transitions, their strength and relevance have varied.

At the local level, the transitions have been characterized by specific milestones, barriers, enablers, as well as different types of engagement and commitment from the municipal government. *Table 3.4*details the characteristics of these three transitions for the city.

Table 3.4 Multi-level perespective of Municipal Solid Waste Management system transitions in Bolivia

	1st Transition: Collection and Centralized Disposal	2nd Transition: Environmentally Controlled Disposal	3rd Transition: Integrated Solid Waste Management
Landscape factors	- Population growth - Demographic factors - Geographical characteristics-Urbanization patterns	- Land availability - State-society relations - Political and regional tensions-Environmental narratives	- State-society relations - Informal/formal sectos' conflicts - Environmental narratives-Socio-economic patterns - External aspects (recyclables market/ "high-technology alternatives")
Regime shift	- Dumping practices to collection systems	- Open dumps to sanitary landfills	- No recovery to material and energy recovery
Niches	- Micro-enterprises collection services-Corporate collection services - Curbside collection - Container collection	- Controlled" dumps-Landfill technologies	- Community recycling-Informal recycling - Formal Recycling - Energy Recovery

Table 3.5 Municipal Solid Waste Management System transitions

Aspect	1st Transition: Collection and Centralized Disposal 1970s–2010s	2nd Transition: Environmentally Controlled Disposal 1990s–present	3rd Transition: Integrated Solid Waste Management 2000s–unknown
Milestones	- Privately paid collection and disposal at abandoned areas in the periphery of the city - Collection services and centralized disposal from 1970s to 1994 in "El Gallito" open dump. - Improvement of collection coverage through contract with multinational company in 2013	- Normandia landfill operating from 1995. Currently operating almost at full capacity. - Uncontrolled human settlements within a 500 m of the landfill since the early 2000s - New landfill expected to start operating in 2019.	- Zero waste initiatives in 2004 - Waste pickers formalization process from 2005–2013 - New municipal cleansing contract with expanded scope in 2013
Barriers	- Unplanned growth and extent of the city - Lack of community education and awareness of appropriate MSWM practices	- Lack of funding for initial investments and operation - Illegal settlements around the landfill areas - Inadequate landfill operation by various private companies	- Conflicts among waste pickers and other actors - Resistance from local residents for establishing recycling points - Frailty and small size of industrial sector - Lack of municipality leadership in MSWM processes - Lack of political priority of MSWM issues
Enablers	- Private sector's initiatives - Leadership and vision of representatives of EMACRUZ in early stages	- International cooperation and donors support to build landfill facilities - Hiring of technical officers with environmental focus in EMACRUZ	- Vocal NGOs involvement in waste picker formalization process - Municipal government support during the early stages of the waste pickers formalization process. - Increased scope of the cleansing contract

3.4.1 Transitions characterization

3.4.1.1 1st Transition: Collection and Centralized Disposal (1940s–2010s)

The first transition is characterized by the shift from a regime where the solid waste generated was dumped, to a regime where the municipality organized collection activities and established centralized disposal sites. After various decades of collection activities, it is safe to assume that this transition is currently at a stabilization stage with the transition reaching a state of equilibrium. The break-through of the first transition originated from sudden population growth, which created a real need to deal with the generated waste in an organized manner. Geographic conditions have largely influenced the choice of technologies (e.g., use of containers, type of collection trucks) and the choice of original disposal sites. Urbanization and demographic patterns have influenced the collection quality and its different formats in wealthier and poorer areas.

For this transition, there is evidence of a pre-development stage in the 1960s, when a private company collected waste without the involvement of the municipality as a paid service for residents (Gobierno Autonomo Departamental de Santa Cruz, 2018). The first municipal collection services started around the 1970s, with a small enterprise collecting the waste for the municipality, and dumping it in an open field that became the first open dump in the city (Gobierno Autonomo Departamental de Santa Cruz, 2018). This first open dump (called “El Gallito”) operated formally between 1978 and 1994 when it was replaced by the sanitary landfill “Normandia” (Gobierno Autonomo Departamental de Santa Cruz, 2018) (Section 3.4.1.2). However, even until the early 1990s, the collection services were very deficient and was still common for people to throw away their garbage in the street (Herzog, Dool Van den, Davidson, & Skinner, 2001). Nowadays, “El Gallito” area is completely urbanized with lower-income households. The only impact assessment study conducted on it considers the area to be safe for human settlements, identifying “mild” groundwater pollution as the only negative impact (Gobierno Autonomo Departamental de Santa Cruz, 2018).

During the 1990s international cooperation efforts at the national level strengthened collection micro-enterprises and engaged them as service operators (PAHO, 2002)(personal comm: I1). As a result, for some years micro-enterprises carried out collection services in some urban areas, usually in the periphery. Eventually, due to problems with service quality and financial problems of the micro-enterprises (personal comm: I1), this arrangement changed to the current one, with cleansing contracts granted to one big corporation in charge of the whole collection and disposal service (Section 3.3.2).

In recent years, collection service improved substantially in terms of effectiveness and coverage, which now stands at around 95% (Ministerio de Medio Ambiente y Agua, 2011a) (personal comm: C3; I2). Still, some actors question the quality of collection services (personal comm: F6; F8; J1; C3), pointing that small illegal dumps have proliferated outside the city center (personal comm: C3; F8). As a response, the MCE has increased the number of collection rounds in the problematic areas, and even requested the development of a specific service in charge of illegal dumps. However, this seems to have created a vicious cycle, in that the higher the collection frequency in dumping areas, the more waste is dumped (personal comm: C3).

Finally, as in most developing countries (Lohri et al., 2014; Rodić & Wilson, 2017; Yukalang, Clarke, & Ross, 2017) (Section 1.2), the cost of waste collection and disposal is not covered through the revenues from collection fees, but from municipality funds budget and other sources. In this sense, the new ISWM law includes the possibility to use funds from the fossil fuel industry revenues for solid waste management activities (personal comm: C3; C1; C7; I2; I1), which is an aspect that had been unclear in previous decentralization related legislation (Section 2.2.1). The deficit in collection fees is an important constraint for the prioritization of MSWM policies at the national and the local level (personal comm: C7; D2; F11), with the financial sustainability of the MSWM system identified as an important barrier (personal comm: F2; C2; D1; E1; K2). While Santa Cruz de la Sierra has higher collection fees compared to smaller municipalities, the city still highly subsidize its collection services (personal comm: C3). Being currently the third major expenditure in the municipal budget (Ortiz, 2019) with a raise in recent years since the new cleansing contract was implemented, MSWM expenditures present an increase from approximately 1.1 million USD/month in 2012 to 2.6 million USD/month in 2013 and 4 million USD/month in 2019 (Delgado, 2012; Ortiz, 2019). This trends would most likely pose the need to perform a substantial redesign of the collection fee schemes at some point (personal comm: C3; F9; A2; C1; F2), increasing the risk of social conflict (personal comm: I2; K1; D2; F12; A2; K2); conduct a review of the cleansing contract conditions; or achieve a major reduction in waste generated and landfilled (which seems unlikely) in order to decrease costs. In this sense, the city seems to have had some progress in the collection of fee charges, having updated the tariffs twice in the last two decades (the last time was in 2012) (Empresa Municipal de Aseo de Santa Cruz, 2018).

3.4.1.2 2nd Transition: Environmentally Controlled Disposal (1990s–~2030s)

The second transition reflects the regime shift from disposal methods that are harmful for human health and the environment (e.g., open dumps), to practices that guarantee the minimum conditions for environmentally sound solid waste management (e.g., sanitary landfills). Unlike countries with relatively limited land availability, Bolivia is a rather large country in geographical extent. This favored the choice of sanitary landfills over other waste management practices such as incineration (personal comm: I2). Despite this, finding suitable places for sanitary landfills has become increasingly difficult due to various political and social conflicts related to their location.

Currently there are no additional transfer or treatment stages in the MSWM system (e.g., incineration, pyrolysis), which means that waste is directly taken to disposal sites after collection. Following the 1st transition (Section 3.4.1.1), Santa Cruz de la Sierra was one of the first cities in Bolivia to adopt sanitary landfill technologies and remains among the few ones with this type of technology in the country.

Until recently, “controlled dumps” were the preferred practice in other cities. However, they are not considered to be environmentally adequate, as they focus only in the use of specific types of soil (e.g., clay) to act as a filter for leachate and cover the waste to avoid disease vectors and odors (personal comm: C1;C7; F2).

In Santa Cruz de la Sierra, the Normandia landfill remained operational until ends of 2019, being substituted by a new landfill that will not be included in the present research due to this extemporaneity. Normandia landfill is located within the urban area of the municipality and had reached the end of its lifespan many months before its closure. It was originally authorized to operate until 2018 (Gobierno Autonomo Departamental de Santa Cruz, 2018), but was ultimately given an extension of one additional year. The landfill has been widely criticized during its operation, particularly due to the bad management of some private cleansing companies, which implies that some negative environmental impacts might have manifested (Gobierno Autonomo Departamental de Santa Cruz, 2018) (personal comm: E1; F6; I2; K1; F7). However, the main problem has been the failure to restrict human settlement in its periphery. While most relevant legislation bans any human settlement within 2km of landfills, Normandia has entire neighborhoods only within a 500 m radius (Gobierno Autonomo Departamental de Santa Cruz, 2018) (personal comm: G2; F7; I3; K1).

Even though Santa Cruz de la Sierra is a clear frontrunner in the MSWM sector in Bolivia, its case shows that the transition to environmentally controlled disposal is not yet completed, and the situation is still far from ideal. While a new landfill has recently been put in place, the monitoring of Normandia landfill and the quality of life of the communities settled in its surroundings is a pending task. Furthermore, in most of the rest of the country a majority of disposal sites are still open dumps, with few (or even no) mitigation measures (Section 2.2). Although the National Law 755 establishes that all open dumps should disappear from Bolivian cities by 2020, most respondents are skeptical whether this will materialize (personal comm: F2; A2; K1; F2; K2). In this sense, even though the transition to environmentally controlled disposal is already stabilizing, it is expected to last much longer both for Santa Cruz de la Sierra and Bolivia as a whole (personal comm: F3).

3.4.1.3 3rd Transition: Integrated Solid Waste Management (2000s–Unknown)

The 3rd transition consists in the shift towards an Integrated Solid Waste Management system. This would entail the inclusion of multi-stage MSWM approaches that allow material or energy recovery from the solid waste and include social and institutional dimensions that were not previously prioritized. This transition is largely influenced by landscape factors such as the global and national environmental narratives, which have increased community awareness about the need for sustainable MSWM practices. Other influential factors such as the socio-economic and development patterns, and the state-society relations are discussed below.

The transition essentially started in the early 2000s with the implementation of several programs and projects in the main cities of Bolivia, led by various international cooperation agencies and NGOs (personal comm: F9; F10; F11; F8; C3; C4; C1; F7; H1; H3; DELNORTE). These projects have included recycling activities, community education and awareness campaigns, source separation schemes, and processes to formalize the waste picker sector (personal comm: K2; F10; F11; F9; F8; F7).

In Santa Cruz de la Sierra the first milestone of this new transition relates to the Zero Waste initiatives of 2004 (Section 3.2.2) (personal comm: C3; C4; F7; H1; K2). From that point on, and for a period of around ten years, a group of NGOs, EMACRUZ and Red de Recolectores constituted the Bolivian Council of Solid Waste (COBORESO) (Section 3.3.5). This consortium adopted an ISWM vision and aimed to find solutions to prevailing problems for the MSWM system, with a special focus on financial and technical viability, social inclusion and citizen participation (personal comm: F7; F8; H3).

One of the main achievements was the formalization of waste pickers, which reached its highest point around the early 2010s (Caceres et al., 2014). After this peak, there was a deceleration of formalization processes, manifesting through the various internal and external conflicts that led to the fragmentation and weakening of the associations (Caceres et al., 2014) (personal comm: H1; H3; C4; F8). Although the reasons are not clear, some respondents point that the sudden termination of NGO support left the waste pickers' associations in a fragile state (personal comm: F8; C4). Other respondents point at the (a) conflicts with some NGOs due to the apparent funding mismanagement (personal comm: H3; H2); (b) conflicts among associations' leaders that led to fragmentation (personal comm: H2; H3; C3; K1; I2); and (c) formalization attempts under the new municipal cleansing contract in 2013, which seem to have undermined the organizational processes within associations, further contributing to internal conflicts (Caceres et al., 2014) (personal comm: F8; H3).

Interestingly, respondents perceive very differently the new cleansing contract of 2013. Some consider it to be one of the main causes behind the collapse of the waste pickers' formalization process (see above), while others consider it to be an important step towards ISWM (e.g., by expanding the scope of MSWM services far beyond waste collection and disposal) (personal comm: F7; H3; K2; F10; C3). However, it is a completely different discussion whether the goals of the contract were actually achieved. For instance, the contract established separate collection schemes, which have, so far, dubious results (personal comm: C3; H3; F9; J1; G2). While some actors seem to be positive overall about the outcomes of the program (personal comm: I2; C3), others deem it as to be a failure (personal comm: G2; J1). Another unmet contract clause has been the failure to establish the various drop-off facilities in the city (called "Eco-points") due to community opposition (personal comm: C3).

Another important element of this transition relates to the landscape factor linked to the socio-economic patterns and development paradigm in the country (Section 2.3.1.2). As discussed, the industrial and commercial sector are not yet fully developed in Bolivia. Although the situation is a bit better in Santa Cruz compared to the rest of the country, companies still point at the excessive bureaucracy barriers and investment risks that hinder the development of a robust recycling industry (personal comm: G3; F7; F3; F5; F9; G1; G2; F12; G3). Furthermore, the small size of the national domestic demand for recyclable material prevents the development of economies of scale, which further prevents the development of a vibrant recycling industry (personal comm: G2; I3; G3; F2). In this context, the local and national recycling industry is unstable and fragile, which threatens the sustainability transition (personal comm: F5; I3; F2; E1). To enable the effective transition there would be a need for added incentives from the government to help the expansion of the recycling sector (personal comm: C1; C4; G3; F7; G2; F3; F5; F9).

It is interesting to point that there is still no clear definition and understanding of the type of niches that the current IWSM transition will favor. Our analysis suggests that the transition could move across three possible pathways. The first pathway could entail a shift to "high technology alternatives", which are common in more industrialized contexts characterized by higher waste generation levels with lower organic fraction. Such technologies could include incineration (personal comm: C3; I1; I3; F1; A2); pyrolysis (personal comm: C5; C3); and waste bio digestion (personal comm: C6; C3; F10; D1) to name a few. The main inhibiting factors relate to the financial viability of such projects and include (a) the high capital and operational costs of facilities, (b) heavy subsidies of fossil fuel energy in Bolivia (personal comm: C3; I3). It is also unclear the extent to which such alternatives could affect other existing niches, such as the informal and formal recycling initiatives (personal comm: I1).

The second pathway could favor material recovery alternatives, such as the formal recycling niche and the informal recycling niche. For example, the circular economy approach and the new ISWM law prioritize material recovery over energy recovery (Section 3.2.1) (personal comm: I1; K2). However, some actors seem to support the latter as a better alternative for revenue generation, considering the limitations of the recycling industry outlined above (personal comm: C5; C3; F2). Other respondents suggest the "vested interest" of some companies trying to introduce these technologies in the country, regardless of their suitability to the local conditions (personal comm: I3; K2; I2). If “high-technology” alternatives do not muster enough support, then municipalities could choose to continue formalization efforts or the implementation of municipal or formal recycling initiatives.

It is highly possible that neither of these pathways succeeds in mainstreaming new practices. In this case the transition will continue with waste disposal in landfills as the main MSWM alternative. The focus would probably be on small changes for improving current operations and reducing current impacts. This could entail technological improvements (e.g., landfill gas capturing) (personal comm: I3; I2; E1) or improved regulation, enforcement, and conflict management with communities near landfill sites.

3.4.2 ISWM Elements in Municipal Solid Waste Management Systems Sustainability Transitions

When examining the components of the ISWM framework and the transitions across time it is possible obtain a clearer understanding of their evolution and particularities (Figure 3.2). As it is common, the transitions have caused changes in the ISWM elements following a largely similar order, starting with the “Public Health” and “Environment” elements, which is the common progression for MSWM transitions. Similarly, the elements related to the “Governance” dimension are addressed in much later stages. Among those, the “Inclusivity” element, seems to be the most neglected (personal comm: D2; F7). The transitions in Santa Cruz de la Sierra have occurred in a shorter period of time than other main cities in Bolivia with longer development processes, which has added complexity for the management of the transitions. In spite of this, the city has been able to catch up, with notable advances in elements such as “Financial Sustainability” (Section 3.4.1.1) and “Resource Value” (Section 3.4.1.3).

