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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

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APPLICATION OF LEAN MANAGEMENT STRATEGIES TO IMPROVE PERFORMANCE OF A UNIVERSITY INTEGRATED SOLID WASTE MANAGEMENT PROGRAM

THESIS TO OBTAIN THE DEGREE OF

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KEYWORDS

Integrated solid waste management, Lean-green, Value Stream Mapping, Recycling, University Campus

ABSTRACT

Universities generate large and complex waste streams and have a growing potential to positively influence broader society by implementing integrated solid waste management (ISWM). However, in resource-constrained settings, ISWM is often not prioritized, leading to waste mismanagement, and associated social, economic, and environmental costs. Though lean management (LM) aims to create the greatest value with the least resource use and is well suited to resource-constrained settings, it has not often been implemented in environmental service contexts. This thesis applies LM strategies to improve the management of municipal solid waste (MSW) on a campus of the Autonomous University of San Luis Potosí in central Mexico. Prior to application of these strategies, a program had been designed but not fully implemented for the separation of MSW into three categories—organic compostables, inorganic recyclables, and inorganic non-recyclables. LM principles are applied to identify and measure key performance indicators (KPIs), and value stream mapping (VSM) is used to document and analyze the existing management processes for each of the three waste types. A modified waste characterization is performed by grouping the waste categories from Mexican law into product families. Additional information is gathered from students and staff involved in each process step through surveys, semi-structured interviews, and participatory observations. Participatory workshops are conducted to identify possible improvement opportunities. The LM strategies applied facilitate the full implementation of the program by identifying, quantifying, and prioritizing improvement opportunities and thereby demonstrate that LM can create positive environmental impacts by improving environmental service processes on university campuses.

PALABRAS CLAVE

Gestión integral de los residuos sólidos, Lean-green, Mapeo de flujo de valor, Reciclaje, Campus universitario

RESUMEN

Las universidades generan residuos de gran cantidad y complejidad y tienen un potencial creciente para influir positivamente en la sociedad mediante la implementación de la gestión integral de los residuos sólidos (ISWM). *Sin embargo, en entornos con recursos limitados, la ISWM a menudo no se prioriza, lo que genera una mala gestión de los residuos y los costos sociales, económicos y ambientales asociados. Aunque* Lean Management (LM*) tiene como objetivo crear el mayor valor con el menor uso de recursos y se adapta bien a los entornos con recursos limitados, a menudo no se ha implementado en contextos de servicios ambientales. Esta tesis aplica estrategias de LM para mejorar la gestión de los residuos sólidos urbanos (RSU) en un campus de la Universidad Autónoma de San Luis Potosí en el centro de México. Antes de la aplicación de estas estrategias, se había diseñado un programa, pero no se había implementado completamente, para la separación de los RSU en tres categorías: orgánicos compostables, inorgánicos reciclables e inorgánicos no reciclables. Los principios de LM se aplican para identificar y medir indicadores clave de desempeño (KPIs), y el mapeo de flujo de valor (VSM) se utiliza para documentar y analizar los procesos de gestión existentes para cada uno de los tres tipos de residuos. Se realiza una caracterización modificada de los residuos agrupando las categorías de residuos de la legislación mexicana en familias de productos. Se recopila información adicional de los estudiantes y el personal involucrado en cada paso del proceso a través de encuestas, entrevistas semiestructuradas y seguimientos participativos. Se realizan talleres participativos para identificar posibles oportunidades de mejora. Las estrategias de LM aplicadas facilitan la implementación completa del programa mediante la identificación, cuantificación y priorización de oportunidades de mejora y, por lo tanto, demuestran que LM puede generar impactos ambientales positivos al mejorar los servicios ambientales en los campus universitarios.*

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ACRONYMS

AA – *Agenda Ambiental*, Environmental Department of the UASLP
BP – *Bando de Policía y Buen Gobierno*
CE – Circular Economy
EfW – Energy from Waste
EMS – Environmental Management System
GHG – Greenhouse gas
HHW – Household hazardous waste
HIC – High-income country.
HW – Hazardous waste
ISO – International Standardization Organization
ISWM – Integrated Solid Waste Management
IW – Industrial waste
KPI – Key Performance Indicator
LAE – *Ley Ambiental Estatal*, State Environmental Law of San Luis Potosí
LFG – Landfill gas
LGEEPA – *Ley General del Equilibrio Ecológico y la Protección al Abmbiente*, Mexican national law for ecological equilibrium and environmental protection
LGPGIR – *Ley General para la Prevención y Gestión Integral de los Residuos*, Mexican national law for prevention and integrated management of wastes
LGEC – *Ley General de la Economía Circular*, Mexican national law for circular economy
LIC – Low-income country
LM – Lean Management
MSW – Municipal Solid Waste
MSWM – Municipal Solid Waste Management
NVAT – Non-value-added time.
PEC – *Plan de Economía Circular,* Circular Economy Plan
PEPGIR - *Programa Estatal de Prevención y Gestión Integral de Residuos,* State integrated solid waste prevention and management program.
PIDE – *Plan Institucional de Desarrollo Estratégico*, UASLP strategic development plan
PMPGIR - *Programa Municipal de Prevención y Gestión Integral de Residuos,* Municipal integrated solid waste prevention and management program
PNPGIR - *Programa Nacional de Prevención y Gestión Integral de Residuos,* National integrated solid waste prevention and management program
PROSEREM – *Programa de Separación y Reciclaje de Materiales*, UASLP waste separation and recycling program
PSP – Private sector participation
PPP – Public-private partnerships
PUR – *Programa Universitario de Residuos*, UASLP University waste program

RAP – *Reglamento de Aseo Público,* Municipal public cleaning regulation
RME – *Residuos de Manejo Especial*, Waste of Special Management
RP – *Residuos Peligrosos*, Hazardous Waste
RSU – *Residuos Sólidos Urbanos*, Municipal Solid Waste
RVC – Recycling value chain
SDG – Sustainable Development Goals
SEGAM - *Secretaría de Ecología y Gestión Ambiental*, Mexican Secretariate of Ecology and Environmental Management.
SEMARNAT – *Secretaría de Medio Ambiente y Recursos Naturales*, Mexican Secretariate of Environment and Natural Resources*,*
SGA – *Sistema de gestión ambiental*, Environmental Management System
SLP – San Luis Potosí
SME – Subject Matter Expert
SWM – Solid Waste Management
SWMS – Solid Waste Management System
TPB – Theory of Planned Behavior
UANL – *Universidad Autónoma de Nuevo León,* Autonomous University of Nuevo León
UASLP – *Universidad Autónoma de San Luis Potosí*, Autonomous University of San Luis Potosí
VAT – Value-added time
VSM – Value Stream Map/Mapping
WEEE – Waste from Electrical and Electronic Equipment
WtE – Waste to Energy
WUR – Wageningen University & Research

CHAPTER 1. INTRODUCTION

1.1. WASTE

When a person decides to dispose of a product or material that is no longer perceived to be of use, that product or material becomes waste. Solid wastes are those in a solid or semi-solid state, or liquids or gases inside containers. Once such a material has become a waste, it either requires treatment or safe final disposal or may have the potential to be transformed into a product of value for another person or purpose. The three main classes of solid waste according to Mexican law are hazardous wastes (*Residuos Peligrosos, RP*), wastes of special management (*Residuos de Manejo Especial, RME*), and municipal solid wastes (*Residuos Sólidos Urbanos,* RSU), which are the wastes generated in homes by domestic processes, or wastes generated in public spaces that have the same characteristics (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

1.2. INTEGRATED SOLID WASTE MANAGEMENT

According to the Mexican federal Law on the Prevention and Integrated Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos, LGPGIR*), integrated solid waste management (ISWM) is:

> *"The articulated and interrelated set of regulatory, operational, financial, planning, administrative, social, educational, monitoring, supervision, and evaluation actions for management of waste, from its generation to final disposal, in order to achieve environmental benefits, economic optimization of its management, and its social acceptability, responding to the needs and circumstances of each locality or region."*

The explicit inclusion of prevention in the law indicates an attempt to steer national waste management away from a disposal-oriented approach and instead pursue waste minimization and resource reclamation. This approach is intended to be implemented at every level through plans and programs in organizations and municipal, state, and national governments (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003)

1.3. PROSEREM

A central part of the solid waste management program at the Autonomous University of San Luís Potosí (UASLP) is its Material Separation and Recycling Program (*Programa de Separación y Reciclaje de Materiales, PROSEREM*), developed by the university's environmental coordination office (*Agenda Ambiental*) in 2018. The PROSEREM calls for the separation of RSU into three categories—organic compostables, inorganic recyclables, and inorganic non-recyclables. Through the participation of the entire university community in the separation of wastes along these guidelines, the program aims to reduce the amount of the university's waste destined for landfills, open burning, and open dumping by diverting organic waste to composting and inorganic recyclables to responsible recycling facilities (Rosales Guzmán, 2018).

1.4. PROBLEM STATEMENT

Although Mexican law requires the prevention and integrated management of RSU (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003), the UASLP has not yet fully implemented its university waste program (*Programa Universitario de Residuos, PUR*), of which PROSEREM is a central part. Significant time and effort have been invested in the development of the program framework, but various obstacles such as lack of accountability mechanisms, limited staffing, and scarce financial resources have prevented the program from meeting its objectives.

As a result, RSU generation, separation, and disposal are insufficiently monitored, and the university's recycling and composting rates are very low. The UASLP invests staffing, equipment, and financial resources in the collection, transport, and disposal of RSU, which could be reduced with the successful implementation of the PROSEREM.

The legally required municipal integrated solid waste prevention and management program (*Programa Municipal de Prevención y Gestión Integral de Residuos, PMPGIR*) in the municipality of San Luís Potosí has not been developed. The recycling rate for the municipality is also very low, and practices such as open burning and open dumping of wastes are common (MIRPROCS, 2012). Any waste that is not sent directly from UASLP to a responsible recycling company thus enters the final disposal system of the municipality with its negative but unquantified social and environmental impacts (Bernache Pérez, 2011).

When the wastes leave campus, they are delivered to the Peñasco transfer station, an insufficiently controlled site where *pepenadores* (informal waste pickers) scavenge materials of value without personal protective equipment (Barford & Ahmad, 2021; Ramirez Guevara, 2010), and wastes are commonly openly burned, releasing pollutants into the air, soil, and water (Guzmán Chávez & Macías Manzanares, 2012; Ramirez Guevara, 2010). From there, the wastes are transferred again to a sanitary landfill. Instead of being used as compost, the organic wastes decompose and produce greenhouse gases such as methane (INEGI, 2018), and instead of re-entering the economy, recyclable inorganics are landfilled, increasing the need for new primary materials.

Proper waste collection and management is a critical environmental service which must explicitly and intentionally be made “green.” The university has made the decision to provide this service for itself, which gives it significant control and the potential to be an impetus for improved waste management in the broader community (Armijo de Vega et al., 2008; Uhl & Anderson, 2001). Therefore, the UASLP must no longer consider simply collecting, removing, and dumping waste sufficient. Rather, it must manage its waste in a way which minimizes negative environmental impacts and maximizes the reutilization of resources.

However, making the waste management “greener” must be accomplished within a context of severe limitations of staffing, funding, and authority. Methods such as LM, which aim to “do more with less,” achieving improved outcomes without increased resource investment are necessary (Sciortino et al., 2009 in Ciliberto et al., 2021). This thesis examines whether becoming “leaner” could make PROSEREM “greener.”

1.5. JUSTIFICATION

1.5.1. Lean Management

Lean management (LM) is “a systematic approach to identifying and eliminating waste through continuous improvement.” It was first developed at Toyota Motor Corporation (Toyota) following World War II, and its main goal is to efficiently deliver value to the customer through continuous improvement and the elimination of eight key types of waste (Table 6). This is accomplished by applying a set of lean principles and strategies to develop staff and improve systems, guided by key performance indicators (KPIs) (Kilpatrik, 2003; Womack & Jones, 1997).

LM is not a prescribed set of tools and techniques, but rather a set of principles, strategies, and tools that allow all members of an organization to understand and systematically solve their own problems as efficiently as possible in support of larger organizational goals (Marchwinski, 2003). Since Toyota demonstrated the success of this approach, it has been adopted and adapted by countless other organizations all over the world and has been shown to produce measurable improvements in a wide array of sectors (Dieste et al., 2019).

1.5.2. Lean and Green

Significant research has demonstrated the synergies between LM objectives and environmental objectives in manufacturing processes (for a summary of relevant authors consulted see Table 1). However, less research has examined the environmental benefits of LM in other sectors. Typically, manufacturing organizations are profit-driven and therefore operate under pressure to be cost-efficient. Such organizations in many cases have already implemented LM and are exploring the benefits of factoring environmental indicators into their process improvements or the potential of lean to assist in the circular economy transition. This could be characterized as research aimed at making lean organizations green. However, public sector organizations and those who perform environmental services, such as solid waste management, often do not operate under the same expectations for efficiency. Thus, such organizations remain under-represented in lean research, and the inverse, making green organizations lean, remains understudied.

This gap in the literature represents a missed opportunity to understand how efficiency improvements in environmental services can lead to environmental benefits. In a systematic critical review of lean-green research, Garza-Reyes (2015) identified the application of lean-green to non-traditional processes and industries as one of six key priority research streams for future investigation.

This study applies LM to identify improvement strategies for ISWM in the public university context. Lean management is well-suited to overcome the limitations that have prevented the full implementation of the PROSEREM at UASLP because its core premise is about doing more with less, which is precisely what PROSEREM, and many environmental service processes, are pressured to do. However, given that LM originated in an entirely different context, adaptations informed by other research areas are necessary. By examining the intersection of ISWM and lean-green research, this study aims to make a novel contribution to both.

Table 1. Overview of lean research as related to ISWM, by author.

	Lean	Lean-green
Manufacturing	Considered only as background for the present study. Consult International Journal of Lean Six Sigma, International Journal of Lean Enterprise Research, Journal of Lean Systems, International Journal of Lean Thinking, the Lean Enterprise Institute, or the Shingo Institute for countless case studies.	(Abreu & Alves, 2015) (Agyabeng-Mensah et al., 2021) (Amaro et al., 2019) (Cherrafi et al., 2018) (Ciliberto et al., 2021) (Fercoq et al., 2016) (Folinas et al., 2014) (Hussain et al., 2019) (Kurdve et al., 2011) (Nadeem et al., 2019) (Silva et al., 2020) (Sindhwani et al., 2019) (S. Thanki et al., 2016) (S. J. Thanki & Thakkar, 2016) (Tortorella et al., 2018)
Municipal, public, or environmental service sector	(Antony et al., 2016) (Sreedharan V. et al., 2018) (Stentoft Arlbjørn et al., 2011) (Week, 2019)	No studies identified.
Solid waste recovery facilities	(Franchetti & Barnala, 2013) (Krook & Eklund, 2010) (Sundin et al., 2011) (Tortorella et al., 2018)	Connection to environmental performance not examined beyond inherent waste management improvements.
Literature review	(Chaple et al., 2021)	(Abualfaraa et al., 2020) (Bhattacharya et al., 2019) (Dieste et al., 2019) (Garza-Reyes, 2015) (Alves et al., 2019)

1.5.3. The Role of the University in Solid Waste Management

The UASLP has a stated mission to promote sustainable development by investigating important current problems and disseminating the knowledge gained throughout broader society (UASLP, Secretaría de Planeación, 2014). Solid waste management is a crisis, in which universities play an increasingly significant role, not only within their own facilities, but at the municipal, state, national, and regional levels as well (MIRPROCS, 2012; Tello Espinoza et al., 2011; Wilson et al., 2015).