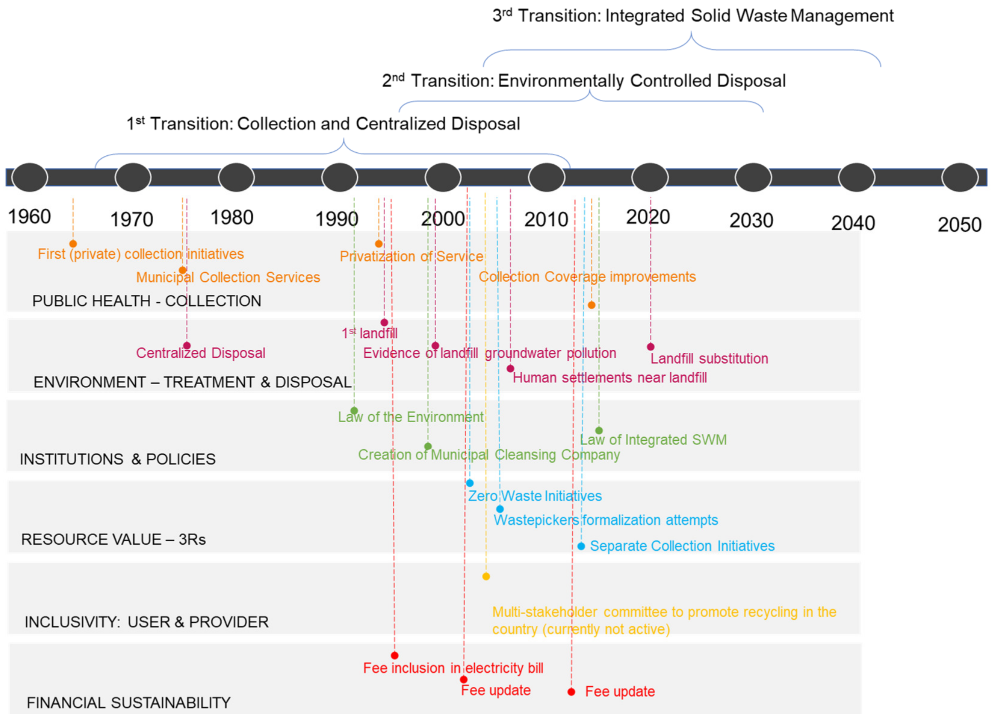


Figure 3.2 Timeline of MSWM systems sustainability transitions and ISWM elements

3.5 Discussion

3.5.1 MSWM transitions in Santa Cruz de la Sierra

Santa Cruz de la Sierra, as other developing cities, is experiencing transitions in its MSWM system (Table 3.5) going from a system focused on "collection and centralized disposal" (Section 3.4.1.1), to "environmentally controlled disposal" (Section 3.4.1.2), to an "integrated solid waste management" (Section 3.4.1.3). However, the timelines, speed and elements of these transitions are somewhat different from other cities, even compared to cities of similar size in Bolivia (Lozano Lazo & Gasparatos, 2019). It is suggested that these differences have occurred largely due to the city's inherent characteristics (Section 2.2.2), institutions and regulations (Section 3.2.2) and stakeholders dynamics (Section 3.3).

The city is essentially a young metropolis whose development is largely driven by private sector initiatives (Section 2.2.2). This socioeconomic context has influenced positively some aspects of the MSWM transitions by creating an enabling environment for actors in the formal and informal recycling sectors to thrive and become catalysts for the 3rd transition (Section 3.4.1.3). At the same time, the rapid population growth during the last decades led to a largely unplanned urban development, which has hindered the stabilization of the 1st and 2nd transitions (Sections 3.4.1.1 and 3.4.1.2).

3.5.2 Dynamics within and between government levels

Sections 3.2 and 3.3.1 outline the responsibilities of each government level in the MSWM system in Bolivia, and how their interactions can have important ramifications for the transitions. In particular, many respondents specifically mentioned the lack of coordination among different government levels, and between government and other actors as an important barrier (personal comm: I2; F9; F2; G2; G1; J2; F8; J1; F6; K2; F10; E1). This results in institutional gaps and overlaps, which often cause confusion or resistance from local and regional governments to assume their institutional responsibilities (personal comm: A1; A2; F1; D1; C1; D2; K2; F12).

A possible reason for this is the autonomy and decentralization process that has been ongoing for the past 30 years (Section 2.2.1). Though not inherently negative, this process has been blamed for delaying the process and being indirectly responsible for the failure of local authorities (at different levels) to assume their responsibilities (personal comm: I1; F10; A2; D1; F6). In this sense, the ignorance, or misinterpretations of the current legislation (Section 3.2), coupled with political rivalries, are major factors for government's dysfunctionality in the MSWM system (personal comm F10; F2; A1; E1; F11; K2). Besides the issues related to the lack of ownership, the unfinished decentralization process and political rivalries can also be considered to have affected the financial sustainability of the system, by preventing the use of an important amount of funds coming from the revenues of hydrocarbons exploitation, during a period of time of abundance of them (Sections 2.2.1, 3.2.1, 3.4.1.1).

Related to this dysfunctionality is the perceived lack of leadership and capacity of municipal governments and cleansing companies (personal comm: I2; K1; F5; H1; F7; F8; F2; G1; E1; J1). While this perception can be affected partly by managerial issues in the MSWM organizational structure of the MCE (Section 3.3.1), it would seem that this "lack of leadership" is highly influenced by political issues (see below in this section). For instance many respondents mentioned the "selfish" interests of politicians in relation to MSWM initiatives (personal comm: C3; F9; F10; J2; F12; F8; G3; I3; F2; A1; E1; K2), and the political will (or the lack of it) to address them (C3; F9; F2; G1; F8; I3; F1; A1; D1; F6; F11; K2).

The above illustrates how elements of the MSWM socio-technical regime (i.e., government dynamics) are influenced by landscape factors such as the political and regional tensions (Section 2.1.2). In a context where at least two transitions occur simultaneously in different cities of the country, and within the same city (Table 7), there is a clean need for a strong governmental role to assist decision-making and setting priorities within the MSWM sector (Brunner & Fellner, 2007; Rodić & Wilson, 2017). However, it is important to note that the two transitions are at different stages, which would require different consideration from the government. In Santa Cruz de la Sierra, the 1st and 2nd transitions are most likely at a stabilization stage (Sections 3.4.1.1, 3.4.1.2), while the

3rd transition is probably at a pre-development or take-off stage, depending on the niche (Section 3.3.3). This suggests that the role of the local governments should be different in both cases, focusing more on consolidating and avoiding the negative impacts in the stabilizing transition (2nd transition), and leading and reinforcing the transition that is taking-off (3rd transition) (Rotmans et al., 2001). This would indeed require very different capacities, incentives and processes, which, as discussed throughout this paper, are often lacking. In order to stimulate the transition there is a clear need to maintain a broad range of communication channels to include the various actors to create a common vision (Rotmans et al., 2001; Späth & Rohracher, 2010), which is regrettably lacking according to the interviews.

3.5.3 Dynamics among private sector actors

Dynamics among market actors can also play a major role in fostering or preventing transitions. For instance, many interviews highlight how the recycling value chain can catalyze the 3rd transition, and the conflicts arising through the competition among various niches and mainstream MSWM practices (Sections 3.3 and 3.4.1.3).

First, conflicts often occur between private cleansing companies and recycling initiatives, which, if not adequately addressed by municipal governments, could hinder the ongoing attempts to boost recycling (personal comment: C3; H3; F7; H1; F3). This situation arises, partially, from the fact that municipal cleansing contracts establish a payment scheme based on the amount of waste collected and disposed. This reduces the incentive of cleansing companies to collaborate in the implementation of source separation and recycling programs driven by municipalities (personal comm: K2; F2; I3; G3; F10; F11; F12; F7). Furthermore, there is an apparent systemic neglect of monitoring and evaluation to assure the compliance with contractual obligations (personal com: K2; F10; F8).

Second, semi-formal waste pickers often conflict with cleansing companies (personal comm: C3; F3; H1; F7; H3). This is particularly evident in Santa Cruz de la Sierra, where the formalization process is more advanced (Section 3.3.3). In this case, a major aspect of the conflict is the access to the recyclable material and the participation of waste pickers in partnerships for recycling activities (C3; I2; H1; H3). From the perspective of the private cleansing company, the current partnerships (Section 3.3.3) benefit primarily the waste pickers associations. Thus, the private cleansing company regards this joint work as a corporate social responsibility (CSR) activity, which even though it is considered successful, it essentializes waste pickers as a “complicated sector” due to their internal conflicts and general distrust (personal comm: I2). From the perspective of the waste pickers, the conflicts originate in (a) the unfavorable conditions of these partnerships, (b) the disregard of the waste pickers demands for inclusion and support from the authorities and the private company, and (c) the attempts to weaken associations and "take away" their recycling niche (H1; H2; H3).

Third, there are also conflicts between waste picker associations, and recycling companies, and middlemen (C1; F8; I3; H3; K2). Recycling companies tend to complain about the quality of the recyclable material, and the lack of understanding of the associations about the international oil prices dynamics on recycling material price (personal comm: F2; G3; G3; H3; H2). Conversely, the waste pickers point that recycling companies and middlemen take advantage of their bigger negotiation power (personal comm: I3; F8; H3; K2), especially considering that the value chains of most materials are oligopsonistic (personal comm: G2; F5; E1).

Stakeholder dynamics enabling or hindering MSWM transitions are deeply rooted in economic interests and are key in determining the transitions pathways (Fischer & Newig, 2016; Oyake-Ombis, van Vliet, & Mol, 2015).

3.5.4 Political aspects of MSWM systems' transitions

The dynamics mentioned in the previous section are deeply rooted in economic interests and are key in determining the transitions pathways, however, how these dynamics unfold also largely depends on the capacity of the different stakeholders to achieve political influence and mainstream the niche that is more favorable to their own interests. In this sense the political context and tensions are one of the most relevant landscape factors influencing MSWM transitions (Section 2.3.1.2).

However, transition theory has been criticized for not paying enough attention to how power relations influence the construction of the dominant narratives that lead the transitional processes (Geels, 2011; Turnheim et al., 2019; Wittmayer, Avelino, van Steenbergen, & Loorbach, 2017). Recent studies on solid waste management transitions (e.g., e-waste), have focused on how power dynamics can unfold transitions (Lawhon, 2012), and impose vested interests that lead to problems of trust and legitimacy.

As discussed above, the economic interests of actors involved in MSWM systems play an important role in the transitions. In this sense, it is expected that the actors with more economic strength will ultimately be able to exert more influence (Fischer & Newig, 2016). Studies from the Urban Management Program on MSWM in Low-income Countries in 1995 (Klunder, 1995), which included other main cities of Bolivia, already pointed to how contracting conditions favorable to cleansing companies could have a negative impact on recycling initiatives. A relevant aspect is the importance of local governments to fulfill their role as "clients" in public-private partnerships common in MSWM systems (Rodić & Wilson, 2017). However, with changes in landscape factors such as land use issues and environmental awareness (Section 2.3.1.2), combined with the strengthening of recycling niches (Section 3.4.1.3), the transition pathway could change in the near future.

When it comes to government actors, power and trust issues take a different meaning, which is more related to the clashes between national and subnational governments (Hodson & Marvin, 2010) (Section 4.2.1) that originate on the political situation in the country (Section 2.3.1.2). This ultimately manifests in the "selfish interests" mentioned in Section 3.5.2, which in this case arise from political calculations about the possible political outcomes of any event or decision (e.g., how it can offer an advantage over political rivals), rather than the public benefit.

Finally, when it comes to state-society relationships, many local transition scholars have argued that trust-building is crucial for adopting a common transition vision, which could facilitate public acceptance, and ultimately the allocation of funds to steer effectively the transition (Hendriks, 2009; Lawhon, 2012; T, 2006). As our case studies portray, trust in state-society relationships is a fundamental element of MSWM activities, from accepting changes in collection fees (Section 3.4.1), to allowing the construction of recycling facilities near residential areas (Section 3.3.2). For example, the unfulfilled promises of local authorities and the high turnover of government officials contributed to the absence of trust in a waste management project in a semi-rural Bolivian municipality (Mancilla García, 2017).

3.6 Conclusion

This chapter provided a broad picture of the institutional aspects of the MSWM system at the national and local level through an analysis of the regulations, stakeholders roles and sustainability transitions in the last decades. Regarding the regulatory aspect, overall a positive shift at the national level through the first comprehensive law for ISWM, and a setback at the local level with a return to a "cleansing" approach were identified. Municipal cleansing enterprise, private cleansing company, informal private sector and NGOs were identified as the main stakeholders at the local level, with conflicts between the informal waste pickers and the first two. Additionally, conflicts across government levels were identified, impacting the ownership of responsibilities and the funds availability for MSWM projects.

Three overlapping transitions, landscape factors, niches, barriers, and enablers were identified. The first two transitions are considered to be in a stabilizing stage, and the third one in a pre-development, or take-off stage. In this sense, while the first two transitions require governance approaches that assure monitoring and compliance to avoid destabilization, the third transition requires more inclusive approaches that create a shared vision of the future transition directions among stakeholders, acting as a catalyzer of the process. However, whether the local government (and other stakeholders) possess the necessary leadership and capacities to conduct these processes, is questionable.

CHAPTER 4

PARTICIPATORY MODELING OF THE MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM

Chapter 4 cannot be disclosed, as its content will be published as part of a scholarly journal.

CHAPTER 5

ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES

Chapter 5 cannot be disclosed, as its content will be published as part of a scholarly journal.

CHAPTER 6

SYSTEM DYNAMICS MODELLING

Chapter 6 cannot be disclosed, as its content will be published as part of a scholarly journal.

CHAPTER 7

SYNTHESIS AND RESEARCH IMPLICATIONS

7.1 Synthesis of results

As indicated in Chapter 1, this research analyzed MSWM in Santa Cruz de la Sierra, a rapidly urbanizing city of Bolivia, from a transdisciplinary and system-based perspective, in order to explore pathways influencing its sustainability. The objectives definition followed a funnel approach, going from a broad perspective identifying societal aspects relevant for MSWM (Obj. 1), to a general understanding of practices (Obj. 2), an assessment of specific practices (Obj. 3) and the combination of previous results to explore future outcomes (Obj. 4).

In this sense, each objective has findings that relate to different levels of analysis, which are summarized in Table 7.1. These levels have been defined adapting and combining the concepts from the multilevel perspective on transitions (Section 2.3.1.2) and the capacity development approach used by Japan International Cooperation Agency (JICA, 2005).

Table 7.1: Summary of main findings

	Macro-level (societal)	**Meso-level (organizations/institutions)**	**Micro-level (individuals, practices)**
Chapter 3 (Obj. 1): Institutions and transitions	• Political rivalries and vested interests across actors with variate economic and political power • Lack of trust from society in political system • Inequality influencing/resulting from urban growth patterns • Global environmental discourses influencing views on MSWM	• Regulatory improvements at national level, setbacks at the local level • Coordination problems among governmental levels influencing ownership and resources access • Responsibility void between municipal government and MCE • Transitions stages require different capacities from local government	• Improved but unstable/unequal collection service • Increases in MSWM costs in the last decade • Competition for recyclable materials between informal and formal recovery actors
Chapter 4 (Obj. 2): Variables and interlinkages impacting MSWM sustainability		• Political will influences policy implementation and resources allocation • Community awareness and demands influence political will	• Household waste is the most relevant stream in MSWM system • Main unsustainable practices are household waste dumping and burning • Main sustainable practices are source separation, formal and informal recyclables recovery
Chapter 5 (Obj. 3): Assessment of main practices			• Waste generation is influenced primarily by socio-demographic factors • High levels of source separation behavior despite lack of formal programs • Contextual factors more influential for unsustainable practices, latent constructs more relevant for sustainable practices • Informal waste picking outcomes are influenced primarily by available

			equipment and association membership
Chapter 6 (Obj. 4): Future outcomes exploration	• Unplanned growth is one of the major influencing factors in unsustainable practices	• Community unsatisfaction with MSWM service promotes unsustainable practices	• Unplanned growth could lead to doubled rates of dumping and burning in the next 10 years. • Improving source separation and separate collection would significantly improve the formal recovery but could reduce informal recovery by more than 10% in the next 10 years • Improvements in separate collection and source separation would not significantly reduce the amount of waste landfilled in the next 10 years.

The previous table shows the findings classified across objectives and level of analysis. In this sense, the pathways influencing sustainability are determined by the existence of sustainable and unsustainable practices, for which the main influencing factors have been identified and the possible outcomes estimated through software simulation. However, it is important to highlight that this does not entail that these pathways refer exclusively to the key factors that have been identified through the assessments, but rather the overall findings and conclusions across levels in each of the objectives.

7.1.1 Institutional analysis and sustainability transitions of the municipal solid waste management system (Objective 1, Chapter 3)

Chapter 3 focused on the institutional aspects and transitions in the MSWM system. Three overlapping transitions were identified, corresponding to the start of the centralized collection (1st transition), environmentally controlled disposal (2nd transition) and integrated solid waste management (3rd transition) (Section 3.4). While each transition had specific factors at the macro level influencing them, as well as specific barriers and challenges, the main relevant aspects identified across all of them related to political rivalries and vested interests across actors with variate economic and political power (Sections 3.5.2, 3.5.3), lack of trust from society in political system (Section 3.5.4), inequality influencing/resulting from urban growth patterns (Sections 3.4.1.1, 3.4.1.2) and global environmental discourses influencing views on MSWM (Section 3.4.1.3).

At the meso level, the regulatory aspect is characterized by a recent regulation shift at the national level which aims to set the base for the transition to an integrated solid waste management in the country. Conversely, at the local level, the main advances in the regulatory aspect seem to have occurred in the early 2000s, with recent regulations taking a step back towards the "cleansing" approach rather than the integrated solid waste management approach. Regarding the stakeholders' analysis, results point at the deficient coordination across government levels, due to issues related to the decentralization process and political rivalries, resulting in issues regarding ownership of roles and resource allocation (Sections 3.3.1, 3.5.2). Additionally, results suggest an organizational problem related to the disconnection or voids between the municipal cleansing enterprise and the local government

(Section 3.3.1). Finally, the research suggests that transition stages require different practices and capacities from the government which in the case of transitions in early stages need not only monitoring and control activities, but rather the ability to create a common vision with the stakeholders involved (Section 3.5.2).

At the micro level, it was identified that while collection services have consistently improved in the last decades, there is still an unstable and unequal performance of these services, with their effects being noticeable particularly in the outskirts of the city (Section 3.4.1.1). At the same time, the service has experienced an increase of costs in the last decade, which has led to stakeholders questioning the financial sustainability of the service (Section 3.4.1.1). Finally, regarding the recovery of recyclable material, the importance of informal waste picking activities was confirmed, as well as the decline in the formalization attempts since the early 2000s and the current scenario or resource competition between informal and formal recovery initiatives (Sections 3.4.1.3, 3.5.3).

7.1.2 Participatory modeling of the municipal solid waste management system (Objective 2, Chapter 4)

Chapter 4, focused on mapping the variables related to the main sustainability impacts in the system, and the mechanisms influencing these activities, through a participatory approach with local stakeholders. While the outcomes of the technique itself are not considered the main finding from the chapter, it is important to highlight that its use proved to have various positive aspects and the potential for an expanded scope for policy analysis and design. Some of the positive aspects relate to the mental model alignment and consensus building potential, while the limitations relate to the learning curve of the tool, time requirements and internal dynamics influencing the outcomes.

Section 4.3 presented the causal loop diagram (CLD) created through the participatory process with stakeholders, diving it into 5 modules for an easier visualization: waste generation, common SWM practices, source separation practices and recycling activities, waste disposal and main flows and costs.

The findings at the meso level, reflected the views from stakeholders that had already been perceived in Chapter 3, related to the influence of political will in policy implementation and resources allocation, the importance of economic resources for effective policies implementation. On the other side, it also reflected the influence of community awareness on political will through demands for prioritization of MSWM issues (Section 4.3.1).

At the micro-level, the findings indicate that household waste is the most important stream in municipal waste, with the main unsustainable practices being represented by household waste dumping and burning, and the main sustainable practices corresponding to source separation, as well as formal and informal recyclables recovery (Section 4.4.1).

The generation module indicates that waste generation per capita depends on income and a "consumerist behavior" with the introduction of reduction policies following the mechanisms mentioned above (Section 4.3.1). Regarding the household dumping and burning, the common practices module (Section 4.3.2) proposed factors such as knowledge, awareness, and habits as the main mechanisms for the occurrence of this practices. Module about source separation and recycling indicated an influence of awareness, habits and incentives for separation behavior. For the informal recycling practices, the module indicated factors related to health aspects, storage capacity and equipment influencing amounts recovered and profits (Section 4.3.3).

The disposal module focuses only in the disposal aspect, which would be influenced by the flows coming from other modules, and which would have various impacts related to land use, economic cost, pollution, and human health. Balancing effects were identified for the disposal amount in relation to the increase in disposal costs, and the reduction in land availability. Similarly, the module related to the main flows and costs, was used to collect these flows, which would represent the main economic impacts for the municipality. Flows included are the waste generated, waste collected, and waste landfilled. For the costs, the relevant ones are the collection cost, disposal cost, formal recovery cost and total cost.

7.1.3 Assessment of municipal solid waste management practices (Objective 3, Chapter 5)

Chapter 5 assessed the main solid waste management practices in the MSWM system identified in Chapter 4: a) household waste generation, b) household solid waste management practices, and c) informal waste picking activies. The first study, regarding the assessment of the household waste generation consists in a waste characterization study where the rates, composition and factors influencing these rates were determined. For the second study, the prevalence of positive and negative practices in household waste management is determined, as well as the factors influencing these behaviors. For the third study, related to informal waste picking activities, characteristics, outcomes and factors influencing these outcomes were identified. For this objective, all the findings correspond to the micro level.

7.1.3.1 Household waste generation

The household waste generation study (Section 5.2) estimated a median generation rate of 0.51 kg/capita for low-income households, 0.59 kg/capita for medium-income households and 0.62 for high income households, which would back up results of some studies that indicate an increase in household waste related to higher income levels. However, when tested through a Kruskal Wallis test, these differences were not found to be statistically significant. Regardless, mean and median generation rates were calculated for the whole city, through a weighted average using the estimated population belonging to each strata. The results indicate an estimated mean generation of 0.71

kg/capita/day (1225 ton/day) and a median generation of 0.55 kg/capita/day (943 ton/day) for the whole city (Section 5.2.1).

Regarding the composition, differences across strata were found to be statistically significant for most of the components (i.e. organic, plastics, fine residue, sanitary waste). Results reflected characteristics of a rapidly developing city with organic waste accounting for around 50–70% for each of the strata, and fine residue accounting for around 10% in the estimation for the whole city and 15% for the low-income strata (Section 5.2.2)

Regarding the factors influencing generation rates, results of the multilinear regression established that the model explaining most of the variability in generation rates was composed by variables such as the number of members in the household, the household head education, the percentage of children in the household and the existence of an additional livelihood activity such a kiosk in the house. For the number of family members, the coefficient is negative indicating a reduction in waste per capita generation when the household size increases. Similarly, higher education level of the household head and the percentage of children were found to negatively influence the generation rates. On the contrary, the existence of a kiosk in the household increased the generation rate per capita. (Section 5.2.3)

7.1.3.2 Household solid waste management practices

Section 5.3 presents the assessment of household solid waste management practices. General information about the characteristics of the neighborhoods was collected, finding that 67% of the households are located in a paved road, 96% of the households have collection coverage in the neighborhood, 18% had the separate collection in the neighborhood, 46% households had a waste container, and 72% had informal waste picking activities in the neighborhood.

Regarding the behaviors, 23% of the households engaged in waste burning practices, 17% of the households engaged in improper dumping activities, 77% of the households conducted some type of waste separation, with approximately 76% donating the recyclable materials. Around 11% of the households used a recyclables drop-off facility, while 22% sell the recyclable materials by themselves.

For the assessment of the latent constructs in household waste management behaviors (Section 5.3.1), the EFA resulted in 5 factors (i.e. general awareness, general satisfaction, dumping impact awareness and burning impacts awareness) suitable to test their influence in the negative behaviors (i.e. waste burning and waste dumping). In the case of positive behaviors (i.e. source separation and recycling), factors selected through the EFA procedure were general awareness, general satisfaction, local context knowledge, education and communication satisfaction, attitude, facilities knowledge, concrete knowledge, and separation intention.

During the assessment of the factors influencing the waste management behaviors (Section 5.3.2), for the negative behaviors model, it was found that the construct that most affects burning and dumping behaviors is the general satisfaction. In the case of burning, though, observable variables related to the household head education, and the location of the household were more important. For the assessment of positive behaviors, latent constructs played a more important role, being concrete knowledge the most important for separation. Attitude also influenced the separation and the recyclables donation, although the results should be considered carefully due to the factor issues in the process.

7.1.3.3 Informal waste picking activities

Section 5.4 presented the assessment of informal waste picking activities. Regarding the socio-demographic characteristics of the respondents, the sample presented a slight majority of men (58%), with most of the respondents reporting to be the household head (82%). Regarding education, more than 60% of the respondents only reached middle school level, and the rest of the sample reaching high school education as the maximum education level.

In relation to the characteristics of the work, main aspects considered refer to the income generated, the amounts of materials recovered and the working hours. All the variables show great variability, providing evidence of the striking differences within the sector. A majority of the people reported to earn from 100 to 200 USD per month, while 24% reports earning less than 100 $us per month. Less than 10% of the respondents indicating having incomes above 400 USD/month. For the amount of material recovered, approximately half of the respondents recovers less than 150 kg/week of material, and 11% recovering more than 900 kg/week. Regarding the weekly working hours, 16% of people work less than 20 hours/week in the activity, 10 % reporting to work up to from 84 to 105 hours/week, and 65%. working between 20 and 60 hours/week in the activity.

Regarding the determination of influencing factors, while the original model intended to find influencing factors for chronic pain as one of the most common health impacts of the activity, the path analysis provided poor results resulting in the exclusion of the variable. For the other variables, belonging to an association was found to be the most influencing factor for the material recovery (0.39), and a statistically significant factor for the income earned (0.22). The preparation equipment represented the highest influence for the income earned (0.25), while the transport equipment was found to be influential for the material recovered (0.22). As expected, working hours influenced both the material recovered (0.22) and the income earned (0.24), however other variables such as education or the storage practice, did not seem to be significant.

7.1.3.4 Summary of the assessment of practices

As explained in Section 5.1 and 5.6, results of the empirical studies to assess the main practices in the MSWM system were used to populate the variables and validate the mechanisms identified in Chapter 4. In that sense, differences were found in some of the mechanisms while others were confirmed. For instance, regarding waste generation, Chapter 4 indicated a mechanism based solely on the income and a "consumerist behavior" (Section 4.3.1), while the study in Chapter 5 (Section 5.2) found no definite influence from income, or other consumption behaviors (e.g. cooking habits), but rather on socio-demographic factors (i.e. household size, education, kiosks and percentage of children). Regarding the negative practices, Section 4.3.2 proposed factors such as knowledge, awareness, and habits as the main mechanisms influencing them, however Chapter 5 found that household location and satisfaction with the service being the most relevant ones (Section 5.3). For separation practices, results in Chapter 5 confirmed the influence of knowledge, attitudes, and awareness. Regarding waste picking activities, no significant effects were found from the impact of health aspects or storage capacity, however the influence of preparation and transportation equipment was confirmed, and the influence of association membership included.

7.1.4 System dynamics modeling (Objective 4, Chapter 6)

Chapter 6 focused on to exploring future outcomes in the MSWM system in Santa Cruz de la Sierra. As mentioned in Sections 2.1 and 2.3.4, this was done by using the structure identified in Chapter 4 and the results of the assessments in Chapter 5 as inputs for the creation of the stocks and flows diagram (SFD). While the results of this process are also at the micro-level, estimating the changes across time of the main waste loads, the results relate to aspects at the macro and meso level which were identified in previous chapters.

7.1.4.1 Stocks and flows diagram of the MSWM system

The stocks and flows diagram (SFD) modeled the MSWM system, for the household waste flows, based on the inputs of the participatory modeling with stakeholders (Chapter 4) and the assessment of the municipal solid waste management practices of the city (Chapter 5). The model is presented in four parts corresponding to the stocks and flows for the i) household waste generation, ii) waste burning and dumping practices, iii) source separation and recycling activities and iv) main flows and costs.

The SFD for the waste generation is built upon the study corresponding to the waste generation in households (Section 5.2), and a typical population model. Total generation is obtained from the generation per capita, which is influenced by the size of the household, the percentage of children and the existence of an additional livelihood item. For the data input, some data was obtained from the study mentioned, while others were obtained from secondary data projections. The main stock in this section corresponds to the waste generation amount.

The SFD for the waste burning and dumping practices was built upon the study corresponding to household waste management practices (Section 5.3). The flows for both negatives practices was obtained from the rates of waste generation, the prevalence of behaviors and the frequency of occurrence of the behaviors. Most of the data input for variables obtained from the said study and informed assumptions. In this case waste burned, waste dumped, and additional waste collected as a result of the dumping are modeled as the main stocks of interest.

The SFD for the source separation and recycling activities was built with information from the households' solid waste management practices study (Section 5.3) and the informal waste pickers study (Section 5.3). The separation behavior is modeled in a similar way to the dumping and burning behaviors. The formal collection was modeled as depending on the available recyclable material and the efficiency of the formal collection system. For the informal collection a similar approach was taken but considering that the recyclable material available would depend also on the formal recycling collection, which would have a priority under current scenario. On the other side, On the other side the commercialization of recyclables was modeled after the productivity of the waste pickers and the size of the sector, while also showcasing the effects of the use of equipment in their profit and opportunities to further invest in equipment. Main stocks modeled in this section were related to the separated material, informal recycling recovery, formal recycling recovery, recyclables commercialization and waste pickers capital.

The SFD for the main flows and costs combined the flows coming from the other subsystems regarding the collection service, the additional collection service, and the flows substracted through the recycling activities. Using secondary information, the costs for each flow were calculated and added up. The main stocks modeled in this section were the waste collected, waste landfilled and waste management expenditures.

7.1.4.2 Simulation of the municipal solid waste management system

For the simulation of the MSWM system, first a baseline simulation was generated for three sets of variables, the first one referring to the waste generation and landfilling, the second one to the waste burning and dumping, and the third one to the recyclable material availability and recovery, representing the baseline scenario if the current practices are maintained in the future. Subsequently, four simulations were run with additional scenarios representing low and high values of specific leverage variables considered to be capable of producing change in the system outcomes. Simulations were run for a period of 10 years.

Regarding the baseline scenario, the first set of variables (generation and landfilling) estimated a daily generation starting at approximately 1315 ton/day and reaching to 1785 ton/day at the end of the simulation period, producing a total amount of 5.6 M tons at that point. For the landfilling it was estimated an initial rate of 1192 ton/day which would reach 1539 ton/day at the end of the simulation period, producing a total amount of 4.9 M ton at that point. Both of the generation and landfilling present very similar values due to low level of recovery through recycling existing under current conditions.

For the burning and dumping, it is estimated that burning rate is currently around 1008 kg/day reaching to 1368 kg/day at the end of the simulation period, and accounting for a total of 4269 ton at that point. Similarly, the waste dumped is estimated to be currently 1050 kg/day, reaching a rate of 1424 at the end of the simulation, with 3111 ton. While the estimated dumping rate is larger, the cumulated amount is lower because the model includes the additional collection aspect, which is assumed to capture partly the waste dumped.

For the recyclable material availability and recovery, the separation rate starts at a rate of 134 ton/day and reaches a value of 364 ton/day at the end of the simulation. For the informal recovery, initial rate is estimated to be 50 ton/day, reaching a rate of 134 ton/day at the end of the simulation. Formal recovery is estimated to start at 8 ton/day reaching to 21 ton/day at the end of the simulation period.

Moving on to the alternative scenarios, the first one refers to the effects of an increasing and a decreasing level of unplanned growth over time which is modeled as the main variable affecting burning rates. In the high unplanned growth scenario, burning rates reach 2 ton/day, while in the case of a more controlled level of unplanned growth the rates would reach a value of 1 ton/day.

Regarding the dumping rates, the scenario comparison was done using the unplanned growth variable as well as the general satisfaction with MSWM services. Dumping rates at the end of the simulation period varied from about 1 ton/day for the scenario of decreasing unplanned growth, to 1.2 ton/day for an increasing service satisfaction, to almost 2 ton/day in an scenario of increasing unplanned growth.

Regrading the recyclable material recovery the comparison was done using the variables concrete knowledge on one side, and on the other, a combination of separated collection coverage and separated collection quality. Results show that an increase of concrete knowledge in the population would lead to values of 144 ton/day for the informal recovery and 23 ton/day for the formal recovery at the end of the simulation. In the case of improvements in the separated collection coverage and quality, the informal recovery would decrease to a value of 118 ton/day, while the formal recovery would increase to approximately 62 ton/day. These same scenarios were used to explore the impact on the landfilling rates, obtaining a decrease from a baseline scenario of 1539 ton/day to a rate of 1527 ton/day in the case of an improvement in the concrete knowledge, to 1514 ton/day in the case of improvement in the separated collection coverage and quality.

7.2 Policy and practice implications and recommendations

Policy recommendations have been grouped based on the main dimensions of the ISWM framework:

Dimension	Policy Implication
Physical	• Redesign of collection service to improve satisfaction, particularly in poorly served areas • Further analysis of initiatives to improve source separation • Further analysis of trade-offs and unwanted effects of promoting one recycling niche over the other (formal vs. informal)
Governance	• Strengthening of prefectural government role • Organizational redesign of municipal cleansing enterprise • Redesign of SWM fees or revise cleansing contract conditions • International cooperation's role in advocating for holistic approaches in MSWM

7.2.1 Physical Dimension

The physical dimension of MSWM systems is more related to specific practices related to the collection, disposal and resource recovery activities. In this sense, most of the insights for policy implication come from Chapter 5, however elements from other chapters will also be discussed in this section.

Results from the household waste generation and household solid waste management practices (Sections 5.2, 5.3) displayed the differences in these aspects (i.e. waste composition, generation per capita, unsustainable practices) across households based on the location and socio-demographic characteristics. These results pose the need to consider the implementation of special and oversized garbage collection schemes based on the different characteristics of the different neighborhoods in the city (e.g. highly urbanized vs lowly urbanized), as well as to provide adequate waste containers, which currently are the responsibility of households. Additionally, implementing transfer stations could help to improve the quality of collection in areas in the outskirts of the city, where it is difficult to reach because of the long distances. Results from Section 5.3 also suggest that education campaigns would not be so relevant for negative practices, as they would be for positive practices (i.e. source separation and recycling). However, looking at results from simulations (Section 6.2), even improvements these practices would not have a significant effect on landfilling rates in the next years, which leads to the need to conduct appropriate cost-benefit analysis.

Regarding the recycling activities through the recovery of formal and informal actors, as indicated in Chapter 3, the scenario of resource competition has been identified as a barrier for the transition to integrated solid waste management practices. Chapter 6 provided estimations of the trade-offs of promoting one niche over the other, which should be further analyzed, providing the relevant mitigation measures for the social impacts in case of selecting the formal approach. In case of making the decision to promote the informal actors, results from Chapter 5 suggest that the support should go to the strengthening of associations and equipment support.

7.2.2 Governance Dimension

The institutional analysis conducted in Chapter 3 (Obj. 1) provided important insights about the broader societal aspects interacting with the MSWM system, as well as policy and institutions deficiencies. While the regulation at the national level has taken an important step in the advance towards sustainability, the mechanisms to lower down these regulations to the municipal level are not in place. One reason for this has been the disconnection of the three levels of the government due to political interests, as well as the uncomplete decentralization process existing in the country, which has not adequately delineated the responsibilities at each level. In this sense, the prefectural government in Santa Cruz department could play a central role, even more considering the metropolization process, occurring in recent years between Santa Cruz de la Sierra and surrounding cities. In this regard, as some of the interviewees expressed, the prefectural government can serve as the linkage between national and local government and contribute to create synergies regarding the operational activities (Sections 3.3.1, 3.5.2).

Another deficiency found in this regard was related to the functioning of the municipal cleansing enterprise, as a "semi-autonomous" part of the municipality. While the study did not go deeper into this aspect, not being possible to assess if this setting is inherently inadequate, there is evidence of poor functioning in the case of Santa Cruz de la Sierra. The blurred division between the municipal cleansing enterprise and the municipality, generates voids regarding the governance dimension, such as the regulatory aspect, but also regarding the establishment of programs and projects, as well as the monitoring and sanctioning aspect. Furthermore, the municipal cleansing enterprise has problems in leading the transitional processes in MSWM because of this disconnection to the municipal government and its maximum authority, the city mayor. In this sense, it is recommended that this organizational aspect is further analyzed and improved (Sections 3.3.1, 3.5.2).