Thus, the improvement of the PROSEREM is important for several reasons. First, as more and more people seek higher education, universities offer an expanding array of programs and services, which generate larger and more complex waste streams. In terms of RSU generated, universities are comparable to small cities and have a corresponding duty to properly manage their waste (Jibril et al., 2012). Through proper enterprise management practices on their campuses, universities can significantly reduce their environmental impacts and demonstrate more sustainable practices to other organizations (Serrano-Bedia & Perez-Perez, 2022).

Secondly, universities contribute to sustainable development, including the sustainable management of RSU, through the development of human capital (Salas et al., 2021). University students tend to be “early adopters” of sustainable practices including recycling and composting behavior (Zhang et al., 2017 in Chao et al., 2021). By encouraging sustainable waste management behaviors and attitudes in their students and staff, universities can promote the “transformation of knowledge into innovation” (Nunes et al., 2018) and a shift toward relating to the environment in more sustainable ways, not only on campus, but beyond (Alzaidi & Iyanna, 2021; Serrano-Bedia & Perez-Perez, 2022).

Universities have a duty to look beyond their campus borders and promote systemic changes to address broader societal problems (Castillo et al., 2021 in Serrano-Bedia & Perez-Perez, 2022). They have significant public influence not only through education, but because of their size, prestige, and impact on the environment and surrounding communities (Uhl & Anderson, 2001). According to the Global University Network for Innovation, universities “have to increasingly rethink their role in the twenty-first century and look to be both more responsive to societal needs and to become agents of change towards solving global challenges” (Serrano-Bedia & Perez-Perez, 2022). By discovering and sharing solutions to its own solid waste management problems, and collaborating with municipal and state authorities, UASLP has the potential to propel progress at every level (Armijo de Vega et al., 2008; Serrano-Bedia & Perez-Perez, 2022).

1.6. RESEARCH QUESTIONS

Given the important role universities can play in promoting ISWM and the potential of LM to improve sustainability in resource-constrained settings, this thesis investigates the following key questions about the potential impacts of applying LM in this context:

1. How can LM principles, strategies, and tools be adapted to the university ISWM context?
2. What KPIs are necessary and desirable for a university RSU management program?
3. What measurable outcomes can be expected from implementing adapted LM strategies in this context?

1.7. GENERAL OBJECTIVE

Evaluate the adaptation of LM strategies to measurably improve the performance of the PROSEREM at the UASLP *Zona Universitaria Poniente* (ZUP) campus.

1.7.1. Specific Objectives

1. Identify KPIs for the PROSEREM aligned to broader university goals.
2. Characterize the current performance of the PROSEREM processes on the UASLP ZUP campus in terms of the KPIs.
3. Propose measurable improvements for the PROSEREM on the UASLP ZUP campus.

These objectives are pursued in order to contribute to improving the performance of the PROSEREM at the UASLP despite resource constraints.

1.8. SCOPE

The scope of this work is delimited geographically, organizationally, conceptually, and theoretically as follows:

- Geographical scope – This thesis considers wastes disposed on the ZUP campus of the UASLP.
- Organizational scope – This thesis considers wastes whose disposal is currently the responsibility of the maintenance department of the UASLP.
- Conceptual scope – This thesis considers only municipal solid wastes defined as RSU under the LGPGIR and does not directly address RME, RP, or RPBI.
- Theoretical scope – This thesis considers only the ZUP campus PROSEREM subsystem, which is a complicated subsystem within larger, complex university and urban systems (see the Cynefin Framework in Figure 6).

1.9. METHODOLOGY

The adaptation of LM strategies was evaluated by applying one iteration of Value Stream Mapping, an established LM strategy, to the PROSEREM processes. Using VSM, an improvement action plan was proposed, and the potential improvements in process function and KPI values achievable through the implementation of that plan were estimated or, where possible, calculated. The measurable changes in KPIs, the visible change in process function, the adaptations necessary in the implementation process, and the obstacles encountered served to assess the application of LM quantitatively and qualitatively in this context.

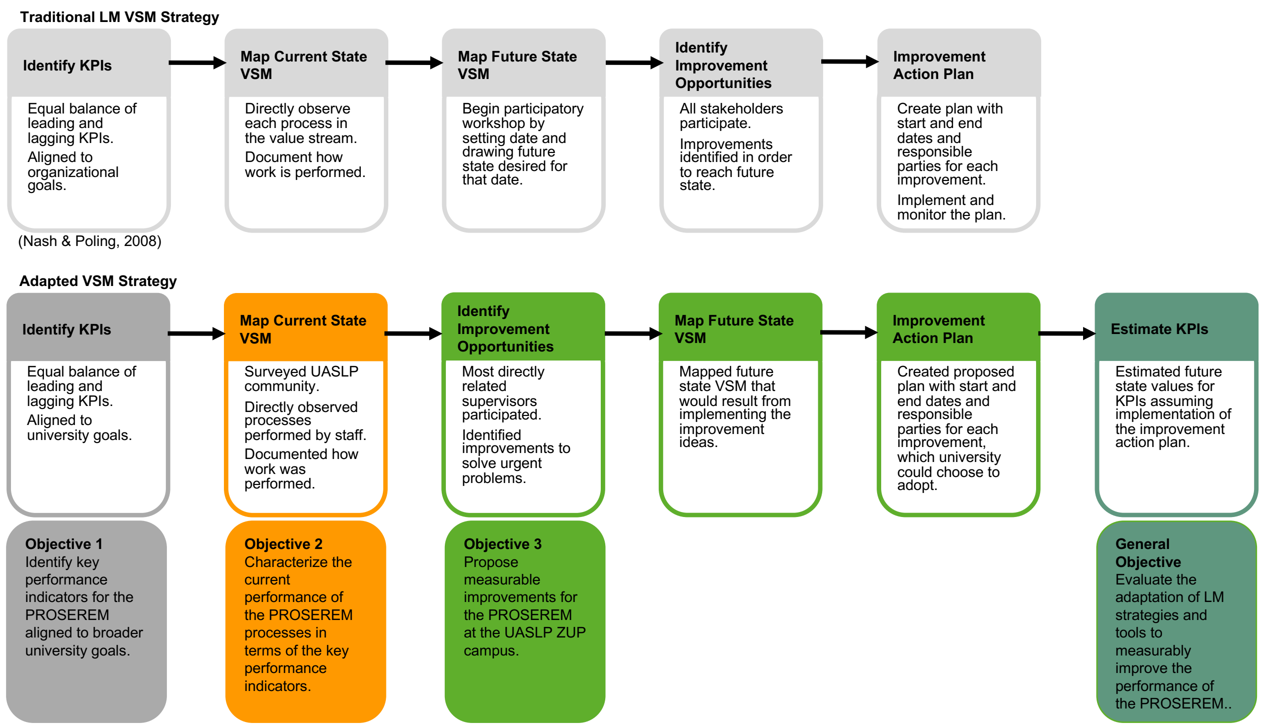


Figure 1. Overview of methodology and corresponding to objectives compared to traditional VSM strategy, by author.

Figure 1 summarizes the traditional VSM strategy and shows how the strategy was adapted for application in this methodology. The main difference is the identification of improvement opportunities before the future state value stream mapping and the addition of the final KPI estimation step. In a traditional VSM strategy, this process would be iterative until the desired future state was reached, and the KPIs would be measured as the improvement action plan was executed. However, in this study, the process was only begun, and the improvement action plan was hypothetical, and thus the impact on KPIs could not be directly measured.

The specific adaptations and methods used for each step are discussed in more detail in Chapter 5, Applying an Adapted Lean Management Strategy. The following three chapters provide conceptual, theoretical, and case-specific information necessary for understanding these details.

CHAPTER 2. GLOBAL SOLID WASTE OUTLOOK

2.1. TYPES OF WASTES

Each year, humanity produces between seven and nine billion tons of solid waste (Wilson and Velis, 2015 in Chen et al., 2020). These billions of tons of material are the result of domestic, industrial, construction, agricultural, medical, educational, and other processes.

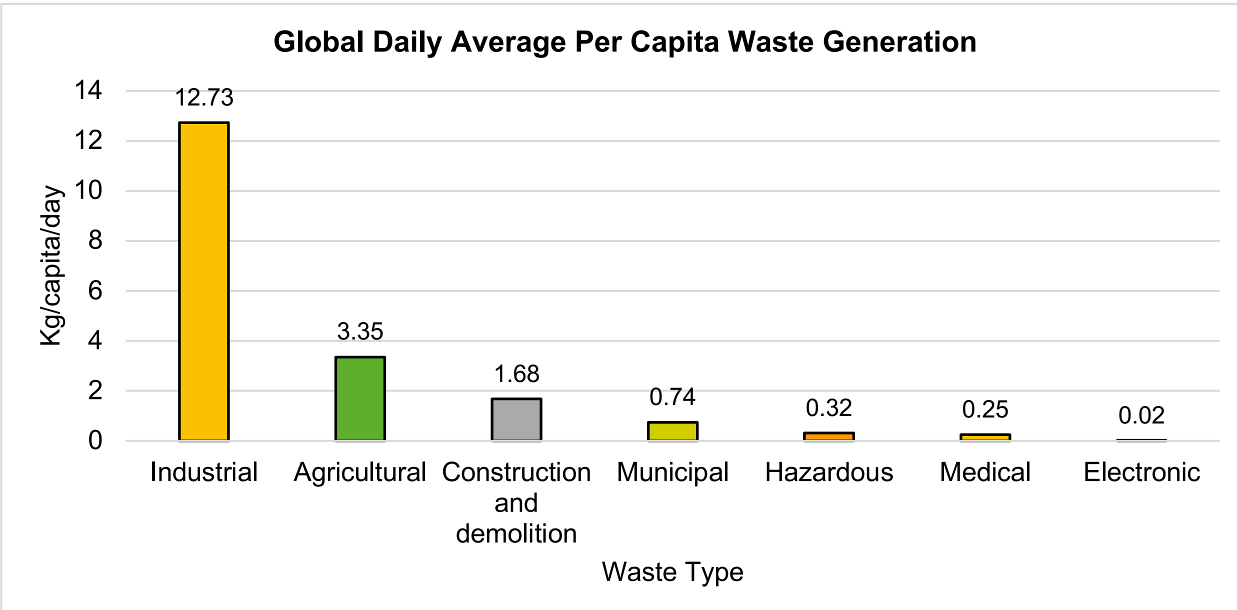


Figure 2. Global daily average per capita waste generation by waste type, modified by author from (Kaza et al., 2018).

2.1.1. Hazardous Waste

The mismanagement of hazardous waste (HW) caused various environmental and public health disasters in the mid- and late 1900s, which began to draw public attention to the issue of SWM in general. Incidents such as the public health crisis caused by dioxin contamination at Love Canal, USA, or the mass mercury poisoning due to bioaccumulation in shellfish in Minamata Bay, Japan, both in the 1960s, drew public protest and prompted the passing of some of the first waste legislation in developed countries (LaGrega et al., 2010; Wilson et al., 2015).

Since then, extensive public debate, from the local to the international level, has led to deeper investigation, more detailed policies, new management strategies, international treaties, and continuously evolving definitions of what exactly constitutes hazardous waste. Legally, HW is defined differently depending on the legislating body, but for general purposes, LaGrega's definition adapted from the United Nations Environment Program is complete and comprehensible:

> *Hazardous wastes mean wastes [solids, sludges, liquids, and containerized gases] other than radioactive and infectious wastes which, by reason of their chemical activity or toxic, explosive, corrosive, or other characteristics, cause danger or likely will cause danger to health or the environment, whether alone or when coming into contact with other waste (LaGrega et al., 2010).*

Though HW represents a comparatively small portion of all solid waste (Figure 2) (Kaza et al., 2018), by nature it demands highly specialized treatment and can have outsized negative impacts when handled inappropriately. Its management and regulation are also complex because HW can be generated in vastly different settings and processes, from the simple act of changing a fluorescent lightbulb in one's home to the industrial scale manufacturing of chemical substances. Thus, HW is the only category of waste defined by its properties and not by its quantity or source.

A detailed examination of HW policy, legislation, disposal, and treatment is outside the scope of this thesis, but what is relevant and problematic for MSW management at any scale is the likelihood of MSW becoming contaminated with HW through improper disposal of household hazardous waste (HHW). HHW is equally difficult to universally define, but generally speaking, it is any material discarded by a household, which presents risks to human health or the environment due to its chemical, biological, toxic, corrosive, flammable, or reactive properties if not properly disposed (Inglezakis & Moustakas, 2015).

HHW is difficult to quantify because it is often mixed with MSW and overlooked in waste statistics, but it is estimated to represent only 1% of MSW by weight. However, it includes common household items such as batteries, compact fluorescent light bulbs, pesticides, antifreeze, solvents, oil-based paints, and unused medicines (Inglezakis & Moustakas, 2015). Considering the ubiquity of synthetic chemicals in daily life, that only about 2% of those on the market have undergone testing for toxicity (Slack et al., 2009 in Inglezakis & Moustakas, 2015), and that the rate of product development continues to outpace that of regulation, HHW will continue to be a concern far into the future.

2.1.2. Medical Waste

The World Health Organization classifies medical waste as "waste that is generated in the diagnosis, treatment or immunization of human beings or animals." United States policy additionally includes waste produced in medical research or biological testing (Windfeld & Brooks, 2015). An estimated 20% of all medical waste generated is considered hazardous due to either toxic, radioactive, or infectious characteristics, but the remainder can theoretically be disposed of without special treatment along with regular MSW.

One of the greatest challenges related to medical waste is proper separation. Numerous categories exist based on the waste source, the level of infectiousness, or the corresponding disposal practice, and the categories are not globally or even nationally standardized, creating confusion and health risks, especially to medical personnel (Windfeld & Brooks, 2015). Often, wastes that could be handled as MSW are unnecessarily handled as hazardous medical waste (Windfeld & Brooks, 2015), while in other cases hazardous medical waste may be incorrectly disposed of in the MSW bin due to lack of awareness. High disposal fees for infectious medical wastes also create a strong incentive for activities such as illegal dumping or illegal reuse or recycling of medical materials (Windfeld & Brooks, 2015) which pose serious health and environmental risks.

2.1.3. Industrial Waste

The industrial sector generates more waste than any other, and although it does contribute to HW as mentioned above, most industrial waste is nonhazardous. In Europe, for example, only an estimated 3.8% of industrial waste is classified as hazardous. The portion of industrial waste which exhibits the hazardous properties described above is classified and regulated as HW, and the rest is defined differently depending on the regulating body. Therefore, broadly defined, industrial waste (IW) is the waste resulting from industrial activities, that poses no threat to human health or environment (Millati et al., 2019).

IW has composition and properties similar to MSW, and is therefore distinguished not by its characteristics, but by its quantity (Millati et al., 2019). Globally, the generation of IW is eighteen times that of MSW (Kaza et al., 2018; Sharma & Jain, 2020). The ratio of industrial to municipal waste of course varies from one country to another depending on the level of industrialization and which types of industrial activities are most common. Some industrial sectors, such as mining and construction, produce more solid waste than others (Millati et al., 2019). Some countries with significant activity in these sectors, including Mexico, have elected to distinguish mining wastes from other types to allow for special on-site disposal options. In the absence of specific regulations for certain subtypes, IW can be disposed of in much the same way as MSW, which means it competes for landfill space in many cases (Kaza et al., 2018).