For the financial sustainability of the system, insights were drawn from various chapters. In Chapter 3 the transition analysis showed that the city has done better than other cities of the country regarding the establishment of a collection fee, which has been updated in few occasions, remaining to be relatively low-priced compared to other public services (Section 3.4.1.1). However, various stakeholders mentioned that the system is still heavily subsidized (approx. 50%), with collection costs continuously growing due to the increases in generation, but also because of the changes in the city cleansing contract, which establishes much higher prices than in previous decades (Section 3.4.1.1). Chapter 2 and 3 also highlighted how the flawed decentralization process in the country had affected the financial sustainability, by not allowing the use of resources providing from hydrocarbon exploitation in the highest peak of prices in last decades (Sections 2.2.1, 3.4.1.1). Finally, chapter 5 provided some idea of the acceptance of an increase in the fees, with less than 30% of people being willing to pay more for the service. In that sense, the local government should analyze alternatives regarding the redesign of the fee, considering the possible conflicts arising from this measure, or to revise contracting conditions with the private cleansing companies in order to obtain better conditions (Section 3.5.3).

While international cooperation has only been slightly touched in the research (Sections 1.2, 3.3.4), an important opportunity comes from the role of these organizations to influence governments to design projects with holistic approaches for municipal solid waste management systems. As mentioned in Chapter 1, previous approaches have usually provided unwanted results by focusing excessively on infrastructural or organizational aspects, while neglecting the social dimension and the capacity development in local managers.

7.3 Limitations and future research

It is important to acknowledge some limitations of this research. On one side, the topic of waste management presents sensitive aspects in various parts of the system, which pose a barrier in the data collection and its reliability. This is addressed in various parts of the research and important effort has been put in minimizing these problems. However, as an exploratory study, which is the first in the city and in Bolivia for most of its parts, more research is required in each of these aspects.

On the other side, transdisciplinary approaches present a series of difficulties in the integration of knowledge of the different actors involved. Conflicting interests and world views across stakeholders, as well as conflicting approaches between the disciplines combined in the research require a high level of reflexivity from the researcher about her own biases and the decisions made at each step of the research process.

Finally, the lack of secondary data was a strong limitation, which aimed to be addressed through the different methodologies implemented. The present study aims also to contribute to this aspect for future research in Bolivia and other similar contexts in developing countries.

Further research directions of this research include as predominant aspect the iterative process with local stakeholders for the improvement of the model and validation of the results, in order to keep building the confidence in the results, and the use of the technique for policy planning and testing. On the other side, it is expected to be able to estimate some environmental impacts such as GHG emissions in the system using emissions factors now that the waste loads across the system have been estimated.

REFERENCES

Abu Qdais, H. A., Hamoda, M. F., & Newham, J. (1997). Analysis of Residential Solid Waste At Generation Sites. *Waste Management & Research*, *15*(4), 395–405. https://doi.org/10.1177/0734242X9701500407

Adedibu, A. A. (1988). Measuring waste generation in third world cities: A case study of Ilorin, Nigeria. *Environmental Monitoring and Assessment*, *10*(2), 89–103. https://doi.org/10.1007/BF00401775

Adzawla, W., Tahidu, A., Mustapha, S., & Azumah, S. B. (2019). Do socioeconomic factors influence households' solid waste disposal systems? Evidence from Ghana. *Waste Management and Research*, *37*(1_suppl), 51–57. https://doi.org/10.1177/0734242X18817717

Agamuthu, P. (2010). The role of informal sector for sustainable waste management. *Waste Management & Research : The Journal of the International Solid Wastes and Public Cleansing Association, ISWA*, *28*(8), 671–672. https://doi.org/10.1177/0734242X10377834

Agamuthu, P., Khidzir, K. M., & Hamid, F. S. (2009). Drivers of sustainable waste management in Asia. *Waste Management & Research*, *27*(7), 625–633. https://doi.org/10.1177/0734242X09103191

Ahmad, K. (2012). A system Dynamics Modeling of Municipal Solid Waste Management Systems in Delhi. *International Journal of Research in Engineering and Technology*, *01*(04), 628–641. https://doi.org/10.15623/ijret.2012.0104014

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Akpo, E., Crane, T. A., Vissoh, P. V., & Tossou, R. C. (2015). Co-production of Knowledge in Multi-stakeholder Processes: Analyzing Joint Experimentation as Social Learning. *Journal of Agricultural Education and Extension*, *21*(4), 369–388. https://doi.org/10.1080/1389224X.2014.939201

America, L., & Caribbean, T. H. E. (n.d.). *Global Environment Outlook. Geo-6. Regional Assessment for Latin America and the Caribbean*.

Amini, F., Ahmad, J., & Ambali, A. R. (2014). The Influence of Reward and Penalty on Households' Recycling Intention. *APCBEE Procedia*, *10*, 187–192. https://doi.org/10.1016/j.apcbee.2014.10.036

Anantharaman, M. (2014). Networked ecological citizenship, the new middle classes and the provisioning of sustainable waste management in Bangalore, India. *Journal of Cleaner Production*, *63*, 173–183. https://doi.org/10.1016/j.jclepro.2013.08.041

Andersen, D. F., & Richardson, G. P. (1997). Scripts for group model building. *System Dynamics Review*, *13*(2), 107–129. https://doi.org/10.1002/(sici)1099-1727(199722)13:2<107::aid-sdr120>3.3.co;2-z

Andersen, D. F., Richardson, G. P., & Vennix, J. A. M. (1997). Group model building: Adding more science to the craft. *System Dynamics Review*, *13*(2), 187–201. https://doi.org/10.1002/(SICI)1099-1727(199722)13:2<187::AID-SDR124>3.0.CO;2-O

Andersen, L. E., & Jemio, L. C. (2016). *Decentralization and poverty reduction in Bolivia: Challenges and opportunities*. *Handbook of Multilevel Finance*. La Paz. https://doi.org/10.4337/9780857932297

Andrianisa, H. A., Brou, Y. O. K., & Séhi bi, A. (2016). Role and importance of informal collectors in the municipal waste pre-collection system in Abidjan, Côte d'Ivoire. *Habitat International*, *53*, 265–273. https://doi.org/10.1016/j.habitatint.2015.11.036

Ansah, J. P., Islam, A. M., Koh, V., Ly, V., Kol, H., Matchar, D. B., … Loun, M. (2019). Systems modelling as an approach for understanding and building consensus on non-communicable diseases (NCD) management in Cambodia. *BMC Health Services Research*, *19*(1), 1–10. https://doi.org/10.1186/s12913-018-3830-2

Arbona, J. M., & Kohl, B. (2004). La Paz-El Alto. *Cities*, *21*(3), 255–265. https://doi.org/10.1016/j.cities.2004.02.004

Armitage, C. J., & Conner, M. (2010). Efficacy of the Theory of Planned Behaviour : A Meta-Analytic Review E Y cacy of the Theory of Planned Behaviour : A meta-analytic review, (July 2017), 471–499. https://doi.org/10.1348/014466601164939

Babaei, A. A., Alavi, N., Goudarzi, G., Teymouri, P., Ahmadi, K., & Rafiee, M. (2015). Household recycling knowledge, attitudes and practices towards solid waste management. *Resources, Conservation and Recycling*, *102*, 94–100. https://doi.org/10.1016/j.resconrec.2015.06.014

Bagozzi, R. P. (1992). TThe Self-Regulation of Attitudes, Intentions, and Behavior Author(s): *Social Psychology*, *55*(2), 178–204. https://doi.org/10.1007/sl21

Bai, X., McPhearson, T., Cleugh, H., Nagendra, H., Tong, X., Zhu, T., & Zhu, Y.-G. (2017). Linking Urbanization and the Environment: Conceptual and Empirical Advances. *Annual Review of Environment and Resources*, *42*(1), 215–240. https://doi.org/10.1146/annurev-environ-102016-061128

Banar, M., Cokaygil, Z., & Ozkan, A. (2009). Life cycle assessment of solid waste management options for Eskisehir, Turkey. *Waste Management*, *29*(1), 54–62. https://doi.org/10.1016/j.wasman.2007.12.006

Bandara, N. J. G. J., Hettiaratchi, J. P. A., Wirasinghe, S. C., & Pilapiiya, S. (2007). Relation of waste generation and composition to socio-economic factors: A case study. *Environmental Monitoring and Assessment*, *135*(1–3), 31–39. https://doi.org/10.1007/s10661-007-9705-3

Banerjee, S., Aditya, G., & Saha, G. K. (2013). Household disposables as breeding habitats of dengue vectors: Linking wastes and public health. *Waste Management*, *33*(1), 233–239. https://doi.org/10.1016/j.wasman.2012.09.013

Barr, S., Gilg, A. W., & Ford, N. J. (2001). A conceptual framework for understanding and analysing attitudes towards household-waste management. *Environment and Planning A*, *33*(11), 2025–2048. https://doi.org/10.1068/a33225

Bartl, A. (2015). Circular Economy: Cycles, Loops and Cascades. *International Solid Waste Association*, 1–48. Retrieved from http://www.iswa.org/uploads/tx_iswaknowledgebase/Thiel.pdf

Bazargan-Hejazi, S., Teruya, S., Pan, D., Lin, J., Gordon, D., Krochalk, P. C., & Bazargan, M. (2017). The theory of planned behavior (TPB) and texting while driving behavior in college students. *Traffic Injury Prevention*, *18*(1), 56–62. https://doi.org/10.1080/15389588.2016.1172703

Beall, A., Fiedler, F., Boll, J., & Cosens, B. (2011). Sustainable water resource management and participatory system dynamics. Case study: Developing the palouse basin participatory model. *Sustainability*, *3*(5), 720–742. https://doi.org/10.3390/su3050720

Bergmann Matthias, Jahn Thomas, Knobloch Tobias, Krohn Wolfgag, Pohl Christian, S. E. (2012). *Methods for Transdisciplinary Research*. Frankfurt.

Bernache-Pérez, G., Sánchez-Colón, S., Garmendia, A. M., Dávila-Villarreal, A., & Sánchez-Salazar, M. E. (2001). Solid waste characterisation study in the Guadalajara Metropolitan Zone, Mexico. *Waste Management & Research*, *19*(5), 413–424. https://doi.org/10.1177/0734242X0101900506

Besen, G. R., & Fracalanza, A. P. (2016). Challenges for the Sustainable Management of Municipal Solid Waste in Brazil. *Disp*, *52*(2), 45–52. https://doi.org/10.1080/02513625.2016.1195583

Bhawal Mukherji, S., Sekiyama, M., Mino, T., & Chaturvedi, B. (2016). Resident Knowledge and Willingness to Engage in Waste Management in Delhi, India. *Sustainability*, *8*(10), 1065. https://doi.org/10.3390/su8101065

Bhuiyan, S. H. (2010). A crisis in governance: Urban solid waste management in Bangladesh. *Habitat International*, *34*(1), 125–133. https://doi.org/10.1016/j.habitatint.2009.08.002

Binder, T., Vox, A., Belyazid, S., Haraldsson, H., & Svensson, M. (2004). Developing system dynamics models from causal loop diagrams. *Proceedings of the 22nd International Conference of the System Dynamic Society*, 1–21.

Boadi, K. O., & Kuitunen, M. (2005). Environmental and health impacts of household solid waste handling and disposal practices in third world cities. *Journal of Environmental Health*, *68*(4), 32–36.

Bonett, D. G., & Wright, T. A. (2015). Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *Journal of Organizational Behavior*, *36*(1), 3–15. https://doi.org/10.1002/job.1960

Botello-Álvarez, J. E., Rivas-García, P., Fausto-Castro, L., Estrada-Baltazar, A., & Gomez-Gonzalez, R. (2018). Informal collection, recycling and export of valuable waste as transcendent factor in the municipal solid waste management: A Latin-American reality. *Journal of Cleaner Production*, *182*, 485–495. https://doi.org/10.1016/j.jclepro.2018.02.065

Britton, P. W. (1972). Improving Manual Solid Waste Separation Studies. *Journal of the Sanitary Engineering Division*, *98*(5), 717–730.

Brown, T. A. (2015). *Confirmatory Factor Analysis for Applied Research*. (T. D. Little, Ed.) (Second). New York: The Guilford Press.

Brunner, P. H., & Fellner, J. (2007). Setting priorities for waste management strategies in developing countries. *Waste Management and Research*, *25*(3), 234–240. https://doi.org/10.1177/0734242X07078296

Brunner, P. H., & Rechberger, H. (2015). Waste to energy - key element for sustainable waste management. *Waste Management*, *37*, 3–12. https://doi.org/10.1016/j.wasman.2014.02.003

Buenrostro, O., Bocco, G., & Bernache, G. (2001). Urban solid waste generation and disposal in Mexico: A case study. *Waste Management and Research*, *19*(2), 169–176. https://doi.org/10.1177/0734242x0101900208

Buenrostro, O., Bocco, G., & Cram, S. (2001). Classification of sources of municipal solid wastes in developing countries. *Resources, Conservation and Recycling*, *32*(1), 29–41. https://doi.org/10.1016/S0921-3449(00)00094-X

Buenrostro, O., Bocco, G., & Vence, J. (2001). Forecasting generation of urban solid waste in developing countries - A case study in Mexico. *Journal of the Air and Waste Management Association*, *51*(1), 86–93. https://doi.org/10.1080/10473289.2001.10464258

C.T. Agnew. (1984). Checkland 's soft systems approach. *The Royal Geographical Society (with the Institute of British Geographers)*, *16*(2), 167–174. Retrieved from https://www.jstor.org/stable/20002049

Caceres, O. A. ., Prado, I., & Moreno, C. (2014). *Gestion de Residuos Solidos Urbanos con Inclusion de Recolectores en Bolivia*. Santa Cruz de la Sierra.

Cai, L., & Liu, Y. (2013). Application of System Dynamics for MWM in China- A Case Study of Beijing. In *Conference Proceedings of the 31st International Conference of the System Dynamics Society* (pp. 1–31). Cambridge.

Captura Consulting. (2017). *Segmentacion, cuantificacion y descripcion de los niveles socioeconomicos en Santa Cruz, La Paz, El Alto y Cochabamba*.

Casa de la mujer. (1999). *La segunda vida de nuestra basura*. Santa Cruz de la Sierra.

Chaerul, M., Tanaka, M., & Shekdar, A. V. (2008). A system dynamics approach for hospital waste management. *Waste Management*, *28*(2), 442–449. https://doi.org/10.1016/j.wasman.2007.01.007

Chammas, G., Kayed, S., Al Shami, A., Kays, W., Citton, M., Kalot, M., … Saliba, N. A. (2020). Transdisciplinary interventions for environmental sustainability. *Waste Management*, *107*, 159–171. https://doi.org/10.1016/j.wasman.2020.03.043

Chang, N. Bin, Pires, A., & Martinho, G. (2011). *Empowering systems analysis for solid waste management: Challenges, trends, and perspectives*. *Critical Reviews in Environmental Science and Technology* (Vol. 41). https://doi.org/10.1080/10643381003608326

Chen, S. F., Wang, S., & Chen, C. Y. (2012). A simulation study using EFA and CFA programs based the impact of missing data on test dimensionality. *Expert Systems with Applications*, *39*(4), 4026–4031. https://doi.org/10.1016/j.eswa.2011.09.085

Chen, Y. C. (2018). Effects of urbanization on municipal solid waste composition. *Waste Management*, *79*, 828–836. https://doi.org/10.1016/j.wasman.2018.04.017

Chifari, R., Lo Piano, S., Bukkens, S. G. F., & Giampietro, M. (2016). A holistic framework for the integrated assessment of urban waste management systems. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2016.03.006

Chong, Y. T., Teo, K. M., & Tang, L. C. (2016). A lifecycle-based sustainability indicator framework for waste-to-energy systems and a proposed metric of sustainability. *Renewable and Sustainable Energy Reviews*, *56*, 797–809. https://doi.org/10.1016/j.rser.2015.11.036

Chowdhury, M. (2009). Searching quality data for municipal solid waste planning. *Waste Management*, *29*(8), 2240–2247. https://doi.org/10.1016/j.wasman.2009.04.005

Chung, S. S., & Lo, C. W. H. (2004). Waste management in Guangdong Cities: The waste management literacy and waste reduction preferences of domestic waste generators. *Environmental Management*, *33*(5), 692–711. https://doi.org/10.1007/s00267-004-0020-2

Cobo, S., Dominguez-Ramos, A., & Irabien, A. (2018). From linear to circular integrated waste management systems: a review of methodological approaches. *Resources, Conservation and Recycling*, *135*(August 2017), 279–295. https://doi.org/10.1016/j.resconrec.2017.08.003

Crabtree, J. (2020). Assessing Evo's Bolivia: Inclusion, Ethnicity, and Class. *Latin American Research Review*, *55*(2), 379–390. https://doi.org/10.25222/larr.863

Crabtree, J., & Whitehead, L. (2008). *Unresolved tensions: Bolivia past and present*. University of Pittsburgh Press.