2.1.4. Agricultural Waste

The next most generated waste type is agricultural waste, which includes the solid byproducts from forestry, agricultural cultivation, and the processing of agricultural products. The most common examples globally are rice straw and husk, wood slabs, bark, sawdust, corncobs, wheat straw, and oil palm empty fruit bunch (Millati et al., 2019). Because agricultural waste is all organic material and often large quantities of the same material, significant opportunities exist to use it as the input to other agricultural or industrial processes. Given that agricultural waste is generated in quantities 4.5 times greater than MSW, significant research and investment has been directed toward these possible methods of reuse (Kaza et al., 2018)

2.1.5. E-Waste

Waste from Electrical and Electronic Equipment (WEEE), commonly known as electronic waste or e-waste, is the fastest growing waste stream worldwide, thanks in part to increasing consumer demand and an increasingly fast obsolescence rate (N. Perkins et al., 2014). Discarded items that have either an electric power cord or a battery are considered WEEE and fall into six general groups—temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment, and small IT and telecom equipment (Forti et al., 2020a). Televisions, refrigerators, cell phones, laptops, printers, and microwaves are just a few of the many examples of EEE used and disposed of by households and industrial users alike.

In 2012, global annual per capita e-waste generation was 6.4 kg. In 2019, it had risen to 7.3 kg, and by 2030 it is expected to reach 9 kg per capita, totaling 74.7 million metric tons (Forti et al., 2020a). The generation and disposal of e-waste is closely tied to income levels, with high income countries being the major generators and low income countries the main disposers (Kaza et al., 2018; N. Perkins et al., 2014). E-waste is commonly exported from developed to developing countries due to the high cost of labor and stricter environmental regulations in developed countries. Estimates state that between 75 and 80% of e-waste is exported to Asia and Africa, but the final destination of nearly 70% of e-waste is not officially documented (N. Perkins et al., 2014).

WEEE is a distinct type of hazardous waste because of its ubiquity, complexity, and economic value. EEE contains as many as 69 different elements, including precious metals, like gold, silver, copper, and platinum, as well as other valuable materials such as cobalt, antimony, iron, and aluminum (Forti et al., 2020a). However, alongside these substances of value are hazardous substances, including mercury, cadmium, lead, flame retardants, hydrochlorofluorocarbons, and chlorofluorocarbons, among others, which cause environmental and human health impacts (Forti et al., 2020a; N. Perkins et al., 2014; Wilson et al., 2015).

The developing nations where most WEEE recycling is conducted often lack the regulations and infrastructure necessary to ensure it is recycled safely. This work tends to be performed by the informal sector involving manual disassembly, child labor, open air burning, and other unsafe and uncontrolled practices (N. Perkins et al., 2014; Wilson et al., 2015). While some companies provide take-back services for used EEE, the rate of documented e-waste collection remains low (Forti et al., 2020b; N. Perkins et al., 2014).

In the absence of effective collection systems and public awareness, e-waste is often disposed of along with normal household waste, which is then treated without the techniques necessary to ensure environmental protection or resource recovery (Forti et al., 2020a).

2.1.6. Municipal Solid Waste

What many people commonly think of when they hear the word "trash" is likely municipal solid waste (MSW). MSW is non-hazardous solid waste generated in homes from typical domestic activities, or in small businesses or public places that has the same characteristics. Approximately two thirds of MSW is in fact generated by households, while the remainder is generated in spaces such as restaurants, parks, schools, small businesses, or other public spaces (Inglezakis & Moustakas, 2015). The term municipal solid waste alludes to the fact that the responsibility for managing this category of solid waste is almost always held by local municipal government.

2.2. GLOBAL MUNICIPAL SOLID WASTE TRENDS

Globally, an average of 0.74 kg of MSW is generated per capita each day (Kaza et al., 2018), amounting to over 2 billion tons of MSW each year (Chen et al., 2020). Much of this waste is either recyclable or compostable, with dry recyclables comprising 38% and food and green waste 44% of the global waste stream. Of the recyclable waste stream, paper, cardboard, and plastic make up the largest shares (Figure 3) (Kaza et al., 2018).

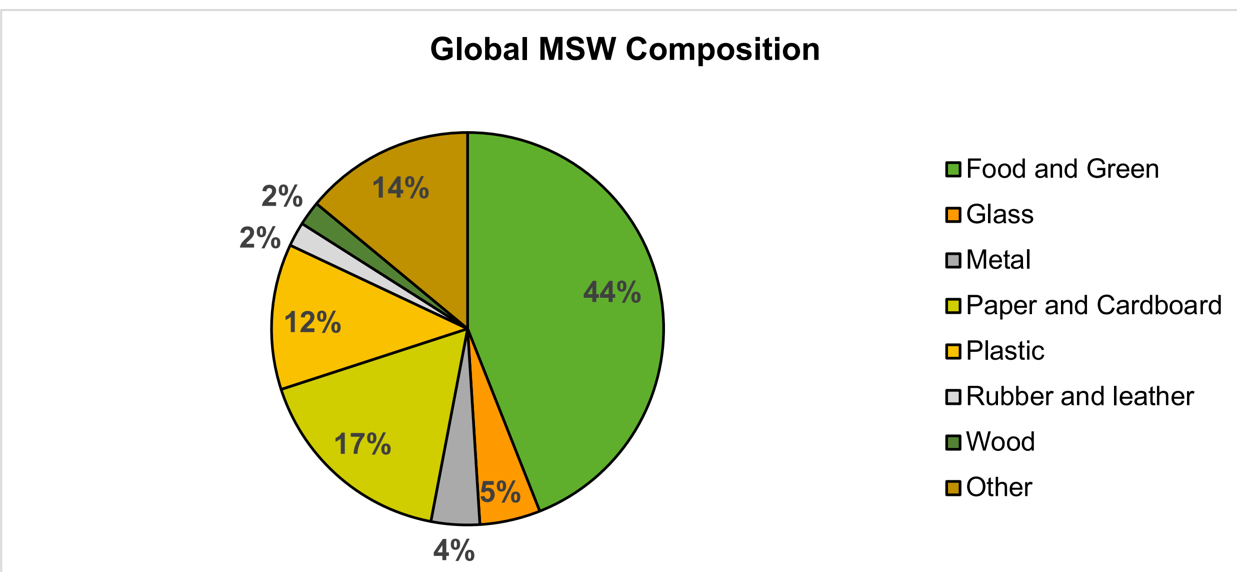


Figure 3. Global municipal solid waste composition, adapted by author from (Kaza et al., 2018).

However, these global averages mask the high degree of variation in MSW generation and composition that exists between and within countries. Regionally, the Middle East and North Africa produces the least MSW in terms of absolute mass, while East Asia and the Pacific produces the most. In contrast, with 2.21 kg per day, North America (Bermuda, Canada, and the United States) has the highest per capita generation of any region (Kaza et al., 2018). Some of this regional variation is due to factors such as climate and geography, but much more can be explained by levels of economic development and urbanization (Chen et al., 2020; Kaza et al., 2018).

In fact, GDP per capita corresponds more closely to MSW generation per capita than any other factor (Chen et al., 2020). In high-income countries (HICs), the average per capita MSW generation is 1.58 kg/day, while in low-income countries (LICs) it is just 0.4 kg/day (Sharma & Jain, 2020). Income level also affects the composition of MSW, with HICs having a higher percentage of recyclables in the waste stream (Kaza et al., 2018) while LICs tend to have a higher percentage of compostable organics. Although the degree of informality in waste management is undoubtedly higher in LICs, the actual recycling rate has not been found to correlate to GDP (Sharma & Jain, 2020).

Municipal solid waste generation is also closely related to urbanization, with more urbanized areas having higher per capita and total MSW generation rates (Kaza et al., 2018; Sharma & Jain, 2020). A comparison of North America with Sub-Saharan Africa, for example, reveals that the former has double the urbanization rate and more than four times the per capita MSW generation than the later (Kaza et al., 2018). The rapid global urbanization rate is being outpaced by an even more rapid increase in MSW generation in newly urbanized areas (Sharma & Jain, 2020).

Models predict that MSW generation will continue to increase, though at a slightly decreasing rate (Chen et al., 2020). As these trends continue, the World Bank projects yearly MSW generation will rise to 2.59 billion tons by 2030 and 3.4 billion tons by 2050 (Chao et al., 2021a; Kaza et al., 2018). The most significant increase in generation rate is projected in LICs, which are expected to generate 204% more MSW by 2050. HICs are also expected to increase, but by a more modest 53% by the same year. This prediction is based on already high rates of economic develop and urbanization in HICs as well as lower population growth rates as compared to LICs, which are expected to become not only much more populous, but also more prosperous (Sharma & Jain, 2020).

Due to these interrelated trends of increasing urbanization, economic development, and population growth, global MSW generation will not peak any time soon. Several studies project it will continue to increase at least through the end of this century (Chen et al., 2020). The question thus becomes, what will be done with all that waste?

2.3. MUNICIPAL SOLID WASTE COLLECTION, TREATMENT, AND DISPOSAL

After generation, which has been described in the previous section, the basic steps in any waste management system are separation, collection, transport and transfer, treatment, and final disposal (Guerrero et al., 2013). Globally, over US$500 billion is spent each year to provide these services (Sharma & Jain, 2020), and due to economic, social, environmental, and regulatory pressures, simpler, lower-cost, and lower-impact methods of doing so are constantly being sought. What follows is a brief explanation of the most common strategies for each of these basic steps.

2.3.1. Collection

MSW collection may sound like a simple task—picking up the waste generated in homes, businesses, and public spaces, and loading it onto some kind of vehicle for removal. However, although providing solid waste collection to urban populations has been a key public health aim for almost two centuries, an estimated 2 billion people still do not have access to this basic service (Wilson et al., 2015).

What makes collection so challenging is its high cost compared to generally low public willingness or ability to pay. Solid waste collection is considered affordable if the cost per ton of waste is less than 1% of a person's annual income. Especially in low-income countries, providing collection service at such a low cost is a serious challenge, and collection can represent as much as 90% of the total solid waste management costs (Wilson et al., 2015).

Waste collection rates are much higher in urban than in rural areas due to shorter distances, better road infrastructure, greater demand for the service, and greater willingness to pay (Kaza et al., 2018). Various models of collection systems exist which employ different types of vehicles, types of containers, degrees of waste separation, collection frequencies, and degrees of involvement of the informal sector. These models can be grouped into the broad categories of drop-off center systems, communal bin systems, and door-to-door collection systems (Calabrò & Satira, 2020).

The most common type of system is door-to-door collection, in which some type of vehicle is used to pick up wastes from individual users, usually following a predetermined route and frequency. Vehicles range from human- or animal-drawn carts, to pick-up trucks, to enclosed trucks, to specialized waste collection vehicles with on-board compactors (Kaza et al., 2018). Collection frequencies vary from daily to weekly, based on factors such as waste generation rate, population density, and availability of resources (Calabrò & Satira, 2020). Generally the lower the collection frequency, the less costly the service, but the more improper waste management practices, such as open burning, open dumping, or animal feeding, are observed at the household level (Tello Espinoza et al., 2011).

Other collection strategies designed to reduce costs include public or centralized bins, for example a large, shared dumpster for an entire city block or apartment building, or waste drop-off centers. In bin collection systems, collection routes can be simplified and expedited, and collection frequency can be reduced, but convenience for customers is reduced. In drop-off center systems, no collection route exists, and significant effort on the part of customers is required to deliver the wastes to the drop-off location, which can incentivize other improper waste disposal practices (Calabrò & Satira, 2020).

Combinations of collection strategies are also common, and the design of the collection system depends on many local factors, including the degree of separation of the waste stream and the final disposal practices. In mixed waste collection systems, all MSW is collected as a single waste stream without any separation. This type of system is most conducive to landfilling or incineration. Other systems call for separation between mixed waste and dry recyclables (often called single-stream recyclables), which makes recycling more feasible but still requires post-collection processing of the recyclable material. Still others include a separate waste stream for organic waste which makes composting possible. At the most complex level, some systems also call for separate collection by material, such as plastic, paper, cardboard, glass, and metal (Calabrò & Satira, 2020). Many possible hybrid systems exist. For example, it is not uncommon to offer door-to-door mixed waste collection in combination with drop-off centers for recyclables or compostables.

Whatever the system, providing locally appropriate waste collection is the first crucial step toward responsible solid waste management. Only through collection is it possible to offer other waste management services that protect human health and the environment (Wilson et al., 2015).

2.3.2. Open Dumping

Open dumping is the practice of discarding solid waste directly into the environment without control measures to prevent its dispersal. On the smallest scale, littering could be considered a form of open dumping, but the term generally implies some degree of collection of wastes followed by bulk discarding. This could be at the household level as a solution to lacking collection services (Chen et al., 2020; Tello Espinoza et al., 2011), or even at the municipal level in the absence of controlled final disposal options (Wilson et al., 2015).

This practice was nearly universal until environmental and health impacts of openly dumping an increasingly complex and hazardous waste stream began to call public attention in the 1960s (LaGrega et al., 2010; Wilson et al., 2015). It is estimated that at least three billion people still lack access to a controlled waste disposal facility that adequately protects human health and the environment, mostly in developing countries, where open dumping, accompanied by open burning, is still the norm (Wilson et al., 2015).

The contrast between HICs and LICs is stark. In the former, only about 2% of solid waste is openly dumped, while in the latter that figure is 93% (Kaza et al., 2018). This is slowly changing, and as economic development increases, a shift from open dumping to controlled landfill use is observed, a trend which is expected to continue (Chen et al., 2020).

2.3.3. Controlled Landfills

Sometimes referred to as engineered landfills, controlled landfills consist of a large pit with a compacted lined bottom to prevent leachate percolation, a leachate collection and treatment system, a landfill gas (LFG) capture system, and a groundwater monitoring system (Sharma & Jain, 2020). The exact design, location, construction, and operation of controlled MSW landfills is commonly stipulated in either national or state legislation, which usually includes different requirements based on the quantity of MSW received.

When compared to open dumping, controlled landfills have many advantages. They use less space, prevent the dispersal of waste into the environment, and prevent the release of contaminants into the air, soil, and water. However, they have a finite useful life, and the valuable resources within the landfilled waste never re-enter productive use, which makes landfilling the least desirable of legally acceptable waste management solutions. However, because it is also the simplest safe option, requiring the least investment of economic and human capital, it is also the most common (Sharma & Jain, 2020).

Worldwide, 70% of waste is sent to either open dumps or landfills, and landfilling is expected to remain the dominant practice at least through 2050 (Chen et al., 2020). Currently, it is most popular in upper-middle income countries, while lower-income countries are still transitioning from open dumping, and higher-income countries are slowly transitioning toward resource recovery options such as recycling, compost, and incineration (Kaza et al., 2018).

2.3.4. Waste to Energy

Waste to Energy (WtE) or Energy from Waste (EfW) is a general term for various methods of obtaining thermal, electric, or chemical energy from solid waste. Three main categories of WtE include combustion with heat and energy recovery, gasification, and pyrolysis. Gasification and pyrolysis produce synthetic gas and liquid fuel, respectively, and generate less air pollution. However, more pretreatment of the waste stream is required to apply these technologies to MSW, and in part for this reason, combustion with heat and gas recovery is much more widely used (Wilson et al., 2015).

The combustion process, sometimes referred to as incineration, produces heat, electricity, or both and reduces the volume of the feedstock by up to 90%, leaving a sterile ash which then requires disposal. Incineration plants emit 200-800 kg less CO_2 per ton of waste compared to landfills (Sharma & Jain, 2020). However, they require sophisticated air pollution prevention technology (Sharma & Jain, 2020; Wilson et al., 2015). They are also expensive to build and require more specialized training to operate than landfills, which are both hindrances to their adoption in developing countries.

Currently, WtE is most common in high-income countries, especially in Europe, Japan, and the United, but also in China. Countries like Brazil and Mexico are still inhibited from using WtE by low budgets and poor SWM practices but are slowly moving in that direction. The WtE market is expected to grow as technology improves and costs are reduced, which could promote broader application of these technologies (Sharma & Jain, 2020).