Cucchiella, F., D'Adamo, I., & Gastaldi, M. (2014). Sustainable management of waste-to-energy facilities. *Renewable and Sustainable Energy Reviews*, *33*, 719–728. https://doi.org/10.1016/j.rser.2014.02.015

Dahlén, L., & Lagerkvist, A. (2008). Methods for household waste composition studies. *Waste Management*, *28*(7), 1100–1112. https://doi.org/10.1016/j.wasman.2007.08.014

Dai, T., & Shan, S. (2020). Path analysis of Beijing's dematerialization development based on system dynamics. *Sustainability (Switzerland)*, *12*(3). https://doi.org/10.3390/su12030829

Danish, M. S. S., Senjyu, T., Zaheb, H., Sabory, N. R., Ibrahimi, A. M., & Matayoshi, H. (2019). A novel transdisciplinary paradigm for municipal solid waste to energy. *Journal of Cleaner Production*, *233*, 880–892. https://doi.org/10.1016/j.jclepro.2019.05.402

Delgado, C. (2012, December 14). El nuevo servicio de aseo urbano costará más del doble. *EL DEBER*. Retrieved from https://eju.tv/2012/12/el-nuevo-servicio-de-aseo-urbano-costar-ms-del-doble/

Dennison, G. J., Dodd, V. A., & Whelan, B. (1996). A socio-economic based survey of household waste characteristics in the city of Dublin, Ireland. I. Waste composition. *Resources, Conservation and Recycling*, *17*(3), 227–244. https://doi.org/10.1016/0921-3449(96)01070-1

Dijkema, G. P. J., Reuter, M. A., & Verhoef, E. V. (2000). A new paradigm for waste management. *Waste Management*, *20*(8), 633–638. https://doi.org/10.1016/S0956-053X(00)00052-0

Ding, Z., Yi, G., Tam, V. W. Y., & Huang, T. (2016). A system dynamics-based environmental performance simulation of construction waste reduction management in China. *Waste Management*, *51*, 130–141. https://doi.org/10.1016/j.wasman.2016.03.001

Dong, Y., & Peng, C. Y. J. (2013). Principled missing data methods for researchers. *SpringerPlus*, *2*(1), 1–17. https://doi.org/10.1186/2193-1801-2-222

Dyson, B., & Chang, N. Bin. (2005). Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling. *Waste Management*, *25*(7), 669–679. https://doi.org/10.1016/j.wasman.2004.10.005

Edjabou, M. E., Jensen, M. B., Götze, R., Pivnenko, K., Petersen, C., Scheutz, C., & Astrup, T. F. (2015). Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation. *Waste Management*, *36*, 12–23. https://doi.org/10.1016/j.wasman.2014.11.009

Eker, S., Zimmermann, N., Carnohan, S., & Davies, M. (2018). Participatory system dynamics modelling for housing, energy and wellbeing interactions. *Building Research & Information*, *46*(7), 738–754. https://doi.org/10.1080/09613218.2017.1362919

Elagroudy, S., Warith, M. A., & El Zayat, M. (2016). *Municipal solid waste management and Green Economy*. *China Petrochemical Press*. Retrieved from https://scholar.google.ca/scholar?q=城市固体废物管理与处理处置技术&btnG=&hl=en&as_sdt=0,5#0

EMACRUZ. (2016). Caracterizacion de Residuos Solidos en Santa Cruz de la Sierra. Retrieved April 10, 2020, from http://www.emacruz.com.bo/wp-content/uploads/2016/10/RESIDUOS-SOLIDOS.pdf

Empresa Municipal de Aseo de Santa Cruz. (2018). *Informe Tecnico Economico y de Costos de la Tasa de Aseo Urbano del Municipio de Santa Cruz de la Sierra*. Santa Cruz de la Sierra.

Enders, C. K. (2003). Using the Expectation Maximization Algorithm to Estimate Coefficient Alpha for Scales with Item-Level Missing Data. *Psychological Methods*, *8*(3), 322–337. https://doi.org/10.1037/1082-989X.8.3.322

Estado Plurinacional de Bolivia. Ley del Medio Ambiente - Ley 1333, Gaceta Oficial de Bolivia § (1992). Bolivia.

Estado Plurinacional de Bolivia. Ley Nº 300 Ley Marco de la Madre Tierra y Desarrollo Integral para Vivir Bien (2012). Bolivia.

Estado Plurinacional de Bolivia. Ley 755 - Ley de Gestion Integral de Residuos Solidos (2015). Bolivia.

Estrellan, C. R., & Iino, F. (2010). Toxic emissions from open burning. *Chemosphere*, *80*(3), 193–207. https://doi.org/10.1016/j.chemosphere.2010.03.057

European Commission. (2004). Methodology for the Analysis of Solid Waste (SWA-Tool) User Version. European Commission. 5th Framework Programme, European Union.

Ezeah, C., Fazakerley, J. A., & Roberts, C. L. (2013). Emerging trends in informal sector recycling in developing and transition countries. *Waste Management*, *33*(11), 2509–2519. https://doi.org/10.1016/j.wasman.2013.06.020

Ezeah, C., & Roberts, C. L. (2012). Analysis of barriers and success factors affecting the adoption of sustainable management of municipal solid waste in Nigeria. *Journal of Environmental Management*, *103*, 9–14. https://doi.org/10.1016/j.jenvman.2012.02.027

Ezeah, C., & Roberts, C. L. (2014). Waste governance agenda in Nigerian cities: A comparative analysis. *Habitat International*, *41*, 121–128. https://doi.org/10.1016/j.habitatint.2013.07.007

Fabricant, N., & Postero, N. (2015). Sacrificing Indigenous Bodies and Lands: The Political-Economic History of Lowland Bolivia in Light of the Recent TIPNIS Debate. *Journal of Latin American and Caribbean Anthropology*, *20*(3), 452–474. https://doi.org/10.1111/jlca.12173

Fabrigar, L. R., MacCallum, R. C., Wegener, D. T., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, *4*(3), 272–299. https://doi.org/10.1037/1082-989X.4.3.272

Faguet, J., & Faguet, J. (2018). The Lessons of Bolivia Latin America ' s Shifting Politics The Lessons of Bolivia, *29*(4), 89–101.

Faguet, J. P. (2004). Does decentralization increase government responsiveness to local needs? Evidence from Bolivia. *Journal of Public Economics*, *88*(3–4), 867–893. https://doi.org/10.1016/S0047-2727(02)00185-8

Fahmi, W., & Sutton, K. (2010). Cairo's contested garbage: Sustainable solid waste management and the Zabaleen's right to the city. *Sustainability*, *2*(6), 1765–1783. https://doi.org/10.3390/su2061765

Featherston, C., & Doolan, M. (2012). A Critical Review of the Criticisms of System Dynamics. *Proceedings of the 30th International Conference of the System Dynamics Society*, 1–13. Retrieved from http://www.systemdynamics.org/conferences/2012/proceed/papers/P1228.pdf

Fischer, L. B., & Newig, J. (2016). Importance of actors and agency in sustainability transitions: A systematic exploration of the literature. *Sustainability (Switzerland)*, *8*(5). https://doi.org/10.3390/su8050476

Forrester, J. A. Y. W. (1968). Industrial Dynamics - After the First Decade. *Management Science*, *14*(7), 398–415.

Forrester, J. W. (1994). System dynamics, systems thinking, and soft OR. *System Dynamics Review*, *10*(2–3), 245–256. https://doi.org/10.1002/sdr.4260100211

Frankel, J. A. (2010). *The Natural Resource Course - A survey*. Cambridge.

Fundacion PAP. (2010). Recolectores de residuos solidos urbanos de la ciudad de Santa Cruz de la Sierra. Santa Cruz de la Sierra. Retrieved from https://www.aseca.com/maquinaria/recolectores

Gallagher, D., Ting, L., & Palmer, A. (2008). A journey into the unknown; taking the fear out of structural equation modeling with AMOS for the first-time user. *The Marketing Review*, *8*(3), 255–275. https://doi.org/10.1362/146934708x337672

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Ghisolfi, V., Diniz Chaves, G. de L., Ribeiro Siman, R., & Xavier, L. H. (2017). System dynamics applied to closed loop supply chains of desktops and laptops in Brazil: A perspective for social inclusion of waste pickers. *Waste Management*, *60*, 14–31. https://doi.org/10.1016/j.wasman.2016.12.018

Giannis, A., Chen, M., Yin, K., Tong, H., & Veksha, A. (2017). Application of system dynamics modeling for evaluation of different recycling scenarios in Singapore. *Journal of Material Cycles and Waste Management*, *19*(3), 1177–1185. https://doi.org/10.1007/s10163-016-0503-2

Gobierno Autonomo Departamental de Santa Cruz. (2018). *Auditoria Ambiental Ex Botadero El Gallito y Vertedero de Normandia*.

Gobierno Autonomo Municipal de Santa Cruz de la Sierra. (2016). *Plan Territorial de Desarrollo Integral Santa Cruz de la Sierra 2016-2020*.

Gobierno Autonomo Municipal de Santa Cruz de la Sierra. (2019). Gobierno Autonomo Municipal de Santa Cruz de la Sierra - Leyes y Decretos. Retrieved from http://www.gmsantacruz.gob.bo/index.php/mas/leyes-y-decretos-municipales

Gomez, G., Meneses, M., Ballinas, L., & Castells, F. (2008). Characterization of urban solid waste in Chihuahua, Mexico. *Waste Management*, *28*(12), 2465–2471. https://doi.org/10.1016/j.wasman.2007.10.023

Gonçalves, J., Gomes, M. C., Ezequiel, S., Moreira, F., & Loupa-Ramos, I. (2017). Differentiating peri-urban areas: A transdisciplinary approach towards a typology. *Land Use Policy*, *63*, 331–341. https://doi.org/10.1016/j.landusepol.2017.01.041

Goven, J., Langer, E. R. L., Baker, V., Ataria, J., & Leckie, A. (2015). A transdisciplinary approach to local waste management in New Zealand: Addressing interrelated challenges through indigenous partnership. *Futures*, *73*, 22–36. https://doi.org/10.1016/j.futures.2015.07.011

Green, G. (1988). The Quest for Tranquilidad: Paths to Home Ownership in Santa Cruz, Bolivia. *Bulletin of Latin American Research*, *7*(1), 1. https://doi.org/10.2307/3338436

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to Sustainable Development: New directions in the study of long term transformative change*. New York.

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1), 220–232. https://doi.org/10.1016/j.wasman.2012.09.008

Guibrunet, L., Sanzana Calvet, M., & Castán Broto, V. (2017). Flows, system boundaries and the politics of urban metabolism: Waste management in Mexico City and Santiago de Chile. *Geoforum*, *85*, 353–367. https://doi.org/10.1016/j.geoforum.2016.10.011

Guo, H., Hobbs, B. F., Lasater, M. E., Parker, C. L., & Winch, P. J. (2016). System dynamics-based evaluation of interventions to promote appropriate waste disposal behaviors in low-income urban areas : A Baltimore case study. *Waste Management*, *56*, 547–560. https://doi.org/10.1016/j.wasman.2016.05.019

Gupt, Y., & Sahay, S. (2015). Review of extended producer responsibility: A case study approach. *Waste Management and Research*, *33*(7), 595–611. https://doi.org/10.1177/0734242X15592275

Hansen, U. E., & Nygaard, I. (2014). Sustainable energy transitions in emerging economies: The formation of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011. *Energy Policy*, *66*, 666–676. https://doi.org/10.1016/j.enpol.2013.11.028

Hendriks, C. M. (2009). Policy design without democracy? Making democratic sense of transition management. *Policy Sciences*, *42*(4), 341–368. https://doi.org/10.1007/s11077-009-9095-1

Herczeg, M. (2013). Municipal waste management in Switzerland. *European Environment Agency (EEA)*, (February), 1–13. Retrieved from https://www.eea.europa.eu/publications/managing-municipal-solid-waste/switzerland-municipal-waste-management/view

Herzog, A., Dool Van den, L., Davidson, F., & Skinner, R. (2001). *Process , politics and participation - Experiences with strategies for local capacity building*. Rotterdam.

Hettiarachchi, H., Ryu, S., Caucci, S., & Silva, R. (2018). Municipal solid waste management in Latin America and the Caribbean: Issues and potential solutions from the governance perspective. *Recycling*, *3*(2). https://doi.org/10.3390/recycling3020019

Hinkin, T. R. (1998). A brief tutorial on the development of measures for use in survey questionnaires. *Organizational Research Methods*, *1*(1), 104–121. https://doi.org/10.1177/109442819800100106

Hoang, M. G., Fujiwara, T., Pham Phu, S. T., & Thi, K. T. N. (2017). Predicting waste generation using Bayesian model averaging. *Global J. Environ. Sci. Manage*, *3*(4), 385–402. https://doi.org/10.22034/gjesm.2017.03.04.005

Hodson, M., & Marvin, S. (2010). Can cities shape socio-technical transitions and how would we know if they were? *Research Policy*, *39*(4), 477–485. https://doi.org/10.1016/j.respol.2010.01.020

Hoornweg, D., & Bhada-tata, P. (2012). What a waste: A global review of solid waste management. *Urban Development Series Knowledge Papers*, 9. https://doi.org/10.1111/febs.13058

Hoornweg, D., & Gianelli, N. (2007, October). Managing municipal solid waste in Latin America and the Caribbean. *Gridlines*, (28), 1–4.

Huang, X., & Zhu, Q. (2002). A pseudo-nearest-neighbor approach for missing data recovery on Gaussian random data sets. *Pattern Recognition Letters*, *23*(13), 1613–1622. https://doi.org/10.1016/S0167-8655(02)00125-3

IADB. (2015). Solid Waste Management in Latin America and the Caribbean. *Inter-American Development Bank*, 6–8. Retrieved from https://publications.iadb.org/handle/11319/7177#sthash.7bODjAHq.dpuf

IBNORCA. (1996). NB-743 Residuos sólidos – Determinación de parámetros de diseño sobre residuos sólidos municipales. La Paz.

INE. (2012). Population Projections in Bolivian municipalities 2012-2020. Retrieved May 10, 2019, from https://www.ine.gob.bo/index.php/demografia/introduccion-2

INE. (2013). Ficha Resumen Censo de Población y Vivienda 2012. Retrieved May 10, 2020, from http://censosbolivia.ine.gob.bo/censofichacomunidad/c_listadof/listar_comunidades

INE. (2017). Recoleccion de residuos solidos por ciudad capital de departamento. Retrieved May 10, 2019, from https://www.ine.gob.bo/index.php/medio-ambiente/introduccion-5

INE. (2018). Households and dwelling types. Retrieved May 1, 2020, from https://www.ine.gob.bo/index.php/vivienda/vivienda-encuesta-de-hogares/

INE. (2020). Municipal Solid Waste Collection per city in Bolivia. Retrieved May 10, 2020, from https://www.ine.gob.bo/index.php/wpfd_file/bolivia-recoleccion-de-residuos-por-ciudad-y-tipo-de-procedencia-2005-2019/

Isa, M. H., Asaari, F. A. H., Ramli, N. A., Ahmad, S., & Siew, T. S. (2005). Solid waste collection and recycling in Nibong Tebal, Penang, Malaysia: A case study. *Waste Management and Research*, *23*(6), 565–570. https://doi.org/10.1177/0734242X05059803

Jadoon, A., Batool, S. A., & Chaudhry, M. N. (2014). Assessment of factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan. *Journal of Material Cycles and Waste Management*, *16*(1), 73–81. https://doi.org/10.1007/s10163-013-0146-5

JICA. (2005). *Supporting Capacity Development in Solid Waste Management in Developing Countries; Towards Improving Solid Waste Management Capacity of Entire Society*. Retrieved from http://open_jicareport.jica.go.jp/pdf/11795846.pdf%0Ahttp://jica-ri.jica.go.jp/IFIC_and_JBICI-Studies/english/publications/reports/study/topical/waste/

Johnson, B. B. (2010). Decolonization and its paradoxes: The (Re)envisioning of health policy in bolivia. *Latin American Perspectives*, *37*(3), 139–159. https://doi.org/10.1177/0094582X10366535

Jönsson, P., & Wohlin, C. (2006). Benchmarking k-nearest neighbour imputation with homogeneous Likert data. *Empirical Software Engineering*, *11*(3), 463–489. https://doi.org/10.1007/s10664-006-9001-9

Karavezyris, V., Timpe, K.-P., & Marzi, R. (2002). Application of system dynamics and fuzzy logic to forecasting of municipal solid waste. *Mathematics and Computers in Simulation*, *60*(3–5), 149–158. https://doi.org/10.1016/S0378-4754(02)00010-1

Karija, M. K., & Lukaw, Y. S. (2013). The Impact of Poor Municipal Solid Waste Management Practices and Sanitation Status on Water Quality and Public Health in Cities of the Least Developed Countries: the Case of Juba, South Sudan. *International Journal of Applied Science and Technology*, *3*(4), 87–99.

Karimy, M., Zareban, I., Araban, M., & Montazeri, A. (2015). An extended theory of planned behavior (TPB) used to predict smoking behavior among a sample of Iranian medical students. *International Journal of High Risk Behaviors and Addiction*, *4*(3), 1–7. https://doi.org/10.5812/ijhrba.24715

Kawai, K., & Osako, M. (2013). Advantages and disadvantages of a municipal solid waste collection service for citizens of Hanoi City, Vietnam. *Waste Management and Research*, *31*(3), 327–332. https://doi.org/10.1177/0734242X12471099

Kawai, K., & Tasaki, T. (2016). Revisiting estimates of municipal solid waste generation per capita and their reliability. *Journal of Material Cycles and Waste Management*, *18*(1), 1–13. https://doi.org/10.1007/s10163-015-0355-1

Kelly, G., Mulgan, G., & Muers, S. (2002). Creating Public Value: An analytical framework for public service reform. *Strategy Unit, Cabinet Office, UK Government*, 1–35. Retrieved from http://webarchive.nationalarchives.gov.uk/20100416132449/http:/www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/public_value2.pdf

Kemp, R. (2007). An Example of a ``Managed Transition'': The Transformation of the Waste Management Subsystem in the Netherlands (1960--2000). *Innovations Towards Sustainability: Conditions and Consequences*, 87–94. https://doi.org/10.1007/978-3-7908-1650-1_6

Keskintürk, T., & Er, Ş. (2007). A genetic algorithm approach to determine stratum boundaries and sample sizes of each stratum in stratified sampling. *Computational Statistics & Data Analysis*, *52*(1), 53–67. https://doi.org/10.1016/j.csda.2007.03.026

Khalili, N. R., & Duecker, S. (2013). Application of multi-criteria decision analysis in design of sustainable environmental management system framework. *Journal of Cleaner Production*, *47*, 188–198. https://doi.org/10.1016/j.jclepro.2012.10.044

Khan, D., Kumar, A., & Samadder, S. R. (2016). Impact of socioeconomic status on municipal solid waste generation rate. *Waste Management*, *49*, 15–25. https://doi.org/10.1016/j.wasman.2016.01.019

Kirshner, J. (2011). Migration, Informalization and Public Space in Santa Cruz, Bolivia. *Bolivian Studies Journal/Revista de Estudios Bolivianos*, *15*, 150–190. https://doi.org/10.5195/bsj.2010.10

Kirshner, J. D. (2013). City profile: Santa Cruz de la Sierra. *Cities*, *31*, 544–552. https://doi.org/10.1016/j.cities.2011.12.009

Kirshner, J. D., & Traverso, A. C. (2009). Santa Cruz de la Sierra en la Era de la Globalización : Informalidad , Inmigración y Visión Política del Espacio Público, (April).