2.3.5. Recycling

The appeal of open dumping, landfilling, and WtE in part is that these simple disposal options do not require waste separation. One disadvantage, however, is that they do not permit the recuperation of usable materials from the waste stream. For that, separation is necessary to prepare wastes for recycling or composting, which are briefly explained in this section and the following.

Recycling is the mechanical reprocessing of discarded materials may include any of the following processes: separation, cleaning, crushing, milling, pulping, melting, extrusion, and forming (Silva de Souza Lima Cano et al., 2022). These processes of course are not perfectly efficient; they require energy, water, and other resources, and in some cases produce material that is of lower quality than the original. Of materials commonly recycled from MSW, aluminum, glass, paper products, ferrous metals, and high-density polyethylene (HDPE) have the highest process efficiency rates, with 96%, 88%, 86%, 84%, and 83% respectively. Polyethylene terephthalate (PET) is also commonly recycled, but has a much lower process efficiency at 61% (Botello-Álvarez et al., 2018).

The actual recycling process is just one step in what is referred to as the recycling value chain (RVC), the process of recovering discarded recyclable materials, recycling them, and distributing them to buyers who can use them as process inputs to make new products. RVCs involve many different stakeholders and tend to take different forms depending on the development context and material (Silva de Souza Lima Cano et al., 2022).

In high-income countries, RVCs are usually formal, involving collaboration between local, state, or national governments and private stakeholders in waste management industry (Silva de Souza Lima Cano et al., 2022). In contrast, in developing countries, the focus of municipalities tends to be on reducing open dumping, and thus the formal recycling rate is near 0%. In such cases, RVCs almost always include stakeholders from both the formal and informal sectors. Informal stakeholders may include waste pickers, or waste buyers who despite negative societal perceptions recover significant amounts of recyclable materials, making a valuable contribution to MSW management (Silva de Souza Lima Cano et al., 2022).

Whether or not a material is recycled depends upon the availability of reprocessing facilities, the processing efficiency, the existence of markets for the reprocessed post-consumer material, and the cost of other disposal alternatives, which determine the overall cost-effectiveness. Countries that lack reprocessing facilities export their recyclable material to be reprocessed abroad (Silva de Souza Lima Cano et al., 2022). In general recycling represents a greater share of waste treatment in wealthier countries, though the actual reprocessing may be carried out elsewhere (Chen et al., 2020).

2.3.6. Composting

Composting is the biological process by which biodegradable waste is broken down into a nutrient-rich humus-like material called compost. When used as a soil treatment, compost can improve soil structure and fertility, erosion resistance, and water retention (Wilson et al., 2015). Theoretically any organic waste is compostable, but some require, pre-processing, longer residence times, or higher temperatures to be safely and efficiently composted (Ali & Harper, 2004). For finished compost to be safely used it is also important for the feed material to be appropriately separated and free from hazardous wastes.

The simplest and lowest cost method of composting is heaps, or at larger scale, windrows. Other methods include barrels or other containers which facilitate turning and mixing, or even large composting vessels that shred, mix, and maintain the temperature of the feedstock for optimal processing or for the elimination of pathogens. In any method, process control is important to ensure weed seeds and potentially infectious material is destroyed (Ali & Harper, 2004; Wilson et al., 2015).

In developing countries, up to 70% of the MSW stream by weight can be compostable organic material, making composting an extremely viable method of reducing the waste management burden. Through separation of organic waste at the source, the feedstock can be maintained at a high quality, and through decentralized or home-based composting systems, the high cost of transporting organic matter can be avoided (Ali & Harper, 2004; Wilson et al., 2015).

Though decentralized composting can be an excellent cost-saving measure, centralized compost collection schemes are unlikely to generate revenue as large markets for finished compost are difficult to find. Generally, the sale of finished compost only recovers approximately 40% of the costs of collection and processing (Ali & Harper, 2004; Wilson et al., 2015). Therefore, in the developing world, composting is most often initiated by NGOs to reduce dependence on inadequate MSW collection systems, improve quality of life, create jobs through manual composting systems, or maintain soil fertility (Ali & Harper, 2004). In developed countries, large scale organic waste collection and composting as part of the municipal waste management system are somewhat more common, especially in densely populated areas with short travel distances. In all development contexts, private entrepreneurs have launched small-scale composting businesses with varying degrees of success (Ali & Harper, 2004; Wilson et al., 2015).

2.4. IMPACTS OF IMPROPER MUNICIPAL SOLID WASTE MANAGEMENT

Improving SWM is nothing short of a global environmental, social, and economic emergency. Proper management of solid waste is as fundamental for a functioning society as energy, transportation, communications, sanitation, or drinking water services. The mismanagement of waste globally is both a symptom and a cause of various interrelated sustainability challenges, which have been summarized excellently in the United Nations Environment Program's Global Waste Management Outlook (Wilson et al., 2015). The following sections highlight a few of the consequences of improper WM.

2.4.1. Environmental Impacts

The most visible and immediate environmental impacts of waste mismanagement are related to the release of solid wastes directly into the environment due to littering, improper waste storage, or insufficient collection systems. As a result, waste accumulates in the environment, harming wildlife, attracting pests, blocking sewers and storm drains, and becoming concentrated in surface water bodies (Sharma & Jain, 2020; Wilson et al., 2015). The Great Pacific Garbage Patch is perhaps the most famous example of what have become known as "marine litter gyres," vast areas in the world's oceans where currents cause solid wastes, especially plastics, to collect. The presence of solid waste in marine habitats presents a threat to many forms of marine life, disrupting the ocean food web and causing significant biodiversity loss (Wilson et al., 2015). The amount of plastic accumulated in the world's oceans is projected to continue increasing beyond the year 2050 with a yearly discharge of 8.76 million kg of plastic (Chen et al., 2020).

Some impacts of improper SWM are less visible but no less worrisome. Incineration and open burning of solid waste cause air pollution (Sharma & Jain, 2020) including toxic dioxins, carcinogenic polyaromatic hydrocarbons (PAHs), and black carbon, a potent short-lived climate pollutant (Wilson et al., 2015). Landfills and open dumps are also important sources of greenhouse gas (GHG) emissions, especially methane and carbon dioxide, representing as much as 12% of total GHG emissions in developing countries according to the World Bank (Sharma & Jain, 2020).

Leachate from open dumps or improperly controlled landfills, which contains an array of contaminants as well as concentrated amounts of reactive nitrogen, percolates into groundwater and surface water bodies, leading to water contamination and contributing to eutrophication (Chen et al., 2020).

Long term, uncertainty still exists about the impacts of certain forms of waste, especially micro- and nano-wastes. Plastic materials never decompose, but rather break down into smaller and smaller pieces, which have come to be referred to as microplastics, or even smaller, nano-plastics, and are nearly omnipresent in the modern environment (Elsheekh et al., 2021). These plastics have been found in the bodies of wildlife and even in human placentas (Ragusa et al., 2021), and the environmental and health impacts of these and other nano-materials are not yet well understood (Wilson et al., 2015).

2.4.2. Social Impacts

Many negative human health impacts are already well documented and understood. In areas where adequate waste collection service is not provided, households commonly burn wastes to reduce their volume, which has been shown to cause diarrhea rates double the average of areas where waste is regularly collected, and respiratory infections six times as high, as well as dioxin poisoning (Chen et al., 2020; Wilson et al., 2015).

Direct contact with MSW is another cause of diarrhea and leads to gastroenteritis and respiratory diseases. Accumulated waste attracts pests and vectors which spread infectious diseases. Flooding caused by waste-blocked drains provides breeding ground for vectors that spread malaria, dengue fever, cholera, and other infectious diseases (Wilson et al., 2015). Animals who directly feed on accumulated solid waste are also at risk, as well as the humans who feed on those animals as hazardous substances enter the food chain (Sharma & Jain, 2020; Wilson et al., 2015).

The human health impacts of mismanaged SW are not experienced equitably. Those who live and work in or near uncontrolled dumpsites bear the greatest share of the burden, although they do not generate the greatest share of the waste. Globally, as previously described, developed countries generate more waste and tend to export large portions of it to developing countries, who generate much less. Of the world's 50 largest uncontrolled dumpsites, all but two are in Latin American, the Caribbean, Africa, and Asia. Most of these sites accept MSW as well as either HW or e-waste originating from all over the world, making the lives of the 64 million people living in close proximity to these sites, a matter of global concern and responsibility (Waste Atlas Partnership, 2014).

Many of the people living in or near such sites are members of a broad, diverse, and informal workforce known as waste pickers. Especially in low- and middle-income countries, waste pickers perform the intensive labor of separating recyclable material from the RSU waste stream and recovering it for a small profit. Typically, these workers are marginalized, working in unsafe conditions for low pay with little or no social protection. In many ways, this informal work picks up the slack of failed or non-existent solid waste management systems, recovering valuable materials, reducing greenhouse gas and other air pollutant emissions, preventing the release of plastics into the worlds' oceans, and reducing the clogging of drainage systems with litter (Barford & Ahmad, 2021).

2.4.3. Economic

The burdens born by waste pickers are just one example of the hidden costs of improper solid waste management. Although proper waste management promotes the overall functioning of the economy, if only financial costs are considered, waste management represents a net financial cost. However, attempts to quantify the social an environmental costs of inaction on SWM, though imperfect, have made a strong case that inaction is in fact much more costly than investing in SWM improvements (Wilson et al., 2015).

The societal costs of littering, dumping, open burning, and waste accumulation outweigh the costs of implementing responsible solid waste management. Various economic valuation methods have been employed which attempt to quantify the impacts on public health, resource availability, the local economy, or the environment in terms of financial cost. Though doing so is difficult or impossible at times, even without firm values for some of the factors involved, the financial cost to society of inaction is clearly greater than the costs of improved solid waste management (Wilson et al., 2015).

2.5. SUSTAINABLE DEVELOPMENT GOALS

As long as human beings have existed, we have exploited natural resources and generated waste. However, with technological advancement and population growth, our ability to do so and the effects of our actions on natural systems have increased dramatically. Human society has reached a level of environmental impact that potentially threatens the very natural systems that support our life on this planet. Humanity has been forced to reflect on how it relates to the rest of the natural world, and from this ongoing reflection, the concept of sustainable development has emerged and evolved (Shi et al., 2019).

Sustainable development as a concept began to take shape in the 1970s and 1980s with the United Nations Conference on the Human Environment (1972) and the publication of "Our Common Future" (1987), also known as the Brundtland report of the World

Commission on Environment and Development (Brundtland, 1987; Shi et al., 2019). In the years that followed, the three pillars of sustainable development—economic, social, and environmental—were established at the 1992 Rio Conference (Shi et al., 2019), and the concept of the "triple bottom line" began to gain traction (Ciliberto et al., 2021). This concept of creating more value with less negative impact (Alves et al., 2019), continued to be refined, and in the year 2000, the United Nations Millennium Development Goals (MDGs) attempted to direct global efforts toward a future aligned to this vision. In 2015, the MDGs were reassessed and revamped to incorporate lessons learned, including their interconnected nature and the need for strong governance to drive progress. The result were the 17 Sustainable Development Goals (SDGs) (Figure 4), which set a global vision of progress toward sustainable development from 2015 until 2030 (Elsheekh et al., 2021; Shi et al., 2019; *THE 17 GOALS | Sustainable Development*, n.d.).

Figure 4. United Nations 2030 Sustainable Development Goals (*THE 17 GOALS* | *Sustainable Development*, n.d.).

At a fundamental level, what humans throw away is a reflection of our lifestyle, and the current SW situation clearly illustrates the unsustainable model in which we are living. It is possible to find connections between SWM and all 17 SDGs, most of them quite direct. Eliminating poverty (Goal 1) and creating decent work for all (Goal 8) would mean formalizing the millions of informal waste pickers worldwide and recognizing their valuable work through safer working conditions and livable wages. Waste to Energy and controlled landfill facilities have an important role to play in the transition toward affordable and clean energy (Goal 7) and climate action (Goal 13). Strengthening public institutions (Goal 16) especially at the municipal level and employing public-private partnerships (Goal 17) will make MSWM more feasible, creating the conditions in which the strength of local government and the quality of SWM services can be mutually reinforcing.

The possible connections between SWM and sustainable development are endless. Elsheekh et al. (2021) conducted a survey of SWM experts asking them to identify these connections, quantified them, and presented the graphically (Figure 5). The score on the vertical axis represents the total number of connections identified by the pool of 30 experts for the corresponding goal.

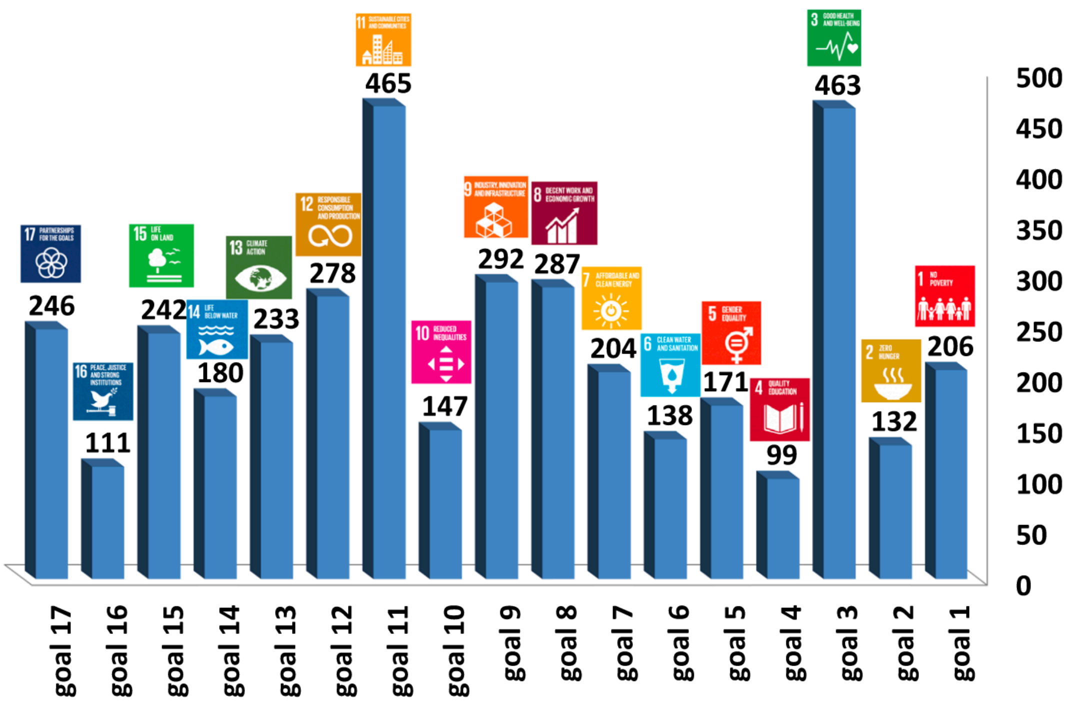


Figure 5. Degree of connection between each Sustainable Development Goal and solid waste management (Elsheekh et al., 2021)

Interestingly, the goals identified as being most impacted by SWM are not necessarily those whose targets and indicators explicitly include SW metrics. Because the SDGs are inherently interrelated, just as are the three pillars of sustainable development, all 17 goals have some relevance to solid waste management (For a detailed discussion of the connections to each goal, see Elsheekh et al. (2021)). However, the targets and indicators for the three goals that explicitly involve solid waste are described in the following sections (Ghafari, n.d.; *THE 17 GOALS | Sustainable Development*, n.d.).

2.5.1. SDG 11: Sustainable Cities and Communities

As previously described, SWM is primarily an urban challenge, and thus it follows that SWM should factor into the vision of sustainable cities. Indeed, experts claim a sustainable city cannot exist without sustainable solid waste management (Elsheekh et al., 2021). Target 11.6 aims to "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management."

Relevant indicator:

11.6.1 Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities.

2.5.2. SDG 12: Sustainable Consumption and Production

Improving the way SW is managed requires a critical reexamination of production and consumption habits. Three of the goal 12 targets for 2030 are directly related to reducing waste generation, increasing recycling, and increasing composting through improved SWM (Chen et al., 2020).

Target 12.3 aims to "halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses."

Relevant indicators:

12.3.1a Food loss index

12.3.1b Food waste index

Target 12.4 aims to "achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment."

Relevant Indicators:

12.4.1 Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement.

12.4.2a Hazardous waste generated per capita.

12.4.2b Proportion of hazardous waste treated, by type of treatment.

Target 12.5 aims to "substantially reduce waste generation through prevention, reduction, recycling and reuse."

Relevant Indicator:

12.5.1 National recycling rate, tons of material recycled.

2.5.3. SDG 14: Life Below Water

The urgency of the negative impacts of SW on the world's oceans is reflected in target 14.1: "By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution."

Relevant Indicator:

14.1.1b Plastic debris density

2.6. CIRCULAR ECONOMY

Meeting these SDG targets will require significant improvement not only in the way SW is managed, but on an even more fundamental level, better data collection to enable the monitoring of progress toward the targets. Many municipalities, especially in the developing world lack reliable data on recycling rates (indicator 12.5.1), for example, and simply gaining enough control over SWM to accurately measure represents a significant challenge on its own. Even so, it is important to note that meeting these already ambitious targets set out in the SDGs is nowhere near enough to achieve sustainability. Reaching truly sustainable SWM must be accompanied by a deep restructuring of the broader consumption and production patterns of our economic system (Wilson et al., 2015).

Increasingly, scholars and activists have begun to describe this structural change as a shift from *linear* to *circular* production and consumption. The Ellen MacArthur Foundation, a well-known non-profit organization working to promote a circular economy (CE), describes the current economic model as "take-make-waste" (*How to Build a Circular Economy | Ellen MacArthur Foundation*, n.d.). In such a model, making products and profits depends upon extracting natural resources and produces waste (Nunes et al., 2018). In contrast, the intent of a CE model is to "decouple" resource consumption from economic growth, such that prosperity may increase without a corresponding increase in resources use (Serrano-Bedia & Perez-Perez, 2022).

The concept of a CE has gained recognition in recent years, but it is a synthesis of other related concepts (Table 2). In the CE model, natural capital is preserved and even restored, and the overall effectiveness of the socio-ecological system is promoted (Serrano-Bedia & Perez-Perez, 2022). Through strategies such as refusal, reduction, redesign, rental, reuse, repair, recycling, reconditioning, remanufacturing, and recovery of materials (Ciliberto et al., 2021; Silva de Souza Lima Cano et al., 2022) and extended producer responsibility (Elsheekh et al., 2021), the concept of "end of life" for goods and products could one day cease to exist.

Table 2. Circular economy concepts, adapted from Nunes et al., 2018 with information from (How to Build a Circular Economy | Ellen MacArthur Foundation, n.d.)

Concept	Definition
Eco-efficiency	The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the Earth's estimated carrying capacity.
Eco-effectiveness	Rather than simply seeking to minimize ecological harm, eco-effectiveness seeks to identify the desirable ecological aspects of products and systems and then define and implement a strategy to achieve them.
Cradle to Cradle	A production approach to achieve eco-effectiveness by viewing all material inputs and outputs either as technical or biological nutrients. Technical nutrients need to be cycled in different streams from biological nutrients which can be readily reintegrated in natural ecosystems.
The Performance Economy	A 'closed loop' approach to production processes which pursues product-life extension and waste prevention while promoting selling services rather than products.
Biomimicry	A discipline that seeks to find solutions to human challenges by emulating strategies and patterns from nature.
Industrial Ecology	The study of material and energy flows through industrial systems aimed at creating closed-loop processes in which waste serves as an input and designing production systems as close to living systems as possible.
Regenerative Design	The practice of designing products to maximize their positive environmental impacts in such a way as to help maintain and regenerate the ecosystems in which they are made and used.
Circular Economy	The antonym of a traditional linear economy, a circular economic model aims to eliminate waste and pollution, circulate products and materials, and regenerate nature.

Breaking the link between natural resource exploitation and economic growth requires technological innovation as well as sweeping behavioral change in the way goods are produced and consumed (Serrano-Bedia & Perez-Perez, 2022). Environmental, social, technical, and economic value must be understood as existing at every stage along the production chain, including what would previously have been viewed as the end-of-life stage (Iacovidou et al., 2017). The CE model maximizes the value at each stage through efficient cycles which minimize raw material use, long cycles which maximize the useful life of materials, multiple cycles which diversify how materials can be used, and pure cycles which maintain materials uncontaminated for reuse (*Towards a Circular Economy Business Rationale for an Accelerated Transition*, 2015). Maintaining the efficient, long, multiple, and pure cycles to enable resource recovery depends on the structure and performance of all the activities in the value chain. Relationships between broad networks of formal, informal, direct, and indirect stakeholders must be managed and governed to maintain the appropriate conditions (Iacovidou et al., 2021).

This CE approach is being increasingly adopted at the national policy level, either through policies explicitly naming CE, such as in the European Union, Japan, and China (Ciliberto et al., 2021; Serrano-Bedia & Perez-Perez, 2022), or through zero-waste policies in various other countries (Sharma & Jain, 2020). Some argue that although CE policies are still uncommon in low-income countries, behaviors aligned with CE are already practiced to a greater extent out of necessity, which could represent an advantage for these countries in the cultural transition toward a CE model (Salas et al., 2021). Whether in high-, low-, or middle-income countries, the shift toward CE is increasingly seen as vital for meeting the SDGs (Serrano-Bedia & Perez-Perez, 2022). However, some scholars caution that, like a perpetual motion machine, CE may be more a metaphorical ideal rather than an achievable reality (Cullen, 2017).

Whether or not CE is fully achievable, there is growing consensus that it should at least be pursued and near unanimous consensus that a new approach to SWM is necessary for doing so. If the dominant disposal-based modes of SWM continue, the SDGs simply will not be met. In a best-case scenario projected from current trends, reusable materials will continue to accumulate in landfills and, in a worst-case scenario, in uncontrolled dumps. The current adoption rate of sustainable waste treatments is not fast enough to overtake the increase in waste generation. For example, even in the EU where ambitious targets have been set and circular economy policies have been adopted, Chen et al. (2020) predict the rate of recycling and composting would have to increase five-fold for these targets to be met.

Inarguably, improving the sustainability of SWM is a prerequisite, not only for a circular economy (Silva de Souza Lima Cano et al., 2022) but also for meeting the SDGs. In the same the way the SDGs were revised to account for the interconnectedness of social, economic, governance, and environmental factors, the approach to SWM must also take a more integrated approach.

2.7. INTEGRATED SOLID WASTE MANAGEMENT

Integrated Solid Waste Management (ISWM) has also been referred to as Integrated *Sustainable* Waste Management (Guerrero et al., 2013), which reflects the aim of this approach. It is supportive of but distinct from a CE approach in its scope. ISWM begins at waste generation, whereas the CE approach encompasses the entire waste hierarchy and production system, attempting to prevent waste generation through the strategies previously described.

Rather than viewing SWM as a series of separate processes, ISWM views these processes as an interrelated system and seeks to increase the overall sustainability of that system through the involvement of all stakeholders (Elsheekh et al., 2021). By doing so, ISWM attempts to achieve environmentally, socially, and economically sustainable solid waste management (Sharma & Jain, 2020). This requires not only improved waste treatment technology, but also regulations, financing, participation, planning, education, monitoring, and evaluation at every level from the national down to the municipal (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

2.8. SOLID WASTE MANAGEMENT SYSTEMS (SWMS)

To understand the systematic integrated solid waste management approach, it is important to clarify the term “management system.” The International Standardization Organization (ISO) defines a management system as a collection of interrelated elements of an organization which interact to establish policies, objectives, and processes to achieve said objectives (ISO, 2015). An environmental management system (EMS) is then defined as a subsystem of the management system focused on managing the environmental aspects of meeting legal and other requirements and addressing risks and opportunities (ISO, 2015). By extension, a solid waste management system (SWMS) would be a further subsystem of the EMS focused on aspects related to solid waste.

Depending on the scale of the system in question, the SWMS may be more or less complex, but what is important is that the interactions between the system elements are acknowledged and leveraged to meet the defined objectives or purpose of the system.

2.8.1. Municipal

Municipal Solid Waste Management (MSWM) has been a public health priority since the mid 1800s when accumulation of wastes was linked to cholera epidemics in industrializing countries (Wilson et al., 2015). It has come to be considered an essential public service to ensure the well-being of all citizens (Sharma & Jain, 2020). However, due its nature, MSWM is best classified as an impure public good, having some public non-excludable aspects and other private excludable aspects. For example, door-to-door collection may be individually paid, but the benefits of a clean neighborhood are enjoyed by all, meaning collection is mostly a public good. Meanwhile, recyclable materials are excludable resources that can be owned and sold for private benefit (Wilson et al., 2015).

Because MSWM is a public good, although with some blurring of private-like characteristics, the responsibility for providing it traditionally falls to the public sector. National governments typically establish policies and regulations, while local municipal governments usually provide MSWM services (Guerrero et al., 2013). Successful MSWM is considered an essential duty of municipal governments, as important as providing health, education, or transportation services (Sharma & Jain, 2020).

However, providing this essential service is both challenging and expensive, representing a significant percentage of local government budgets—from 4% in high-income countries to as much as 20% in low-income countries (Kaza et al., 2018; Sharma & Jain, 2020). Scarce funding is the main limiting factor for MSWM, especially in low-income countries. Collection is given priority, leaving few remaining funds for improved treatment or disposal options, and in most cases, even collection is not provided to all users (Sharma & Jain, 2020). Increasing the efficiency of waste collection is one strategy for avoiding increased taxes or governmental debt (Salazar-Adams, 2021).

On their own, municipalities generally do not have the incentive, expertise, or financial resources to offer ISWM. For example, in scenarios where separate collection of recyclables is offered, the costs are only partly covered by the sale of those materials, and therefore this service is only justified in a context of obligatory recycling targets or prohibitively high costs of other treatment or disposal options (Wilson et al., 2015). National level targets and regulations can help shift the incentives toward offering ISWM, but due to limitations in funding and expertise, local governance models that involve the private and non-profit sectors are also necessary (Guerrero et al., 2013).

A global analysis of MSWM models shows that the most common strategy is a combination of small-scale service provision, NGOs, community organizations, local government, and the private sector. The appropriate mixture depends on the local context and on the activity in question. One model may be most appropriate for mixed waste collection, for example, while another better suited to composting (Wilson et al., 2015).

Although it has been argued that privatization is the solution to increasing MSWM efficiency because the private sector has more incentive to be fiscally efficient than the public sector, the evidence on whether private services are actually more efficient is resoundingly inconclusive (Salazar-Adams, 2021; Wilson et al., 2015). There is also little data about the extent of private sector involvement worldwide, but estimates state that approximately one third of MSWM services are provided through some form of PPP (Sharma & Jain, 2020). What is clear is that many different models of private sector participation (PSP) and public-private partnerships (PPP) exist, and local authorities need expertise to select and maintain one. The most common mechanisms for private sector involvement are contracting, concession, leasing, franchising, and open competition. A brief description of each is provided in (Table 3) (Wilson et al., 2015).

Table 3. Mechanisms for public-private-partnership and private sector participation in offering municipal solid waste management services. Adapted by author from (Wilson et al., 2015)

Mechanism	Definition
Contracting	After a competitive selection process, the government awards a private company with a finite-term contract, under which the company provides a municipal service on behalf of the government in exchange for fee.
Concession	The government awards a concession in the form of a contractual agreement to a private company that allows it to use government-owned resources to set up a facility.
Lease	The government leases the use of its assets to a private company. Profits from the use of the assets are shared.
Franchise	A finite-term monopoly is awarded to a private company to operate in a defined zone. The company pays a license fee, commits to certain standards, and charges customers directly for its services at a price controlled by the government.
Open competition	Licensed private companies freely compete to offer services. Customers choose the service that best meets their needs, and payments are made directly to the private company.

It is also worth noting the informal role the private sector can play in MSWM. Without formally entering a partnership with local authorities, private companies may observe a service deficiency and capitalize on the opportunity to fill the gap. This has been observed with composting and recycling start-ups in many parts of the world where separate collection is not provided by the municipality (Ali & Harper, 2004; Kaza et al., 2018). One pitfall of private sector involvement, whether by formal partnership or not, is that profit-based incentives can drive private companies to “cherry-pick” the most profitable areas to offer their services, and neglect less profitable, usually low-income areas (Wilson et al., 2015).

In low- and middle-income countries, such gaps in municipal service are most often filled by the informal sector. Services commonly offered informally include door-to-door collection of recyclable material, picking recyclable materials from waste at collection or disposal sites, street sweeping, waste buying, and junk shops (Guerrero et al., 2013). Although this work is often either unrecognized or disdained, some municipalities are very dependent upon it, and without it recycling and other services would simply not exist in many cases (Sharma & Jain, 2020). Therefore, governance strategies which promote the recognition, inclusion, and formalization of the informal sector have great potential for extending MSWM services (Barford & Ahmad, 2021; Guerrero et al., 2013).

In an ideal scenario, driven by community involvement, the public, private, and non-profit sectors would work together systematically to offer equitable MSWM of high quality that meets local needs through an ISWM approach (Guerrero et al., 2013). However, there is a need to shift underlying public attitudes about waste. Citizens and businesses need to be encouraged to participate and view SWM as a shared responsibility of all societal actors (Sharma & Jain, 2020).

2.8.2. Industrial and Organizational

Organizations of all kinds are experiencing pressure to increase their environmental responsibility from various sources. Societal perception, financial institutions, NGOs, market forces, and public policy are all beginning to emphasize environment responsibility more heavily. Environmental management systems have helped organizations respond to these shifting expectations and are now seen as essential for companies to remain competitive in global markets (Martín-Peña et al., 2014).

Waste management systems are key parts of organizational EMSs, and successful WMSs have been linked to other benefits such as improved operational efficiency, productivity, and financial performance. However, continually implementing organized, comprehensive, and systematic efforts to reduce and responsibly manage waste depends on the consistent support of upper management and even then, can be challenging (Singh et al., 2015). For that reason, various systems of standards have been developed to support organizations in the development and implementation of EMSs, sharing best practices to promote positive outcomes. Such standards have been successfully implemented in organizations of all sizes and sectors. The most influential of these is the ISO 14000 family of standards (Martín-Peña et al., 2014).

2.8.2.1. ISO 14000 Family of Standards

The ISO 14000 family includes 12 standards in total (Table 4). The foundation is the ISO 14001 standard, which lays out the principles of and requirements for an ISO 14001-certified environmental monitoring system. The rest of the standards are considered supplements to 14001, providing guidance on specific resources, implementation challenges, or collection of specific types of data. The ISO stresses that the entire family is applicable to any organization in any sector or any size (ISO, 2015).

Table 4. International Standards Organization 14000 family of standards, by author with information from (ISO, 2015).