Klee, A. J., & Carruth, D. (1970). Sample Weights in Solid Waste Composition Studies. *Journal of the Sanitary Engineering Division*, *96*(4), 945–954.

Klunder, A. Van De. (1995). *Community and private (formal and informal) sector involvement in Municipal Solid Waste Management in developing countries*.

Klunder, A. Van De, & Anschütz, J. (2001). *Integrated Sustainable Waste Management - the Concept. Tools for Decision-makers. Experiences from the Urban Waste Expertise Programme (1995-2001)*. Retrieved from e-mail: justine@intouch.com

Knussen, C., Yule, F., MacKenzie, J., & Wells, M. (2004). An analysis of intentions to recycle household waste: The roles of past behaviour, perceived habit, and perceived lack of facilities. *Journal of Environmental Psychology*, *24*(2), 237–246. https://doi.org/10.1016/j.jenvp.2003.12.001

Kohl, B., & Bresnahan, R. (2010). Bolivia under morales: Consolidating power, initiating decolonization. *Latin American Perspectives*, *37*(3), 5–17. https://doi.org/10.1177/0094582X10364030

Kohl, B., & Farthing, L. (2012). Material constraints to popular imaginaries: The extractive economy and resource nationalism in Bolivia. *Political Geography*, *31*(4), 225–235. https://doi.org/10.1016/j.polgeo.2012.03.002

Kollikkathara, N., Feng, H., & Yu, D. (2010). A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues. *Waste Management*, *30*(11), 2194–2203. https://doi.org/10.1016/j.wasman.2010.05.012

Krause, M. J., & Townsend, T. G. (2014). Rapid Waste Composition Studies for the Assessment of Solid Waste Management Systems in Developing Countries. *International Journal of Waste Resources*, *04*(02), 2–7. https://doi.org/10.4172/2252-5211.1000145

Kubanza, N. S., & Simatele, D. (2018). Sustainable solid waste management in sub-Saharan African cities: application of system thinking and system dynamic as methodological imperatives in Kinshasa, the Democratic Republic of Congo. *Local Environment*, *23*(2), 220–238. https://doi.org/10.1080/13549839.2017.1399996

Kumar, A., & Samadder, S. R. (2017). A review on technological options of waste to energy for effective management of municipal solid waste. *Waste Management*, *69*, 407–422. https://doi.org/10.1016/j.wasman.2017.08.046

Lalander, R. (2017). Ethnic rights and the dilemma of extractive development in plurinational Bolivia. *International Journal of Human Rights*, *21*(4), 464–481. https://doi.org/10.1080/13642987.2016.1179869

Lane, D. C. (2000). Should System Dynamics be Described as a ` Hard ' or ` Deterministic ' Systems Approach ?, *22*(June 1999), 3–22.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., … Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science*, *7*(SUPPL. 1), 25–43. https://doi.org/10.1007/s11625-011-0149-x

Lawhon, M. (2012). Contesting power, trust and legitimacy in the South African e-waste transition. *Policy Sciences*, *45*(1), 69–86. https://doi.org/10.1007/s11077-012-9146-x

Lebersorger, S., & Beigl, P. (2011). Municipal solid waste generation in municipalities: Quantifying impacts of household structure, commercial waste and domestic fuel. *Waste Management*, *31*(9–10), 1907–1915. https://doi.org/10.1016/j.wasman.2011.05.016

Lehoucq, F., & Pérez-Liñán, A. (2014). Breaking out of the coup trap: Political competition and military coups in Latin America. *Comparative Political Studies*, *47*(8), 1105–1129. https://doi.org/10.1177/0010414013488561

Linzner, R., & Lange, U. (2013). Role and size of informal sector in waste management – a review. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management*, *166*(2), 69–83. https://doi.org/10.1680/warm.12.00012

Loan, L. T. T., Nomura, H., Takahashi, Y., & Yabe, M. (2017). Psychological driving forces behind households' behaviors toward municipal organic waste separation at source in Vietnam: a structural equation modeling approach. *Journal of Material Cycles and Waste Management*, *19*(3), 1052–1060. https://doi.org/10.1007/s10163-017-0587-3

Lohri, C. R., Camenzind, E. J., & Zurbrügg, C. (2014). Financial sustainability in municipal solid waste management - Costs and revenues in Bahir Dar, Ethiopia. *Waste Management*, *34*(2), 542–552. https://doi.org/10.1016/j.wasman.2013.10.014

Lozano Lazo, D. P. (2015). *Waste pickers in Santa Cruz de la Sierra (Bolivia): towards an inclusive municipal solid waste management*. Graduate Institute of International and Development Studies. Retrieved from https://repository.graduateinstitute.ch/record/293529?ln=en

Lozano Lazo, D. P., & Gasparatos, A. (2019). Sustainability Transitions in the Municipal Solid Waste Management Systems of Bolivian Cities: Evidence from La Paz and Santa Cruz de la Sierra. *Sustainability*, *11*(17), 4582. https://doi.org/10.3390/su11174582

Ma, H., Huang, J., Fuller, F., & Rozelle, S. (2006). Getting Rich and Eating Out: Consumption of Food Away from Home in Urban China. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie*, *54*(1), 101–119. https://doi.org/10.1111/j.1744-7976.2006.00040.x

Ma, J., & Hipel, K. W. (2016). Exploring social dimensions of municipal solid waste management around the globe – A systematic literature review. *Waste Management*, *56*, 3–12. https://doi.org/10.1016/j.wasman.2016.06.041

Ma, J., Hipel, K. W., Hanson, M. L., Cai, X., & Liu, Y. (2018). An analysis of influencing factors on municipal solid waste source-separated collection behavior in Guilin, China by Using the Theory of Planned Behavior. *Sustainable Cities and Society*, *37*(September 2017), 336–343. https://doi.org/10.1016/j.scs.2017.11.037

Majeed, A., Batool, S. A., & Chaudhry, M. N. (2017). Informal Waste Management in the Developing World: Economic Contribution Through Integration With the Formal Sector. *Waste and Biomass Valorization*, *8*(3), 679–694. https://doi.org/10.1007/s12649-016-9648-4

Malard, J., Adamowski, J., Rojas, D. M., Carrera, J., Gálvez, J., Monadres, H., & Melgar-Quiñonez, H. (2015). Use of participatory system dynamics modelling to assess the sustainability of smallholder agriculture. *2015 ASABE International Meeting*, (July), 1. https://doi.org/10.13140/RG.2.1.4545.1602

Mamady, K. (2016). Factors influencing attitude, safety behavior, and knowledge regarding household waste management in Guinea: A cross-sectional study. *Journal of Environmental and Public Health*, *2016*. https://doi.org/10.1155/2016/9305768

Mancilla García, M. (2017). Negotiating in the absence of trust: exploring the interactions between officials and residents in a waste management project in Copacabana, Bolivia. *Local Environment*, *22*(6), 667–681. https://doi.org/10.1080/13549839.2016.1252319

Manfredi, E. C., Flury, B., Viviano, G., Thakuri, S., Khanal, S. N., Jha, P. K., … Salerno, F. (2010). Solid waste and water quality management models for sagarmatha national park and buffer zone, Nepal. *Mountain Research and Development*, *30*(2), 127–142. https://doi.org/10.1659/MRD-JOURNAL-D-10-00028.1

Mardani, A., Streimikiene, D., Zavadskas, E. K., Cavallaro, F., Nilashi, M., Jusoh, A., & Zare, H. (2017). Application of Structural Equation Modeling (SEM) to solve environmental sustainability problems: A comprehensive review and meta-analysis. *Sustainability (Switzerland)*, *9*(10).

https://doi.org/10.3390/su9101814

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste Management*, *33*(4), 988–1003. https://doi.org/10.1016/j.wasman.2012.12.023

Marzouk, M., & Azab, S. (2014). Environmental and economic impact assessment of construction and demolition waste disposal using system dynamics. *Resources, Conservation and Recycling*, *82*, 41–49. https://doi.org/10.1016/j.resconrec.2013.10.015

Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., & Moore, H. (2013). Transdisciplinary global change research: The co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability*, *5*(3–4), 420–431. https://doi.org/10.1016/j.cosust.2013.07.001

Mbiba, B. (2014). Urban solid waste characteristics and household appetite for separation at source in Eastern and Southern Africa. *Habitat International*, *43*, 152–162. https://doi.org/10.1016/j.habitatint.2014.02.001

McCarty, J. A., & Shrum, L. J. (1994). Value Orientations , and Attitudes about Recycling as Antecedents of Recycling Behavior. *Journal of Business Research*, *30*, 53–62.

Meadows, D. H. (2008). *Thinking in systems*. (D. Wright, Ed.). Vermont: Chelsea Green.

Medina, L., & Schneider, F. (2018). *Shadow economies around the world: what did we learn over the last 20 years? IMF Working Papers* (Vol. 18). https://doi.org/9781484338636/1018-5941

Memon, M. A. (2010). Integrated solid waste management based on the 3R approach. *Journal of Material Cycles and Waste Management*, *12*(1), 30–40. https://doi.org/10.1007/s10163-009-0274-0

Meylan, G., Lai, A., Hensley, J., Stauffacher, M., & Krütli, P. (2018). Solid waste management of small island developing states—the case of the Seychelles: a systemic and collaborative study of Swiss and Seychellois students to support policy. *Environmental Science and Pollution Research*, *25*(36), 35791–35804. https://doi.org/10.1007/s11356-018-2139-3

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B., & Mensah, M. Y. (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. *Waste Management*, *46*, 15–27. https://doi.org/10.1016/j.wasman.2015.09.009

Ministerio de Medio Ambiente y Agua. (2011a). *Diagnostico de la Gestion de Residuos Solidos en Bolivia*. La Paz.

Ministerio de Medio Ambiente y Agua. (2011b). *Diagnóstico de la Gestión de Residuos Sólidos en el Departamento de Santa Cruz*.

Ministerio de Medio Ambiente y Agua. (2017). *Guia para el Reciclaje de Residuos Solidos en Bolivia* (Vol. 67).

Ministerio de Vivienda y Servicios Basicos. (2001). *Plan Nacional de Saneamiento Basico 2001 - 2010*.

Mmereki, D., Baldwin, A., & Li, B. (2016). A comparative analysis of solid waste management in developed, developing and lesser developed countries. *Environmental Technology Reviews*, *5*(1), 120–141. https://doi.org/10.1080/21622515.2016.1259357

Morrissey, A. J., & Browne, J. (2004). Waste management models and their application to sustainable waste management. *Waste Management*, *24*(3), 297–308. https://doi.org/10.1016/j.wasman.2003.09.005

Mosler, H. J., Tamas, A., Tobias, R., Rodríguez, T. C., & Miranda, O. G. (2008). Deriving interventions on the basis of factors influencing behavioral intentions for waste recycling, composting, and reuse in Cuba. *Environment and Behavior*, *40*(4), 522–544. https://doi.org/10.1177/0013916507300114

Narayana, T. (2009). Municipal solid waste management in India: From waste disposal to recovery of resources? *Waste Management*, *29*(3), 1163–1166. https://doi.org/10.1016/j.wasman.2008.06.038

Navarrete-Hernandez, P., & Navarrete-Hernandez, N. (2018). Unleashing Waste-Pickers’ Potential: Supporting Recycling Cooperatives in Santiago de Chile. *World Development*, *101*, 293–310. https://doi.org/10.1016/j.worlddev.2017.08.016

Newell, B., & Proust, K. (2009). *I see how you think: Using Influence Diagrams to Support Dialogue*.

Nguyen, T. T. P., Zhu, D., & Le, N. P. (2015). Factors influencing waste separation intention of residential households in a developing country: Evidence from Hanoi, Vietnam. *Habitat International*, *48*, 169–176. https://doi.org/10.1016/j.habitatint.2015.03.013

Nijenhuis, G. (2002). *Decentralisation and popular participation in Bolivia: The link between local governance and local development*. *Nederlandse Geografische Studies*.

Nikolaou, P., Basbas, S., & Politis, I. (2020). Trip and Personal Characteristics towards the Intention to Cycle in Larnaca , Cyprus : An EFA-SEM Approach.

Nordtest. (1995). Municipal Solid Waste: Sampling and characterisation. Nordtest, Espoo, Finland. Retrieved from http://www.nordtest.info/images/documents/nt-methods/environment/NT envir 001_Solid waste, municipal_Sampling and characterisation_Nordtest Method.pdf

Nzeadibe, T. C., & Anyadike, R. N. C. (2012). Social participation in city governance and urban livelihoods: Constraints to the informal recycling economy in Aba, Nigeria. *City, Culture and Society*, *3*(4), 313–325. https://doi.org/10.1016/j.ccs.2012.10.001

Ojeda-Benítez, S., Lozano-Olvera, G., Morelos, R. A., & Vega, C. A. de. (2008). Mathematical modeling to predict residential solid waste generation. *Waste Management*, *28*(SUPPL. 1), 7–13. https://doi.org/10.1016/j.wasman.2008.03.020

Ojeda-Benítez, S., Vega, C. A. de, & Marquez-Montenegro, M. Y. (2008). Household solid waste characterization by family socioeconomic profile as unit of analysis. *Resources, Conservation and Recycling*, *52*(7), 992–999. https://doi.org/10.1016/j.resconrec.2008.03.004

Onibokun, A. (1999). *Managing the Monster - Urban Waste and Governance in Africa*. □□□□□□ (Vol. ث ققثق).

Onu, B., Surendran, S. S., & Price, T. (2014). Impact of inadequate urban planning on municipal solid waste management in the Niger Delta Region of Nigeria. *Journal of Sustainable Development*, *7*(6), 27–45. https://doi.org/10.5539/jsd.v7n6p27

Ortiz, D. (2019, August 23). El POA 2020 prioriza salud, finanzas, aseo urbano y educación. *EL DEBER*. Retrieved from https://eldeber.com.bo/santa-cruz/el-poa-2020-prioriza-salud-finanzas-aseo-urbano-y-educacion_143398

Otero, D. (2016). Tras diez años con la misma empresa, La Paz enfrenta nuevos desafíos con la basura.

Owusu, G. (2010). Social effects of poor sanitation and waste management on poor urban communities: A neighborhood-specific study of Sabon Zongo, Accra. *Journal of Urbanism*, *3*(2), 145–160. https://doi.org/10.1080/17549175.2010.502001

Oyake-Ombis, L., van Vliet, B. J. M., & Mol, A. P. J. (2015). Managing plastic waste in East Africa: Niche innovations in plastic production and solid waste. *Habitat International*, *48*, 188–197. https://doi.org/10.1016/j.habitatint.2015.03.019

Oyoo, R., Leemans, R., & Mol, A. P. J. (2011). Future projections of urban waste flows aand their impacts in African metropolises cities. *International Journal of Environmental Research*, *5*(3), 705–724.

Oztekin, C., Teksöz, G., Pamuk, S., Sahin, E., & Kilic, D. S. (2017). Gender perspective on the factors predicting recycling behavior: Implications from the theory of planned behavior. *Waste Management*, *62*, 290–302. https://doi.org/10.1016/j.wasman.2016.12.036

Padilla, A. J., & Trujillo, J. C. (2018). Waste disposal and households' heterogeneity. Identifying factors shaping attitudes towards source-separated recycling in Bogotá, Colombia. *Waste Management*, *74*, 16–33. https://doi.org/10.1016/j.wasman.2017.11.052

Page, G. G., Wise, R. M., Lindenfeld, L., Moug, P., Hodgson, A., Wyborn, C., & Fazey, I. (2016). Co-designing transformation research: lessons learned from research on deliberate practices for transformation. *Current Opinion in Environmental Sustainability*, *20*(October), 86–92. https://doi.org/10.1016/j.cosust.2016.09.001

PAHO. (2002). *Evaluación regional de los servicios de manejo de residuos sólidos municipales*.

Pakpour, A. H., Zeidi, I. M., Emamjomeh, M. M., Asefzadeh, S., & Pearson, H. (2014). Household waste behaviours among a community sample in Iran: An application of the theory of planned behaviour. *Waste Management*, *34*(6), 980–986. https://doi.org/10.1016/j.wasman.2013.10.028

Pando, E., & Morales, J. (2018). *Indice Inmobiliario Ultracasas.com*. Santa Cruz de la Sierra.

Parizeau, K., Maclaren, V., & Chanthy, L. (2006). Waste characterization as an element of waste management planning: Lessons learned from a study in Siem Reap, Cambodia. *Resources, Conservation and Recycling*, *49*(2), 110–128. https://doi.org/10.1016/j.resconrec.2006.03.006

Park, H. S., Levine, T. R., & Sharkey, W. F. (1998). The theory of reasoned action and self-construals: Understanding recycling in hawai'i. *Communication Studies*, *49*(3), 196–208. https://doi.org/10.1080/10510979809368531

Parto, S., Loorbach, D., LansinkAd, & Kemp, R. (2007). Transitions and institutional change : the case of the Dutch waste subsystem. In U. N. University (Ed.), *Industrial innovation and environmental regulation : developing workable solutions* (pp. 233–257).

Perry, G. D. R., & Williams, I. D. (2007). The participation of ethnic minorities in kerbside recycling: A case study. *Resources, Conservation and Recycling*, *49*(3), 308–323. https://doi.org/10.1016/j.resconrec.2006.02.006

Pohl, C. (2008). From science to policy through transdisciplinary research. *Environmental Science and Policy*, *11*(1), 46–53. https://doi.org/10.1016/j.envsci.2007.06.001

Postero, N. (2007). *Now we are citizens - Indigenous Politics in Postmulticultural Bolivia*. Stanford: Stanford University Press.