ISO Standard Number	Title
14001	EMS: Requirements with guidance for use
14002-1	EMS: Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area – Part 1: General
14002-2	EMS: Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area – Part 2: Water
14004	EMS: General guidelines on implementation
14005	EMS: Guidelines for a flexible approach to phased implementation
14006	EMS: Guidelines for incorporating ecodesign
14007	EMS: Guidelines for determining environmental costs and benefits
14008	Monetary valuation of environmental impacts and related environmental aspects
14009	EMS: Guidelines for incorporating material circulation in design and development
14051	EM: MFCA – General framework
14052	EM: MFCA – Guidance for practical implementation in a supply chain
14053	EM: MFCA – Guidance for phased implementation in organizations

2.8.2.2. ISO 14001 Environmental Management System

The purpose of the ISO 14001 standard is for any type of organization to systematically manage its environmental responsibilities and thus contribute to sustainability, comply with legal requirements, improve environmental performance, and achieve environmental objectives. The standard stresses the importance of establishing measurable environmental goals in line with relevant legal requirements and systematically communicating, measuring, monitoring, and updating those goals to continuously improve environmental performance (ISO, 2015).

The recommendations can be beneficial when implemented selectively, but to obtain certification, organizations must fully implement all the aspects of the standard (ISO, 2015). The main requirements were summarized by (Gomes et al., 2023) as follows:

1. Context of the organization – analysis of internal and external issues that can impact on its capacity to meet environmental goals, understanding the needs of the concerned parties, and EMS scope.
2. Leadership – leadership and commitment of the senior management to the EMS, environmental policy, responsibilities, and organizational authorities.
3. Planning – actions to address risks and opportunities: environmental aspects, legal requirements, and action planning; environmental objectives.
4. Support – resources, competence, awareness raising, internal and external communication, documented information, and control.
5. Operation – operational planning and control, preparation, and response in case of emergencies.
6. Performance assessment – monitoring, measurement, analysis, and assessment, evaluation of the extent to which legal and other requirements are met, internal audit, analysis by the management.
7. Improvement – non-compliance and corrective action, continuous improvement.

The degree and success of implementation of this standard depends on many factors, and it is impossible to claim that ISO 14001 certification has universally positive outcomes (Singh et al., 2015). Some positive outcomes documented in literature include improved quality, workplace culture, competitive edge, customer satisfaction, public image, stakeholder relations, operational processes, and environmental performance, as well as legal compliance, access to new sources of funding, and reduced costs. However, the challenges of ISO 14001 certification are the long implementation time, high degrees of complexity, uncertain benefits, and high initial cost of implementation and certification (for a review of relevant literature see Martín-Peña et al., 2014).

The impact of implementing ISO 14001, or any EMS, depends upon the sector, size of the organization, the established goals, and the reasons for implementation. Some organizations seek certification to signal their environmental responsibility to customers. Others may be motivated by cost reduction or reduced environmental impact. Clearly, the motivation behind the EMS has an effect on the decisions made and the outcomes achieved (Singh et al., 2015). The cost of certification may be prohibitive to smaller organizations, which may choose instead to implement certain recommendations without seeking certification.

ISO 14001 EMS and similar EMSs help organizations achieve environmental goals including improved SWM (Singh et al., 2015), and these proactive management systems are capable of producing not only environmental benefits but also competitive advantage (Martín-Peña et al., 2014). Research has shown a significant relationship between ISO

14001 and LM (Singh et al., 2015), which is unsurprising given the two management systems are based on many of the same principles. This finding lends support to the idea that LM can promote effective environmental management and improve both operational and environmental performance.

2.9. WASTE MANAGEMENT IN UNIVERSITIES

On a basic level, a universities is just another type of organization, but universities also tend to be large and complex, consuming large quantities of a wide range of resources, and generating many different types of emissions and wastes (Blok et al., 2015; Uhl & Anderson, 2001). Due to their usually large territories and diversity of activities, they could be viewed as “mini cities” (Alshuwaikhat and Abubakar, 2008 in Adeniran et al., 2017) or even as microcosms of society (Creighton, 1998 in Kılkış, 2017).

Although they are not typically motivated by the same market or regulatory pressures as other organizations, many universities are also choosing to emphasize environmental performance and sustainability in their strategic plans and operational activities (Gomes et al., 2023; Ruiz Moralez, 2017). A growing number of universities are doing so through the implementation of EMSs, and many of these seek ISO 14001 certification (Leal Filho et al., 2018 in Gomes et al., 2023). The recent expansion of EMSs from the industrial sector to higher education institutions (Disterheft et al., 2012) has shown that such systems, including ISO 14001 can be adapted and applied in universities just as successfully as in any other organizational setting (Disterheft et al., 2012; Gomes et al., 2023). The implementation of EMSs is credited with improved environmental performance in university operations, promoting the adoption of university recycling programs for example (Nunes et al., 2018; Silva de Souza Lima Cano et al., 2022).

However, universities need not limit themselves to operational improvements, because they have an additional function as compared to other organizations—education. Universities can seek broader applications of environmental management such as student participation, research, curriculum design, or community outreach (Disterheft et al., 2012; Vargas et al., 2015). They have the opportunity to investigate, pilot, and implement new approaches to resource management and propel their use in society (León-Fernández et al., 2018; Nunes et al., 2018).

Universities educate the intellectual leaders and decision-makers of the future, and thus have a greater potential than other sectors to promote sustainable development (Abdallah, 2018). For this reason universities are said to have a two-fold “environmental imperative” to infuse sustainability into both their operational and educational activities (Disterheft et al., 2012). Educational institutions should adopt EMSs not only to reduce their environmental impacts but also to include students in the development and implementation as part of their learning process (Vargas et al., 2015).

Students experience two types of learning in universities, the planned curriculum and the so-called “hidden curriculum.” Of course, universities do and should continue to incorporate sustainability into their coursework, research, and student projects, but students also learn from what they observe and experience outside of class time. The practices encouraged on campus, the example set by university staff, and other student experiences constitute the hidden curriculum, and this learning can either complement or detract from the curriculum-based learning (Nunes et al., 2018). There is also evidence suggesting that this learning carries over into life off campus and after graduation (Blok et al., 2015; Espinosa et al., 2008; Largo-Wight et al., 2012, 2013). For these reasons, EMSs on university campuses serve more than simply administrative or operational purposes (Ruíz Morales, 2012).

Due to their greater influence as large, educational and research institutions, universities also have greater responsibility. Many authors have argued that universities are positioned to lead the transition toward a circular economy and help achieve the SDGs (Gomes et al., 2023; Ruiz Moralez, 2017; Salas et al., 2021; Serrano-Bedia & Perez-Perez, 2022; Uhl & Anderson, 2001). Their ability to influence broader society calls universities to approach environmental management more holistically. A circular economy approach to EMS at universities requires monitoring the use and impacts of all the natural, financial, social, and intellectual resources, as well as communication and participation from all levels within the university. It requires not only proper waste disposal, but new procurement policies and a continuous rethinking of the concept of waste and how it is managed (Espinosa et al., 2008; León-Fernández et al., 2018; Nunes et al., 2018).

From this perspective, implementation of an EMS and even ISO 14001 certification could be considered only the first essential step for universities. By seeking such certifications, universities can be an example for other universities or organizations and establish a solid basis from which to explore broader more forward-thinking approaches (Armijo de Vega et al., 2008; Gomes et al., 2023).

According to many authors, several forms of participation are essential for universities rising to meet this challenge. These could be described as bottom-up, top-down, inside-out, and outside-in participation. In a university context, bottom-up participation means involving students, professors, and operational and administrative staff (Gomes et al., 2023; León-Fernández et al., 2018). Meaningfully including students, faculty, and staff must go beyond simply informing. Their opinions and ideas must be solicited and put into practice, so that the entire university community can be engaged co-responsibly in the EMS (Disterheft et al., 2012).

However, equally important is top-down participation. Support from university leaders and decision-makers is crucial for the successful implementation of EMSs (Blok et al., 2015; Espinosa et al., 2008; Gomes et al., 2023; León-Fernández et al., 2018). Upper management can incorporate sustainability into the university's vision, mission, and objectives, to encourage participation from staff and faculty, to maintain accountability, and to dedicate financial resources. Funding can be especially important for universities who want to certify their EMSs. Gomes et al. (2023) calculated the annual cost of the ISO 14001 certified EMS at UNISINOS in Brazil, including personnel, waste disposal and treatment, environmental education, auditing, and other costs, at US$54,000 (Gomes et al., 2023). Establishing sustainability as a priority worth investing in can determine the direction and level of success of the EMS (Disterheft et al., 2012; Gomes et al., 2023).

Salas et al. (2021) highlight the importance of inside-out and outside-in participation, emphasizing that universities, especially in the developing world, can identify CE behaviors in their communities, which often already exist out of necessity, merge that practical knowledge with theory, and disseminate the new CE models that result. León-Fernández et al. (2018) identify collaboration with local government, businesses, and NGOs as another important aspect of this form of participation. This sentiment is echoed by Nunes et al. (2018) who point out that partnering with industries who are also implementing EMSs can potentially result in lower long-term costs, student internships, graduate employment, funding opportunities, and positive impact on the university's reputation.

2.9.1. UI GreenMetric Rating System

One final form of participation not previously described is collaboration between universities. One mechanism to promote such collaboration is university ranking systems, which not only allow prospective students to assess the quality of different aspects of universities, but also allow universities to compare themselves to one another. Created by the University of Indonesia in 2010, the GreenMetric system is one such system focused on comparing campus sustainability. The system includes six categories: infrastructure, energy and climate change, waste, water, transport, and education. Universities self-report based on a detailed questionnaire and submit supporting evidence. The questionnaires are scored annually to generate the global GreenMetric rankings, and as of 2022 1,050 universities from 85 countries participated (*Overall Rankings 2021 - UI GreenMetric*, n.d.). The publication of the rankings serves to raise awareness of the role of universities in sustainability and allow universities to compare their environmental performance on a global scale. The indicators themselves can serve as an important baseline reference for universities just starting their EMS implementation (Vitoreli et al., 2021). For those with a longer history of EMS, it can prompt the sharing of best practices and motivate continuous improvement (Kılkış, 2017).

The waste category, which accounts for 18% of the total possible score, includes six equally weighted indicators (Table 5), the first four of which are directly related to MSW. To score well, universities must address organic waste treatment (WS3), recycling (WS1), and final disposal of MSW (WS4) as well as implement waste reduction efforts for certain types of waste (WS2).

From an ISWM or CE perspective, these indicators have some obvious gaps. For example, e-waste is not addressed, nor are purchasing practices or overall waste generation. However, for a typical university, progressing in the six indicators currently included represents a considerable challenge.

Table 5. GreenMetric questionnaire (UI GreenMetric, 2021).

Number	Indicator	Questionnaire
WS1	Recycling program for university's waste	Please select a condition which reflects the current condition of your university efforts to encourage staff and students to recycle waste, from the following options: [1] None. Please select this option if there is no program at your university. [2] Partial (1 - 25% of waste) [3] Partial (> 25 - 50% of waste) [4] Partial (> 50 - 75% of waste) [5] Extensive (> 75% of waste)
WS2	Program to reduce use of paper and plastic on campus	Please select one from the following options which best reflects the current condition of your university in establishing a formal policy to reduce the use of paper and plastic (i.e., double-sided printing policy program, the use of tumblers, the use of reusable bags, print when necessary, free water distribution, policies for dematerialization of administrative procedures, etc.): [1] None. Please select this option if there is no program at your university. [2] 1 program [3] 2 programs [4] 3 programs [5] More than 3 programs
WS3	Organic waste treatment	The method of organic waste (i.e., garbage, discarded vegetable, and plant matter) treatment in your university. Please select an option that best describes your university's overall treatment of the bulk of organic waste: [1] Open dumping [2] Partial (1 - 25% treated) [3] Partial (> 25 - 50% treated) [4] Partial (> 50 - 75% treated) [5] Extensive (> 75% treated)
WS4	Inorganic waste treatment	Please describe the method of inorganic waste (i.e., rubbish/garbage, trash, discarded paper, plastic, metal, etc.) treatment in your university. Please select an option that best describes your university's overall treatment of the bulk of the inorganic waste: [1] Burned in the open [2] Partial (1 - 25% treated) [3] Partial (> 25 - 50% treated) [4] Partial (> 50 - 75% treated) [5] Extensive (> 75% treated)
WS5	Toxic waste treatment	Please select a condition which reflects the current condition of how your university handles toxic wastes. The handling process includes whether toxic wastes are dealt with separately, for example, by classifying and handling them over to a third party or certified handling companies. Please select one of the following options: [1] Not managed [2] Partial (1 - 25% treated) [3] Partial (> 25 - 50% treated) [4] Partial (> 50 - 75% treated) [5] Extensive (> 75% treated)
WS6	Sewage disposal	Please describe the primary method of sewage treatment at your university. Please select an option that best describes how the bulk of the sewage is disposed of: [1] Untreated into waterways [2] Treated conventionally [3] Treated technically for reuse [4] Treated technically for downcycling [5] Treated technically for upcycling

2.9.2. Typical University Environmental and SWM Systems

At many universities, WMSs and EMSs have not been developed, and waste management is still in its infancy. Waste characterization, which is considered foundational for SWM (see section 3.6), has not been completed in many cases. In the developing world, most recycling is still realized by the informal sector, while a study of UK universities found that 88% had at least some form of campus recycling program. Composting and reuse programs were found to be much less common, however (Nunes et al., 2018). This finding was confirmed by Smyth et al. (2010), who identified a tendency for universities to focus on recycling programs while ignoring efforts to reduce waste generation at the source.

In their review of European Universities, Disterheft et al. (2012) identified just 47 who had implemented an EMS, most of which (81%) were pursuing certification. Of the universities with an EMS, 60% employed some form of internal system auditing, and 57% developed sustainability reports using the audit data, indicating that the practice of reporting is still much less common in universities than in other sectors. ‘

The literature also shows that universities are generally not taking advantage of their educational influence with respect to solid waste. Although involving students in environmental management is an acknowledged best practice, one study found that only 18% of universities with EMSs were doing so (Nunes et al., 2018), and another found that 23% had linked their EMS to their curriculum (Disterheft et al., 2012). Clearly, there is still much progress to be made in waste management education in both the planned and hidden curricula. In summary, Nunes et al. (2018) describe most universities’ efforts at environmental management as simply trying to be “less bad.”

2.9.3. Exemplary Universities

Of course, there are some exceptional universities who have embraced the role of leaders in the circular economy transition. Based on the 2022 GreenMetric rankings, Wageningen University & Research (WUR) in the Netherlands is considered the most sustainable university in the world (UI GreenMetric, 2023). Since 2020, it has been guided by a “vision on circularity,” which involves ambitious targets on recycling, composting, and reducing raw material use. As of 2020, WUR reported a “useful recovery” rate of 98%, including 59% recycling, 33% energy recovery, and 6% other recovery (WUR, 2023).

Third place overall in 2022 was the University of Nottingham in the UK, which has a long history of performing well in the GreenMetric rankings (Abdallah, 2018) and also achieved a perfect score in the waste category (UI GreenMetric, 2023). The university reports an overall recycling rate of 99% as of 2018, including composting of food waste from student housing, mulching of garden waste, and recycling of IT equipment (U of N Sustainability Team, n.d.).

Worldwide, 30 universities obtained perfect scores in the waste category in 2022. The only Latin American universities to do so were *Universidad Autónoma de Occidente* in Colombia and *ITESO, Universidad Jesuita de Guadalajara* (UI GreenMetric, 2023). ITESO has an ambitious zero waste goal and has installed a bioreactor, established waste separation containers throughout campus, and eliminated the use of certain difficult to recycle materials, such as Styrofoam, in its facilities (*ITESO - Indicadores*, n.d.).

The highest overall raking university in Mexico in 2022 was *Universidad Autónoma de Nuevo León* (UANL), which achieved a near perfect 1725 out of 1800 in the waste category (UI GreenMetric, 2023). UANL has implemented a recycling system for paper, cardboard, PET, and aluminum (UANL, n.d.). In second place was *Benemérita Universidad Autónoma de Puebla*, also with 1725 in waste, followed by *Universidad Nacional Autónoma de México* (UNAM) with 1650. In comparison, UASLP finished 16th among Mexican universities with a score of 900 in the waste category (UI GreenMetric, 2023).

CHAPTER 3. THEORETICAL FRAMEWORK

3.1. SYSTEMS THINKING

Changing how a system works is not necessarily a simple task. An extensive body of literature on systems thinking has demonstrated that different types of systems behave in different and often unpredictable ways. Understanding the characteristics of the PROSEREM as a system is fundamental for determining how to improve the way it functions.

3.1.1. Cynefin Framework

One framework for making sense of different types of systems is the Cynefin framework developed by Dave Snowden. Snowden intended to offer a sense-making tool that could help understand which type of intervention is appropriate for systems with certain characteristics (Snowden, 2002). The Cynefin framework describes four types of systems based on their complexity and the most appropriate decision-making processes and practices for each ((Nachbagauer, 2021)).

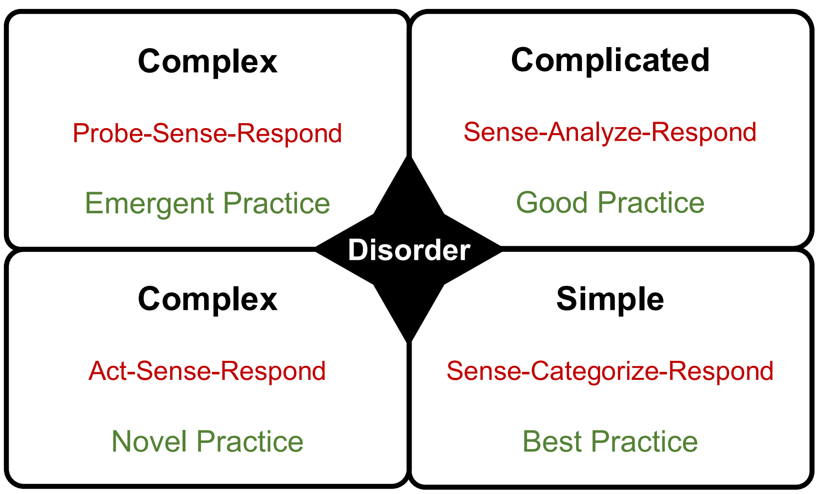


Figure 6. The Cynefin Framework, adapted by author from Nachbagauer (2021).

Importantly, in the center of the framework is the realm of "disorder." In this realm, the type of system is unknown. Without sufficient understanding of the system at hand, managers tend to apply the strategies with which they have the most experience or feel the most comfortable, not necessarily those which are most effective. This leads to wasted resources and effort and can even cause the system to devolve into greater complexity. The framework is based on the principle of bounded applicability, meaning that no solution is applicable in all circumstances (European Commission. Joint Research Centre., 2021). Taking the time to consider the type of system allows managers to select the most appropriate course of action for the context.

In simple systems, cause-and-effect relationships are stable and understood, and thus, prediction of outcomes is feasible (Nachbagauer, 2021). Based on these known cause-and-effect relationships, established best practices can be implemented to promote efficiency and consistency. In this type of system, action takes the form of "sense-categorize-respond" (Kurtz & Snowden, 2003). Managers can observe the phenomena in the system, categorize them based on established known patterns, and respond by applying the corresponding established best practice.

Complicated systems involve cause-and-effect relationships that are not as obvious or direct. Identifying these relationships requires expertise and analysis. Because causes and effects do not follow known patterns, applying an established best practice is not possible. However, through analysis, good practices can be applied that are likely to have positive outcomes. Therefore, in contrast to simple systems, in complicated systems, the appropriate action sequence is "sense-analyze-respond" (Kurtz & Snowden, 2003). To a degree, complicated human-based systems can be shifted toward simplicity through extensive training and standardization to reduce errors and increase outcome predictability (Nachbagauer, 2021). This approach of increasing stability by decreasing variability is closely aligned with the lean thinking concepts of standard work and error-proofing (Marchwinski, 2003).

Simple and complicated systems both fall within the realm of ordered systems, meaning they are predictable, at least to an extent. Complex and chaotic systems on the other hand are within the unpredictable realm of unordered systems. In complex systems, outcomes cannot be predicted based on previously known patterns or expertise gained from other systems, and cause-and-effect relationships are only apparent in hindsight (Nachbagauer, 2021). The only way to determine the behavior of a complex system is to modify it and observe what happens. This should be done through "safe-fail" experiments so that the effects can be observed while allowing for course-correction if necessary. This action sequence is summarized as "probe-sense-respond," and it allows effective "emergent practices" to be identified (Kurtz & Snowden, 2003).

Chaotic systems are even less predictable than complex systems because they lack cause-and-effect relationships. Therefore, experimentation is ineffective because effects are not necessarily repeatable or consistent. In this setting, trial and error is the only option, and the appropriate action sequence is "act-sense-respond," seeking to identify novel practices that will stabilize the system (Kurtz & Snowden, 2003).

The scoping of the present project was informed by the Cynefin framework. Because LM is collection of good practices and adaptable tools, it is most appropriately applied within complicated systems. Currently the solid waste management of the entire UASLP across all campuses would be considered a complex system, with too high a degree of complexity to reasonably apply lean. However, the PROSEREM system delimited within the contained geographical area of the ZUP campus is a complicated system. Though they are not obvious, cause and effect relationships exist, and the expertise about the operation of the system needed to adapt good practices can be accessed by consulting just a few personnel. Practices from other universities or other waste separation programs can offer clues about effective strategies, and strategies must be adapted to the local context. Thus, good practices can be employed, but best practices cannot simply be transferred from elsewhere.

Nachbagauer (2021) built on the Cynefin framework by incorporating a distinction between unique and repetitive projects. Drawing on a previous categorization by Argyris and Schön (1978) he argues that "single loop" learning is most appropriate for unique projects, while "double loop" learning is very valuable for repetitive projects within complicated systems. Single loop learning permits specific solutions to be identified, while double loop learning permits the underlying organizational guidelines, policies, and processes to be examined to better support future projects. In complicated systems, expertise is critical for following the action sequence of "sense-analyze-respond," and in the case of a repetitive project, it is important to develop that expertise internally rather than relying on experts from outside the organization (Nachbagauer, 2021).

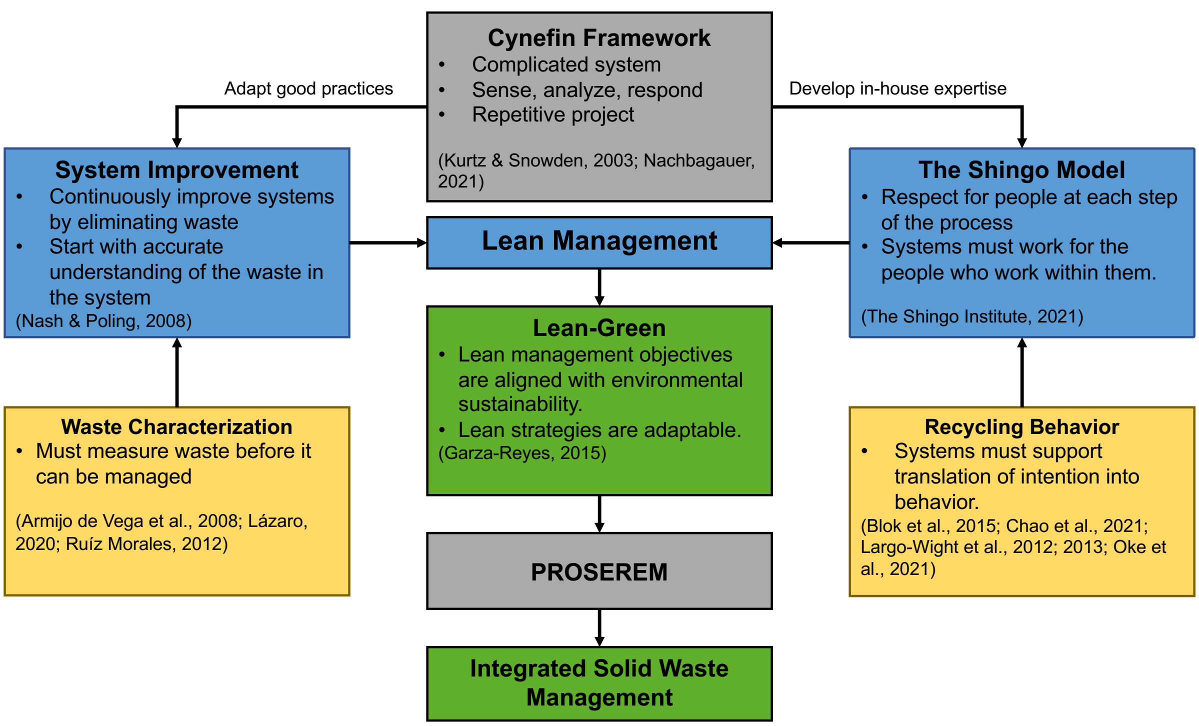


Figure 7. Theoretical framework. Waste characterization and recycling behavior influence how good practices are adapted and in-house expertise is developed, by author.

Based on the Cynefin framework and Nachbagauer's analysis of repetitive projects, it is evident that developing in-house expertise and analyzing the system to apply good practices in an informed manner is appropriate and necessary for improving the PROSEREM at the ZUP campus and eventually implementing it at all the UASLP campuses throughout the state. The following section describes how the Shingo model approach supports the development of in-house expertise, and LM supports the application of good practices adapted for this specific context.

3.2. LEAN MANAGEMENT

Lean management is a management philosophy that aims to "do more with less" (Alves et al., 2019; Bittencourt et al., 2019; Ciliberto et al., 2021). The philosophy is based on two mutually reinforcing aspects, operational efficiency and respect for people and their skills (Alves et al., 2019). It was first developed by Taiichi Ohno, an executive at Toyota Motor Corporation following World War II, when it was known as the Toyota Production System (Womack & Jones, 1997). Ohno's contemporary, Dr. Shigeo Shingo, is credited with emphasizing the importance of tapping into the expertise of those at every level of the organization, respecting their valuable experience and talents (The Shingo Institute, 2021). His model is discussed in more detail in section 3.4. In the late 1980s, John Krafcik of New United Motor Manufacturing, Inc. began referring to TPS as "lean" production because it produced products faster, with fewer resources, and less human capital than other production systems of the time (Alves et al., 2019).

The operational aspects of LM focus on delivering value to the customer as efficiently as possible through the reduction of lead time and the elimination of eight types of waste (Table 6) (Ciliberto et al., 2021; Kilpatrik, 2003; Womack & Jones, 1997). There is no prescribed set of tools or techniques for accomplishing this, but rather a set of principles and good practices that can be adapted to suit the specific context. The five principles of lean are (1) specify value, (2) identify the value stream, (3) flow, (4) pull, and (5) pursue perfection (Womack & Jones, 1997).

Table 6. The eight wastes of LM and their definitions, by author.

		Type of Waste	Definition
1	**D**	DEFECTS	Errors or faulty products.
2	**O**	OVERPRODUCTION	Producing more than is needed to meet customer demand.
3	**W**	WAITING	Inactive, unproductive time before a process step can begin.
4	**N**	NEGLECTED TALENT	Underutilizing the skills and knowledge of employees.
5	**T**	TRANSPORTATION	Moving products or materials from one place to another.
6	**I**	INVENTORY	Stock of products or materials in storage rather than in direct use.
7	**M**	MOTION	Reaching, stooping, standing, walking, turning, or other changes in position.
8	**E**	EXTRA PROCESSING	Performing process steps that do not improve the final product.

Specify value (1) refers to differentiating what is actually of value to the customer—customer being understood broadly as the internal or external recipient of the good or service. Features, or process steps that do not add value from the customer's perspective should be reduced to a minimum. Identify the value stream (2) means determining all the planned and unplanned actions that are taken to deliver the product to the customer (more on value streams in the following section). Flow (3) is the uninterrupted movement of a product through the value stream. To promote flow, errors, unnecessary steps, bottlenecks, equipment failures, and communication breakdowns must be prevented. Pull (4) is the prompt to produce a product. A true pull system is make-to-order, where the exact products needed to meet customer demand are made, with no excess of finished products or inventory. Finally, pursue perfection (5) means to continuously improve. Since perfection is a goal that can never be achieved, its pursuit is a never ending process of seeking incremental improvements (Womack & Jones, 1997).

In pursuit of perfection, lean embraces a system of trial-and-error commonly known as the "Plan-Do-Check-Act" cycle, encouraging employees to systematically solve their own problems by implementing and rapidly testing solutions, evaluating the results, and adjusting to make a new plan for the next iteration (Marchwinski, 2003). This systematic approach promotes "learning by doing" and implementing what is learned to make continuous incremental improvements toward measurable established objectives (Espinosa et al., 2008; Womack & Jones, 1997).

Since Toyota demonstrated the success of this approach, it has been adopted and adapted by countless other organizations all over the world and has been shown to produce measurable improvements in a wide array of sectors (Alves et al., 2019; Amaro et al., 2019; Dieste et al., 2019). Evidence suggests lean can be adapted to nearly any context in which "Plan-Do-Check-Act" can be applied. This type of approach would be overly burdensome for a simple system and too simplistic for a complex system but is appropriate for complicated systems, given the similarity between "Plan-Do-Check-Act" and "sense-analyze-respond."

3.3. VALUE STREAM MAPPING

Although LM is not a prescribed methodology, the value stream map has emerged as a nearly universal tool used in most lean implementations. Because it has been shown to be versatile and impactful in both lean and lean-green applications (US EPA, 2016), it formed the basis of the methodology for this study. A value stream is the collection of all the specific steps required to deliver "value," in the form of products or services, to the "customer," the entity demanding the product or service (Alves et al., 2019; The Shingo Institute, 2021). A value stream map (VSM) is a visual representation of key performance indicators throughout the processes in the value stream that facilitates the identification of improvement opportunities (Figure 8).

Generally, a current state value stream map is made to capture an accurate snapshot of how a process is functioning. This map is informed by measurable data, direct observation, and the input of the participants at each step in the process. Next, stakeholders collaboratively envision the future desired functioning of the process and begin drafting a future state VSM. Throughout this process, improvement opportunities are identified, and their potential impact on key performance indicators is quantified.

Finally, the improvements are systematically implemented until the future state is achieved (Nash & Poling, 2008).