Qu, X. yan, Li, Z. shan, Xie, X. yuan, Sui, Y. mei, Yang, L., & Chen, Y. (2009). Survey of composition and generation rate of household wastes in Beijing, China. *Waste Management*, *29*(10), 2618–2624. https://doi.org/10.1016/j.wasman.2009.05.014

Rahman, M. Z., Siwar, C., & Begum, R. A. (2017). Achieving Sustainable Livelihood Through Solid Waste Management in Dhaka City. *International Journal of GEOMATE*, *12*(30), 19–27. https://doi.org/10.21660/2017.30.160618

Ramayah, T., Lee, J. W. C., & Lim, S. (2012). Sustaining the environment through recycling: An empirical study. *Journal of Environmental Management*, *102*, 141–147. https://doi.org/10.1016/j.jenvman.2012.02.025

Ravetz, J. R. (2006). Post-Normal Science and the complexity of transitions towards sustainability. *Ecological Complexity*, *3*(4), 275–284. https://doi.org/10.1016/j.ecocom.2007.02.001

Regalsky, P. (2010). Political processes and the reconfiguration of the state in bolivia. *Latin American Perspectives*, *37*(3), 35–50. https://doi.org/10.1177/0094582X10364032

Rego, R. F., Moraes, L. R. S., & Dourado, I. (2005). Diarrhoea and garbage disposal in Salvador, Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *99*(1), 48–54. https://doi.org/10.1016/j.trstmh.2004.02.008

Reyna-Bensusan, N., Wilson, D. C., & Smith, S. R. (2018). Uncontrolled burning of solid waste by households in Mexico is a significant contributor to climate change in the country. *Environmental Research*, *163*(October 2017), 280–288. https://doi.org/10.1016/j.envres.2018.01.042

Richardson, G. P. (1986). Problems with causal-loop diagrams, *2*(2), 158–170.

Richardson, G. P., & Andersen, D. F. (1995). Teamwork in group model building. *System Dynamics Review*, *11*(2), 113–137. https://doi.org/10.1002/sdr.4260110203

Rodić, L., & Wilson, D. C. (2017). Resolving governance issues to achieve priority sustainable development goals related to solid waste management in developing countries. *Sustainability (Switzerland)*, *9*(3). https://doi.org/10.3390/su9030404

Rojas C., A., Yabar, H., Mizunoya, T., & Higano, Y. (2018). The Potential Benefits of Introducing Informal Recyclers and Organic Waste Recovery to a Current Waste Management System: The Case Study of Santiago de Chile. *Resources*, *7*(1), 18. https://doi.org/10.3390/resources7010018

Rosa, R., & Vespa, M. A. (2000). *La basura en los barrios populares - Propuesta para un sistema de recoleccion*. Rotterdam.

Rosenberg Daneri, D., Trencher, G., & Petersen, J. (2015). Students as change agents in a town-wide sustainability transformation: The Oberlin Project at Oberlin College. *Current Opinion in Environmental Sustainability*, *16*, 14–21. https://doi.org/10.1016/j.cosust.2015.07.005

Rotmans, J., Kemp, R., & Van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight*, *3*(1), 15–31. https://doi.org/10.1108/14636680110803003

Runfola, J., & Gallardo, A. (2009). Análisis comparativo de los diferentes métodos de caracterización de residuos urbanos para su recolección selectiva en comunidades urbanas. In *II Simposio Iberoamericano de Ingeniería de Residuos*. Barranquilla, Colombia.

Sadia, R. (2014a). GROUP MODELING-BUILDING: LESSONS LEARNED FROM A CASE STUDY. In *The Challenge of Developing Creative Artists in a Standardized World* (Vol. 7, pp. 50–55). https://doi.org/10.14684/intertech.13.2014.50-55

Sadia, R. (2014b). The impact of culture on group model-building process. *PICMET 2014 - Portland International Center for Management of Engineering and Technology, Proceedings: Infrastructure and Service Integration*, 1585–1590.

Sahimaa, O., Hupponen, M., Horttanainen, M., & Sorvari, J. (2015). Method for residual household waste composition studies. *Waste Management*, *46*, 3–14. https://doi.org/10.1016/j.wasman.2015.08.032

Sakurai, K. (1983). Manual de Instruccion de Analisis de Residuos Solidos Programa Regional de la OPS/EHP/CEPIS de mejoramiento de la recoleccion, transporte y disposicion final de residuos solidos. Retrieved from http://www.bvsde.paho.org/eswww/proyecto/repidisc/publica/hdt/hdt017.html

Salman, T. (2006). The jammed democracy: Bolivia's troubled political learning process. *Bulletin of Latin American Research*, *25*(2), 163–182. https://doi.org/10.1111/j.0261-3050.2006.00158.x

Savino, A., Solorzano, G., Quispe, C., & Correal, M. C. (2018). *Waste Management Outlook for Latin America and the Caribbean.* Retrieved from https://wedocs.unep.org/handle/20.500.11822/26448

Schenck, R., Blaauw, D., & Viljoen, K. (2016). Enabling factors for the existence of waste pickers: A systematic review. *Social Work (South Africa)*, *52*(1), 35–53. https://doi.org/10.15270/52-1-478

Schroeder, P., Anggraeni, K., & Weber, U. (2019). The Relevance of Circular Economy Practices to the Sustainable Development Goals. *Journal of Industrial Ecology*, *23*(1), 77–95. https://doi.org/10.1111/jiec.12732

Schumacker, R. E., & Lomax, R. G. (2016). *A Beginner's Guide to Structural Equation Modeling* (1st ed.). New York: Routledge.

Seadon, J. K. (2010). Sustainable waste management systems. *Journal of Cleaner Production*, *18*(16–17), 1639–1651. https://doi.org/10.1016/j.jclepro.2010.07.009

Sekito, T., Prayogo, T. B., Dote, Y., Yoshitake, T., & Bagus, I. (2013). Influence of a community-based waste management system on people’s behavior and waste reduction. *Resources, Conservation and Recycling*, *72*, 84–90. https://doi.org/10.1016/j.resconrec.2013.01.001

Seleme Antelo, S., Prado Salmon, F., Prado Zanini, I., & Ledo Garcia, C. (2006). *Santa Cruz Y Su Gente*. Santa Cruz de la Sierra: CEDURE.

Sembiring, E., & Nitivattananon, V. (2010). Sustainable solid waste management toward an inclusive society: Integration of the informal sector. *Resources, Conservation and Recycling*, *54*(11), 802–809. https://doi.org/10.1016/j.resconrec.2009.12.010

Seravalli, A. (2016). ReTuren : participatory design , co-production and makers ’ culture for sustainable waste handling.

Seravalli, A., Agger Eriksen, M., & Hillgren, P. A. (2017). Co-Design in co-production processes: jointly articulating and appropriating infrastructuring and commoning with civil servants. *CoDesign*, *13*(3), 187–201. https://doi.org/10.1080/15710882.2017.1355004

Sfeir, H., Reinhart, D. R., & McCauley-Bell, P. R. (1999). An evaluation of municipal solid waste composition bias sources. *Journal of the Air and Waste Management Association*, *49*(9), 1096–1102. https://doi.org/10.1080/10473289.1999.10463903

Shamshiry, E., Bin Mokhtar, M., & Abdulai, A.-M. (2014). Comparison of Artificial Neural Network (ANN) and Multiple Regression Analysis for Predicting the amount of Solid Waste Generation in a Tourist and Tropical Area—Langkawi Island. In *International Conference on Biological, Civil and Environmental Engineering (BCEE-2014) March 17-18, 2014 Dubai (UAE)*. International Institute of Chemical, Biological & Environmental Engineering. https://doi.org/10.15242/IICBE.C0314099

Shekdar, A. V. (2009). Sustainable solid waste management - An integrated approach for Asian countries. *Waste Management*, *29*(4), 1438–1448. https://doi.org/10.1016/j.wasman.2008.08.025

Shrestha, S. K., & Burns, R. C. (2016). Integrating Constraints to the Theory of Planned Behavior in Predicting Deer Hunting Participation. *Human Dimensions of Wildlife*, *21*(5), 445–459. https://doi.org/10.1080/10871209.2016.1187779

Silva, A., Rosano, M., Stocker, L., & Gorissen, L. (2017). From waste to sustainable materials management: Three case studies of the transition journey. *Waste Management*, *61*, 547–557. https://doi.org/10.1016/j.wasman.2016.11.038

Singh, S., & Chokhandre, P. (2015). Assessing the impact of waste picking on musculoskeletal disorders among waste pickers in Mumbai, India: A cross-sectional study. *BMJ Open*, *5*(9), 1–8. https://doi.org/10.1136/bmjopen-2015-008474

Späth, P., & Rohracher, H. (2010). “Energy regions”: The transformative power of regional discourses on socio-technical futures. *Research Policy*, *39*(4), 449–458. https://doi.org/10.1016/j.respol.2010.01.017

Stave, K. (2010). Participatory system dynamics modeling for sustainable environmental management: Observations from four cases. *Sustainability*, *2*(9), 2762–2784. https://doi.org/10.3390/su2092762

Stave, K. A., & Dwyer, M. F. (2005). A Group Model Building Process to Integrate Land Use, Transportation, and Air Quality Planning in Las Vegas, Nevada. *Proceedings of the 23rd International Conference of the System Dynamics Society*, *13*(2), 138–139.

Stave, K. a, & Ph, D. (2008). Zero Waste by 2030 : A system dynamics simulation tool for stakeholder involvement in Los Angeles ' solid waste planning initiative. *International Conference of the System Dynamics Society*, (July 2007), 1–12. https://doi.org/10.1016/j.jneb.2016.04.399

Stephanie Von Der Heyde, V. (2014). Towards a sustainable incremental waste management system in Enkanini: A transdisciplinary case study in Sustainable Development Planning and Management in the, (April).

Sterman, J. D. (2000). *Business Dynamics - Systems Thinking and Modeling for a complex world*. McGraw Hill Inc.

Steuer, B., Ramusch, R., Part, F., & Salhofer, S. (2017). Analysis of the value chain and network structure of informal waste recycling in Beijing, China. *Resources, Conservation and Recycling*, *117*, 137–150. https://doi.org/10.1016/j.resconrec.2016.11.007

Stoeva, K., & Alriksson, S. (2017). Influence of recycling programmes on waste separation behaviour. *Waste Management*, *68*, 732–741. https://doi.org/10.1016/j.wasman.2017.06.005

Strydom, W. F. (2018). Applying the theory of planned behavior to recycling behavior in South Africa. *Recycling*, *3*(3). https://doi.org/10.3390/recycling3030043

Sudhir, V., Srinivasan, G., & Muraleedharan, V. R. (1997). Planning for sustainable solid waste management in urban India. *System Dynamics Review*, *13*(3), 223–246. https://doi.org/10.1002/(SICI)1099-1727(199723)13:3<223::AID-SDR127>3.0.CO;2-Q

Sukholthaman, P., & Sharp, A. (2016). A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. *Waste Management*, *52*, 50–61. https://doi.org/10.1016/j.wasman.2016.03.026

Suthar, S., & Singh, P. (2015). Household solid waste generation and composition in different family size and socio-economic groups: A case study. *Sustainable Cities and Society*, *14*(1), 56–63. https://doi.org/10.1016/j.scs.2014.07.004

T, J. (2006). Building trust in economic space. *Progress in Human Geography*, *4*, 427–450.

Tadesse, T., Ruijs, A., & Hagos, F. (2008). Household waste disposal in Mekelle city, Northern Ethiopia. *Waste Management*, *28*(10), 2003–2012. https://doi.org/10.1016/j.wasman.2007.08.015

Taelman, S. E., Tonini, D., Wandl, A., & Dewulf, J. (2018). A Holistic sustainability framework for waste management in European Cities: Concept development. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072184

Talyan, V., Dahiya, R. P., Anand, S., & Sreekrishnan, T. R. (2007). Quantification of methane emission from municipal solid waste disposal in Delhi, *50*(236), 240–259. https://doi.org/10.1016/j.resconrec.2006.06.002

Tan, S. T., Ho, W. S., Hashim, H., Lee, C. T., Taib, M. R., & Ho, C. S. (2015). Energy, economic and environmental (3E) analysis of waste-to-energy (WTE) strategies for municipal solid waste (MSW) management in Malaysia. *Energy Conversion and Management*, *102*, 111–120. https://doi.org/10.1016/j.enconman.2015.02.010

Tatlonghari, R. V, & Jamias, S. B. (2010). Village-Level Knowledge , Attitudes and Practices on Solid Waste Management in Sta . Rosa City , Laguna , Philippines, *13*(December 2005), 35–51.

Tchobanoglous, G., Theisen, H., & Vigil, S. A. (1993). *Integrated Solid Waste Management: Engineering Principle and Management Issues*. New York: McGraw Hill Inc.

Terry, D. J., Hogg, M. A., & White, K. M. (1999). The theory of planned behaviour : Self- Identity, social identity and group norms. *British Journal of Social Psychology*, *38*(3), 225–244. https://doi.org/10.1348/014466699164149

Tirado-Soto, M. M., & Zamberlan, F. L. (2013). Networks of recyclable material waste-picker's cooperatives: An alternative for the solid waste management in the city of Rio de Janeiro. *Waste Management*, *33*(4), 1004–1012. https://doi.org/10.1016/j.wasman.2012.09.025

Toledo Medrano, C. L., & Lujan Perez, M. (2008). Caracterización de residuos sólidos urbanos y análisis de opciones de revalorización de materiales en el municipio de Cercado , Cochabamba , Bolivia. *Acta Nova*, *4*(1), 4–21.

Tong, X., & Yan, L. (2013). From Legal Transplants to Sustainable Transition: Extended Producer Responsibility in Chinese Waste Electrical and Electronic Equipment Management Tong and Yan EPR in Chinese WEEE Management. *Journal of Industrial Ecology*, *17*(2), 199–212. https://doi.org/10.1111/jiec.12013

Tonglet, M., Phillips, P. S., & Read, A. D. (2004). Using the Theory of Planned Behaviour to investigate the determinants of recycling behaviour: A case study from Brixworth, UK. *Resources, Conservation and Recycling*, *41*(3), 191–214. https://doi.org/10.1016/j.resconrec.2003.11.001

Transparency International. (2018). CORRUPTION PERCEPTIONS INDEX 2018. Retrieved May 10, 2019, from https://www.transparency.org/cpi2018

Tremblay, C., Gutberlet, J., & Peredo, A. M. (2010). United We Can: Resource recovery, place and social enterprise. *Resources, Conservation and Recycling*, *54*(7), 422–428. https://doi.org/10.1016/j.resconrec.2009.09.006

Trencher, G., Bai, X., Evans, J., McCormick, K., & Yarime, M. (2014). University partnerships for co-designing and co-producing urban sustainability. *Global Environmental Change*, *28*(1), 153–165. https://doi.org/10.1016/j.gloenvcha.2014.06.009

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., & van Vuuren, D. (2015).

Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. *Global Environmental Change*, *35*, 239–253. https://doi.org/10.1016/j.gloenvcha.2015.08.010

Turnheim, B., Pel, B., Avelino, F., Jenkins, K., Kern, F., Alkemade, F., … Schot, J. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, (January), 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Ulli-beer, S. (2003). Dynamic Interactions Between Citizen Choice and Preferences and Public Policy Initiatives. *International Conference of the System Dynamics Society*, (May).

UN-DESA. (2015). *World Urbanization Prospects 2014*. New York.

UN-DESA. (2018). World Urbanization Prospects: The 2018 Revision. Retrieved May 10, 2019, from https://population.un.org/wpp/

UN-Habitat. (2010a). *Collection of municipal solid waste in developing countries*. *UN-Habitat*. Malta: Gutenberg Press.

UN-Habitat. (2010b). *Solid Waste Management in the worlds cities*. London, Washington DC. Retrieved from http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

UNDP. (2015). *Ascenso social , consumo y bienestar en Bolivia. Investigacion sobre patrones de consumo en sectores emergentes*. La Paz.

UNDP. (2018). Human Development Index 2018. Retrieved May 10, 2019, from http://hdr.undp.org/en/composite/HDI

United Nations Environment Programme. (2005). *Solid waste management (Volume 1)*.

United Nations Statistics Division UNSTATS. (2019). SDG Indicators. Retrieved May 10, 2019, from https://unstats.un.org/sdgs/metadata/

van der Hel, S. (2016). New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth. *Environmental Science and Policy*, *61*, 165–175. https://doi.org/10.1016/j.envsci.2016.03.012

Vargas, R., & Apaza, W. (2015). *El nuevo rostro de Bolivia. Transformación social y Metropolización*. *Primera*. La Paz. Retrieved from http://www.bo.undp.org/content/dam/bolivia/docs/undp_bo_IDH2016.pdf

Velis, C. A., Wilson, D. C., Rocca, O., Smith, S. R., Mavropoulos, A., & Cheeseman, C. R. (2012). An analytical framework and tool ('InteRa') for integrating the informal recycling sector in waste and resource management systems in developing countries. *Waste Management and Research*, *30*(9 SUPPL.1), 43–66. https://doi.org/10.1177/0734242X12454934

Villalba, L., Donalisio, R. S., Cisneros Basualdo, N. E., & Noriega, R. B. (2020). Household solid waste characterization in Tandil (Argentina): Socioeconomic, institutional, temporal and cultural aspects influencing waste quantity and composition. *Resources, Conservation and Recycling*, *152*(September 2019), 104530. https://doi.org/10.1016/j.resconrec.2019.104530

Vitorino de Souza Melaré, A., Montenegro González, S., Faceli, K., & Casadei, V. (2017). Technologies and decision support systems to aid solid-waste management: a systematic review. *Waste Management*, *59*, 567–584. https://doi.org/10.1016/j.wasman.2016.10.045

Vujic, G., Stanisavljevic, N., Batinic, B., Jurakic, Z., & Ubavin, D. (2017). Barriers for implementation of "waste to energy" in developing and transition countries: a case study of Serbia. *Journal of Material Cycles and Waste Management*, *19*(1), 55–69. https://doi.org/10.1007/s10163-015-0377-8

Wäger, P. A., & Hilty, L. M. (2002). A Simulation System for Waste Management – From System Dynamics Modelling to Decision Support. *Structure*, 174–179.

Wang, Cheng, Z., Reisner, A., & Liu, Y. (2018). Compliance with household solid waste management in rural villages in developing countries. *Journal of Cleaner Production*, *202*, 293–298. https://doi.org/10.1016/j.jclepro.2018.08.135

Wang, Z., Guo, D., & Wang, X. (2016). Determinants of residents' e-waste recycling behaviour intentions: Evidence from China. *Journal of Cleaner Production*, *137*(February 2009), 850–860. https://doi.org/10.1016/j.jclepro.2016.07.155

Watkins, M. W. (2018). Exploratory Factor Analysis: A Guide to Best Practice. *Journal of Black Psychology*, *44*(3), 219–246. https://doi.org/10.1177/0095798418771807

Welivita, I., Wattage, P., & Gunawardena, P. (2015). Review of household solid waste charges for developing countries - A focus on quantity-based charge methods. *Waste Management*, *46*, 637–645. https://doi.org/10.1016/j.wasman.2015.08.018

Weston, R., & Gore, P. A. (2006). A Brief Guide to Structural Equation Modeling. *The Counseling Psychologist*, *34*(5), 719–751. https://doi.org/10.1177/0011000006286345

Wieczorek, A. J. (2018). Sustainability transitions in developing countries: Major insights and their implications for research and policy. *Environmental Science and Policy*, *84*(July 2017), 204–216. https://doi.org/10.1016/j.envsci.2017.08.008

Williams, I. D. (2015). Forty years of the waste hierarchy. *Waste Management*, *40*, 1–2. https://doi.org/10.1016/j.wasman.2015.03.014

Wilson, D. C., Araba, A. O., Chinwah, K., & Cheeseman, C. R. (2009). Building recycling rates through the informal sector. *Waste Management*, *29*(2), 629–635. https://doi.org/10.1016/j.wasman.2008.06.016

Wilson, D. C., Rodic, L., Cowing, M. J., Velis, C. A., Whiteman, A. D., Scheinberg, A., … Oelz, B. (2015). "Wasteaware" benchmark indicators for integrated sustainable waste management in cities. *Waste Management*, *35*, 329–342. https://doi.org/10.1016/j.wasman.2014.10.006

Wilson, D. C., Rodic, L., Modak, P., Soos, R., Carpinterio Rogero, A., Velis, C., … Simonett, O. (2015). *Global Waste Management Outlook*. Retrieved from http://journals.sagepub.com/doi/10.1177/0734242X15616055

Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International*, *30*(4), 797–808.

https://doi.org/10.1016/j.habitatint.2005.09.005

Wittmayer, J. M., Avelino, F., van Steenbergen, F., & Loorbach, D. (2017). Actor roles in transition: Insights from sociological perspectives. *Environmental Innovation and Societal Transitions*, *24*, 45–56. https://doi.org/10.1016/j.eist.2016.10.003

Wolstenholme, A. E. F. (1999). Qualitative vs Quantitative Modelling : The Evolving Balance. *The Journal of the Operational Research Society*, *50*(4), 422–428.

World Bank. (2015). *Indigenous Latin America in the Twenty First Century - The first decade*. Washington D.C. Retrieved from http://documents.worldbank.org/curated/en/145891467991974540/pdf/98544-REVISED-WP-P148348-Box394854B-PUBLIC-Indigenous-Latin-America.pdf

World Bank. (2017). Latin America GDP per capita (constant LCU). Retrieved May 5, 2019, from https://data.worldbank.org/indicator/NY.GDP.PCAP.KN?locations=XJ&most_recent_value_desc=false&type=shaded&view=map

World Bank. (2019a). World Bank Data - Bolivia Urban population (% of total). Retrieved May 1, 2019, from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=BO

World Bank. (2019b). World Bank Data - Bolivia Urban population growth (annual %). Retrieved May 1, 2019, from https://data.worldbank.org/indicator/SP.URB.GROW

World Business Council for Sustainable Development WBCSD. (2017). *Informal Approaches Towards a Circular Economy - Learning from the plastics recycling sector in India*. Geneva. Retrieved from http://web.a.ebscohost.com.proxy.findit.dtu.dk/ehost/pdfviewer/pdfviewer?vid=1&sid=d70db029-d9cf-46e7-82ac-eed2db35293b%40sessionmgr4003&hid=4207

Wu, Z., Yu, A. T. W., & Shen, L. (2017). Investigating the determinants of contractor's construction and demolition waste management behavior in Mainland China. *Waste Management*, *60*, 290–300. https://doi.org/10.1016/j.wasman.2016.09.001

Xu, Lilai, Lin, T., Xu, Y., Xiao, L., Ye, Z., & Cui, S. (2016). Path analysis of factors influencing household solid waste generation: a case study of Xiamen Island, China. *Journal of Material Cycles and Waste Management*, *18*(2), 377–384. https://doi.org/10.1007/s10163-014-0340-0

Xu, Lin, Ling, M., Lu, Y., & Shen, M. (2017). Understanding household waste separation behaviour: Testing the roles of moral, past experience, and perceived policy effectiveness within the theory of planned behaviour. *Sustainability (Switzerland)*, *9*(4). https://doi.org/10.3390/su9040625

Yearworth, M. (2014). A Brief Introduction to System Dynamics Modelling. University of Bristol.

Yuan, H., & Wang, J. (2014). A system dynamics model for determining the waste disposal charging fee in construction. *European Journal of Operational Research*, *237*(3), 988–996. https://doi.org/10.1016/j.ejor.2014.02.034

Yukalang, N., Clarke, B., & Ross, K. (2017). Barriers to effective municipal solid waste management in a rapidly urbanizing area in Thailand. *International Journal of Environmental Research and Public Health*, *14*(9), 9–14. https://doi.org/10.3390/ijerph14091013

Zaman, A. U. (2014). Identification of key assessment indicators of the zero waste management systems. *Ecological Indicators*, *36*, 682–693. https://doi.org/10.1016/j.ecolind.2013.09.024

Zanjani, A. J., Saeedi, M., & Vosoogh, A. (2012). The effect of the waste separation policy in municipal solid waste management using the system dynamic approach, *1*(1).

Zhang, D., Huang, G., Yin, X., & Gong, Q. (2015). Residents' waste separation behaviors at the source: Using SEM with the theory of planned behavior in Guangzhou, China. *International Journal of Environmental Research and Public Health*, *12*(8), 9475–9491. https://doi.org/10.3390/ijerph120809475

Zhang, S., Zhang, M., Yu, X., & Ren, H. (2016). What keeps Chinese from recycling: Accessibility of recycling facilities and the behavior. *Resources, Conservation and Recycling*, *109*, 176–186. https://doi.org/10.1016/j.resconrec.2016.02.008

Zhou, H., Romero, S. B., & Qin, X. (2016). An extension of the theory of planned behavior to predict pedestrians' violating crossing behavior using structural equation modeling. *Accident Analysis and Prevention*, *95*, 417–424. https://doi.org/10.1016/j.aap.2015.09.009

Zia, A., Batool, S. A., Chauhdry, M. N., & Munir, S. (2017). Influence of income level and seasons on quantity and composition of municipal solid waste: A case study of the capital city of Pakistan. *Sustainability (Switzerland)*, *9*(9), 1–13. https://doi.org/10.3390/su9091568

Zimmerer, K. S. (2015). Environmental governance through "Speaking Like an Indigenous State" and respatializing resources: Ethical livelihood concepts in Bolivia as versatility or verisimilitude? *Geoforum*, *64*, 314–324. https://doi.org/10.1016/j.geoforum.2013.07.004

Zimmerman, L., Lounsbury, D. W., Rosen, C. S., Kimerling, R., Trafton, J. A., & Lindley, S. E. (2016). Participatory System Dynamics Modeling: Increasing Stakeholder Engagement and Precision to Improve Implementation Planning in Systems. *Administration and Policy in Mental Health and Mental Health Services Research*, *43*(6), 834–849. https://doi.org/10.1007/s10488-016-0754-1

Zohoori, M., & Ghani, A. (2017). Municipal Solid Waste Management Challenges and Problems for Cities in Low-Income and Developing Countries. *International Journal of Science and Engineering Applications*, *6*(2), 039–048. https://doi.org/10.7753/IJSEA0602.1002

APPENDICES

Appendix 1: Interview protocol for stakeholders' interviews

SECTION A: RESPONDENT PROFILE

- Briefly describe your role in your institution/organization and how it is related to the solid waste management in Bolivia
- In which regions of the country are your activities related to the waste management executed? When did its involvement start?

SECTION B: EVOLUTION/CURRENT CONTEXT (for national stakeholders)

- How would you describe the evolution of the solid waste management in the country during the time you have been involved in the problematic?
- Do you think there has been any change in the solid waste management approaches recently? If yes please explain what has changed, how, and why you think it changed.
- Which are the main effects (positive or negative) of the current solid waste management system? [Examples: human health, environment, public expenditure, employment, etc]. Which are the most important in your opinion?
- How will these effects change [Example: increase/decrease, improve/worsen] in the future depending on the success of the implementation of the Law 755 for the Integrated Solid Waste Management in the country?

SECTION B: EVOLUTION/CURRENT CONTEXT (for local stakeholders)

- How would you describe the evolution of waste management in the municipality during the time you have been involved in the problematic? Do you think there has been any change in the waste management approaches recently? If yes please explain what has changed and why do you think it changed.
- What are the main characteristics of the solid waste management system in this municipality at the operational and institutional level? Do you see any difference with other municipalities in the country? If yes, why do you think this happens? [Example: demographics, geography, politics, social aspect, economy]
- Which are the main effects (positive or negative) of the way the solid waste management is currently being carried out [Examples: human health, environment, public expenditure, employment, etc]. Which are the most important in your opinion?
- How will these effects change [Example: increase/decrease, improve/worsen] in the future depending on the success of the implementation of the Law 755 for the Integrated Solid Waste Management in the country?
- Which elements of the operational aspect of the waste management are more relevant for your organization activities? (generation, collection, transport, recycling, reuse, disposal) Please indicate how and why.

SECTION C: SUSTAINABILITY (for national stakeholders)

- Are you familiar with the concept of sustainable/integrated waste management? How do you perceive it? What is your opinion about its applicability in the solid waste management in Bolivia?
- How can the sustainability of the solid waste management in Bolivia be enhanced? What are the main interventions that should be considered? [Example: social, environmental, economic aspects]
- Which factors do you think would influence this transition (facilitating or hindering)? [Example: Policies, implementation, funding, technology, governance, etc.]. Which are the most important in your opinion?
- Do you see the need for any compromises in the enhancing of the sustainability of the solid waste management? How do you think all the needs in relation to this issue should be balanced? [Example: cost vs quality, formal sector vs informal sector, environment vs development, soft vs hard measures]
- Which are the main sectors/stakeholders do you think need to cooperate to promote a sustainable waste management in Bolivia? Do you see any common interests or conflicting interests? Please elaborate

SECTION C: SUSTAINABILITY (for local stakeholders)

- Are you familiar with the concept of sustainable/integrated waste management? How do you perceive it? What is your opinion about its applicability in the solid waste management in this municipality?
- How can the sustainability of the solid waste management in this municipality be enhanced? What are the main policies/interventions in relation to the social, environmental and economic aspect that should be considered?
- Which factors do you think would influence this transition (facilitating or hindering)? [Example: Policies, implementation, funding, technology, governance, etc.]. Which are the most important in your opinion?
- Do you see the need for any compromises in the enhancing of the sustainability of the solid waste management? How do you think all the needs in relation to this issue should be balanced? [Example: cost vs quality, formal sector vs informal sector, environment vs development, soft vs hard measures]
- How do you think your organization and the other stakeholders could contribute to enhance the sustainability of the waste management in the municipality?

D. STAKEHOLDERS' INTERACTIONS (for local stakeholders)

- Which are the main actors at the municipal level with whom you interact in your waste management activities?
- How is your relationship with them? [Example: close/distant, formal/informal, easy/difficult]
- What are the common interests that you have with them in relationship to the waste management in the municipality?
- Do you see any conflicting interests between the stakeholders you are most related to? With your organization or with others?
- Do you also interact with other stakeholders at the national level? Please explain.

E. RELATIONSHIP WITH LOCAL LEVEL (for national stakeholders)

- In relation to the government, which would be the role of each level in the solid waste management and the enhancement of its sustainability? Do you see any overlapping or void in the roles of each government level?
- Do you think the municipalities have all the necessary capacities for the implementation of the solid waste management policies and the enhancement of its sustainability [Example: Mandate, economic resources, technical capacity]?
- Do you see any major differences in the capacities among the municipalities in the country? If yes, why do you think this happens and how do you think this can be solved?

E. RELATIONSHIP WITH NATIONAL LEVEL (for local stakeholders)

- Does your organization have all the necessary capacities for the implementation of the solid waste management policies and the enhancement of its sustainability [Example: Mandate, economic resources, technical capacity]?
- How can you improve these capacities? What can the national government do to help you increase these capacities?

Appendix 2: Waste characterization questionnaire

HOUSEHOLD WASTE CHARACTERIZATION IN SANTA CRUZ DE LA SIERRA
HOUSEHOLD SURVEY

Date:
Household Code:

A. General information

<table>
<tr><td>1. Sex:</td><td>M F</td><td>2. Age:</td><td>Years</td><td colspan="2">3. Are you the household head</td><td>Yes No</td></tr>
<tr><td colspan="5">4. Are you in charge of dealing with the household waste in your home?</td><td colspan="2">Yes No</td></tr>
<tr><td colspan="6">5. Number of household members (sleeping 4 or more days a week in the house)</td><td></td></tr>
<tr><td colspan="4">6. Number of household members eating at least 2 meals in the house (e.g. breakfast, lunch, dinner)</td><td></td><td>7. Meals' preparation</td><td></td></tr>
</table>

B. Dwelling characteristics

<table>
<tr><td>8. Ownership:</td><td></td><td>9. Materials:</td><td></td><td>10. Services</td><td></td></tr>
<tr><td>11. House type</td><td></td><td colspan="2">12. Additional activity</td><td colspan="2"></td></tr>
</table>

C. Economic characteristics

13. Services expenditure:		14. Main service expenditures:	1. 2. 3. 4.	15. Monthly expenditure:	

7. Meal preparation (4 or more days a week) Eat out=1, Buy to go (eat at home)=2, Cook at home=3	**8. Ownership** Own=1, Lease=2, Antichresis=3, Borrowed=4, Other=5 (Specify)
9. Material Painted=1, Brick without painting=2, Clay/wood=3, Other=4 (Specify)	**10. Services (use all that apply)** Drinkable wáter network =1, Electricity=2, Sewage=3, Phone=4, Cable TV =5, Internet=6, All=7
11. House type Single family=1, Multiple families=2	**12. Additional activity (small business only managed by household members)** Mechanic shop=1, Kiok=2, Eatery=3, Other=4 (Specify)
13. Monthly service expenditure 200 Bolivians or less=1, 201 – 400 Bolivians=2, 401 – 800 Bolivians=3, 801-1600 Bolivians =4, More than 1600 Bolivians =5	**14. Main expenditures (Main 4 in descendent order)** Rent= 1, Electricity=2, Water=3, Phone=4, Food=5, Cable/Internet=6, Health=7, Education=8, Fuel=9, Clothing=10, Other =9 (Specify)
15. Monthly expenditure (total): 2.000 Bolivians or less=1, 2.001 – 4.000 Bolivians = 2, 4.001 – 8.000 Bolivians =3, 8.001 – 16.000 Bolivians = 4, More than 16.000 Bolivians = 5	

D. Household demographics

Cod.	Age (years)	Relationship with household head	Sex (M/F)	Occupation	Education
	16.1	16.2	16.3	16.4	16.5
01					
02					
03					
04					
05					
06					
07					
08					
09					
10					
11					

E. Solid Waste Management Practices

17. Solid Waste Disposal (List main three ordering by importance)			1. 2. 3.
18. Waste storing method inside house		19. Waste storing place	
20. Source separation	YES NO	21. Recovered materials	
22. Separation purpose			

16.2 Relationship Household head=1, Spouse=2, Son/daughter=3, Maid (only if sleeps in the house more than 4 days a week)=4, Other=5 (Specify)	**16.4 Occupation** Housekeeping=1, Student = 2, Unemployed = 3, Entrepreneur (Formal) = 4, Informal commerce=5, Part-time employee =6, Full-time employee = 7, Retired =8, Other=9 (Specify)
16.5 Educacion No asistió a la escuela =1, Completó Primaria=2, Completó secundaria=3, Algunos semestres en la Universidad=4, Completó la Universidad=5, Postgrado =6	**17. Waste disposal method** Burn=1, Dump to Street/watercanal=2, Dump in empty field=3, Use container=4, Collection service=6, Other =7 (Specify)
18. Storing method inside house Metal/plastic container =1, Bag=2, Floor=3, Other=4 (Specify)	**19. Storing place** Inside house=1, Yard (covered from sun and rain)=2, Yard, unprotected=3, Undefined=4, Other=5 (Specify)
21. Recovered materials (Select all that apply) Food leftovers=1, Prunning waste=2, PET bottles=3, Aluminium cans=4, Paper/cardboard=5, Other plastics=6, Other metals=7, Other organics=8, Batteries=9, e-waste=10, textiles=11, Others =12 (Specify)	**22. Separation purpose (Select all that apply)** Animal feeding=1, Burn prunning waste=2, Compost=3, Handcraft=4, Sell recyclables=5, Donate recyclables=6, Safe disposal of batteries=7, Separate collection=8, Other=9 (Specify)