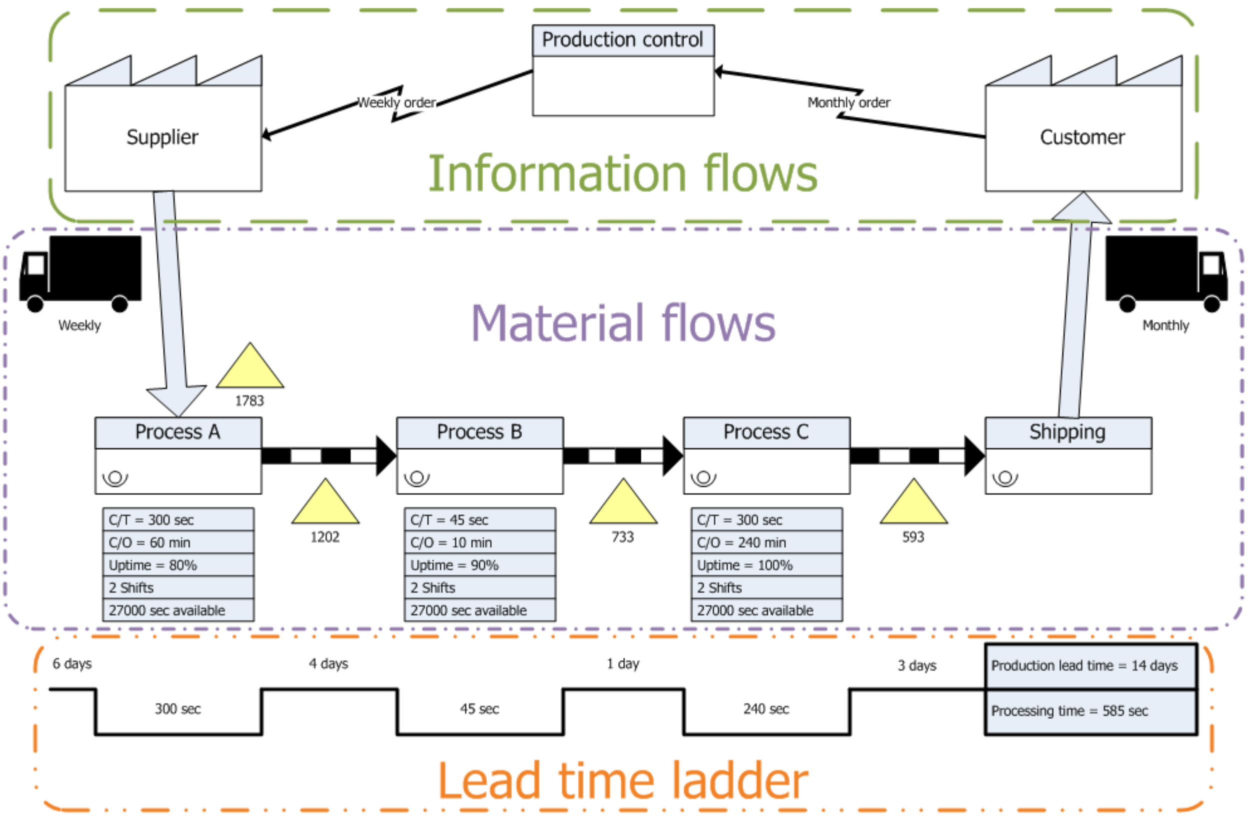


Figure 8. Generic example of a Value Stream Map ("Value Stream Mapping," 2017)

Although the value of LM has been demonstrated in a wide variety of complicated systems in various settings (Alves et al., 2019; Amaro et al., 2019; Chaple et al., 2021; Dieste et al., 2019), its application outside the manufacturing context requires a greater degree of adaptation. This study aims to adapt the good practices from LM to the university solid waste management context by drawing on bodies of knowledge from other research fields.

3.4. THE SHINGO MODEL

One of the original great lean thinkers was Dr. Shigeo Shingo, who worked alongside Ohno in the early days of TPS (The Shingo Institute, 2021). Shingo's legacy is a model for understanding and approaching the human side of LM and navigating the interaction between people and systems. He defined a system as a collection of tools and processes working together to toward a desired outcome, and while he emphasized the importance of well-designed systems, he famously explained that "tools and systems alone do not operate a business, people do" (The Shingo Institute, 2021).

The first guiding principle of the Shingo Model is "respect every individual." Based on this principle, those who seek to improve a process must avoid the temptation to blame problems on people. The conditions created within processes and systems cause people to respond in either desirable or undesirable ways, and all results are thus the consequence of a process:

> *"It is nearly impossible for even good people to consistently produce ideal results with poor processes. It is human nature to blame the people involved when something goes wrong ... But in reality, an issue is usually rooted in an imperfect process, not in the people involved" (The Shingo Institute, 2021).*

Rather than dismissing them as lazy, indifferent, or incompetent, part of respecting people is including them in the improvement process and taking the time to understand the systems in which they work. In other words, systems must work for the people who work within them. At an educational institution, this requires meaningfully including students in consultation, decision-making, and even co-management (Espinosa et al., 2008; León-Fernández et al., 2018).

3.5. LEAN-GREEN

Based on the Cynefin framework described previously, the PROSEREM can be understood as a complicated system, and although known best practices cannot be applied to achieve predictable outcomes, good practices can be adapted to shift the system behavior in somewhat predictable ways. Thus, the question becomes, which good practices should be adapted and applied in this case? If the goal is to make the PROSEREM not only more efficient but also more environmentally friendly, which good practices are appropriate?

The connection between "lean and green" has been a topic of significant research interest, especially in the manufacturing sector, as companies seek to operate at a lower economic and environmental cost (Abualfaraa et al., 2020). Moreira et al. (2010) offered an analysis of the environmental costs of the eight wastes of lean, highlighting the fact that in many cases, errors, delays, and unnecessary process steps also result in more emissions and discharges and wasted raw materials, energy, and water (Figure 9). The United States Environmental Protection Agency has even released a toolkit for "Sustainable Value Stream Mapping," encouraging manufacturers to incorporate environmental indicators into their process improvement considerations (US EPA, 2016).

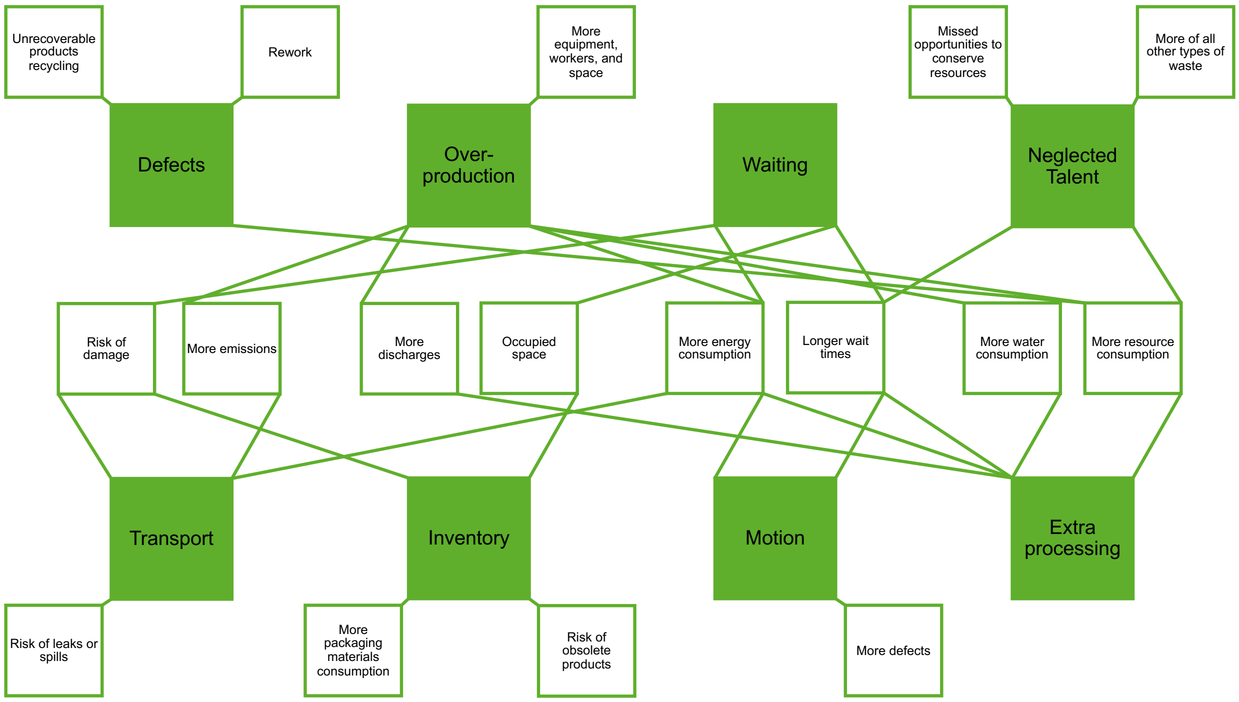


Figure 9. Environmental effects of the eight wastes of lean, adapted by author from Moreira et al. (2010) based on Alves et al. (2019).

Recently, the link between lean and the circular economy has also been examined. Ciliberto et al. (2021) presented a comparative analysis of CE principles and lean principles (Figure 10), which found a positive or strongly positive correlation between all but one of the principles. The exception was the CE principle of innovation, which had a mild negative correlation with the elimination of waste due to the trial and error inherent in the process of innovation. Overall, a great potential was found for lean to promote sustainability, especially sustainable production and consumption, through reducing wastes, simplifying processes, influencing the supply chain, stabilizing prices, and meeting customer needs more directly (Ciliberto et al., 2021). There is a growing consensus that a lean-green approach positively impacts the "triple bottom line"—economic, social, and environmental—and promotes sustainable industrialization, production, and consumption (Alves et al., 2019; Amaro et al., 2019; Ciliberto et al., 2021).

CE features	Reducing lead times	Providing continuous improvement	Guaranteeing reliability	Pursuing perfection	Generation of value	Satisfaction of customers' needs	Elimination of wastes
	Lean production features						
Optimizing	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Regenerating	⊕	⊕	+	⊕	⊕	+	⊕
Sharing	⊕	⊕	⊕	⊕	⊕	+	⊕
Dematerializing	⊕	⊕	+	+	⊕	+	⊕
Innovating	+	⊕	+	⊕	⊕	+	–
Closing the loop	⊕	⊕	+	⊕	⊕	+	⊕
Increasing economic efficiency (reducing price volatility)	⊕	⊕	+	⊕	⊕	⊕	⊕

⊕ Strong positive correlation
\+ Mild positive correlation
⊖ Strong negative correlation
– Mild negative correlation

Figure 10. Comparison of circular economy principles and lean principles (Ciliberto et al., 2021).

These studies have lent credibility to what makes intuitive sense. If value is to be maintained within a circular flow as in the CE model, it is necessary for the value to flow in the first place, with minimal loss of value along the way. The existing body of work on the alignment of lean and green shows that lean objectives can also serve green objectives and that lean tools are flexible enough to also serve environmental purposes. Therefore, it is reasonable that techniques and practices adapted from LM may be implemented to improve the efficiency and sustainability of the PROSEREM.

3.6. WASTE CHARACTERIZATION

The first essential step to improving any process is a detailed accounting of its current performance. In the case of SWM, this requires a characterization of the quantity and composition of the waste (Adeniran et al., 2017; Armijo de Vega et al., 2008). According to the LGPGIR, municipalities should conduct a basic diagnostic study including the determination of the generation of RSU. The associated NMXs establish 26 categories into which RSU should be classified as well as rigorous sampling procedures (Secretaria de Comercio y Fomento Industrial, 1985a, 1985c; Norma Mexicana NMX-AA-022-1985-Protección al Ambiente-Contaminación Del Suelo-Residuos Sólidos Municipales-Selección y Cuantificación de Subproductos, 1985).

Some university waste characterization studies have applied this categorization from Mexican law (Ruíz Morales, 2012), while others have based their characterization on different standard waste categorization systems, such as that of the College and

University Recycling Council (Armijo de Vega et al., 2008) or the ASTM (American Society for Testing Materials) method (Adeniran et al., 2017). Others simplify or modify the methodology to fit the specific organizational capacity or data needs (Lázaro, 2020), which is the approach adopted in this study. Conducting the waste characterization study for product families (Nash & Poling, 2008) rather than individual subproducts in line with the lean principle of "measuring what matters" (The Shingo Institute, 2021) provides the information necessary for successful implementation of the PROSEREM without wasting limited resources.

3.7. RECYCLING BEHAVIOR

The Shingo model closely aligns with the growing body of work on "recycling behavior" (understood in the literature as referring to the behaviors of separating and properly handling wastes, including but not limited to recycling and composting). Significant research has been published about the complicated human behavioral factors involved in solid waste management in household, workplace, and university campus settings (Chao et al., 2021b; Khan et al., 2019; Oke et al., 2021; Pegels et al., 2022; Strydom, 2018). Recycling behavior is often studied through the Theory of Planned Behavior (TPB) (for a detailed explanation see Largo-Wight et al., 2013). In brief, TPB is concerned with the connections and differences between recycling *intention* and actual recycling *behavior*. The distinction can be simply understood by considering that even an individual with a fervent belief in the importance of recycling is unable to act on the intention to recycle in the absence of recycling facilities.

A meta-analysis evaluating 70 interventions across 36 studies found that environmental alterations, such as making waste separation more convenient or giving social cues, were the most effective means of increasing household waste separation behavior (Varotto & Spagnolli, 2017). Another study of household waste separation at the municipal level found that increasing convenience was among the most effective ways to boost waste separation and concluded that low-cost methods of increasing convenience are urgently needed in resource-scarce settings (Pegels et al., 2022). Studies of recycling behavior on college campuses have also found convenience of recycling receptacles to be the single greatest determinant of recycling behavior, regardless of other interventions such as education (Largo-Wight et al., 2013). Finally, studies of recycling behavior in the workplace show that similar behavioral phenomena influence recycling at work as in the household but that managerial leadership and clear procedures also play an important role (Blok et al., 2015).

These findings illustrate that *intention* to recycle is only part of the equation. Intention must be present, but increased intention has little impact unless effective systems to support and reinforce recycling *behavior* are in place. Without a well-designed system, individuals must exert significant effort and overcome various obstacles to align their behaviors with their intentions. Just as Shingo described, well-designed systems remove these obstacles and reduce the effort required, thus allowing intention to lead easily to desired behavior. Connecting these findings from recycling behavior to the Shingo model of LM, the present study operates from the premise that desired behaviors must be encouraged by making the waste separation system and processes as convenient, automatic, and error-proof as possible.

Finally, emphasizing the importance of promoting recycling behavior at the UASLP, is the finding that when employees experience positive outcomes from pro-environmental behaviors in their workplace, they are likely to repeat the behavior in their lives outside of work as well (Alzaidi & Iyanna, 2021). The UASLP can thus contribute to spreading a culture of responsible waste management and recycling behavior throughout society by first encouraging it in their students and staff.

CHAPTER 4. STUDY AREA: WASTE MANAGEMENT AT THE UASLP

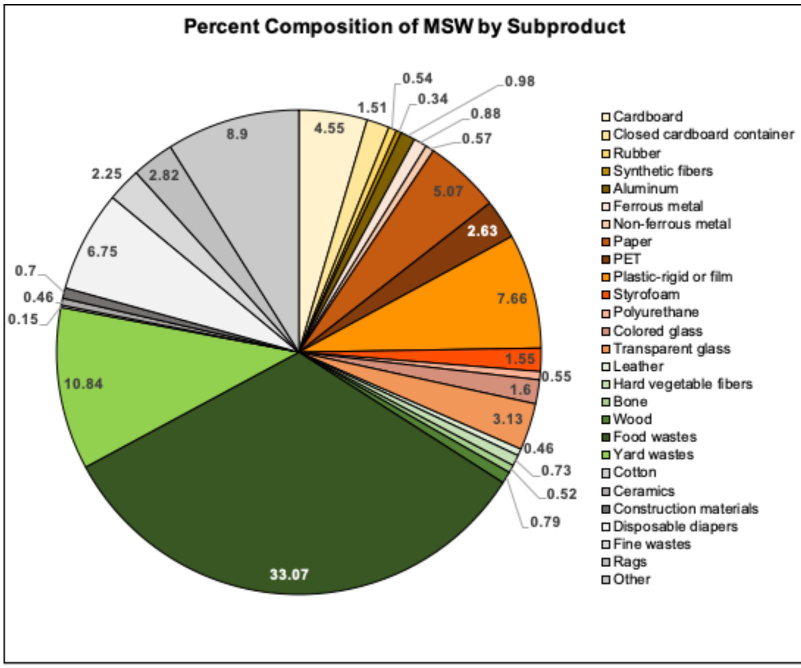
4.1. NATIONAL LEVEL: THE MEXICAN SOLID WASTE CONTEXT

4.1.1. Background and Challenges

In 2020, the Secretariate of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales,* SEMARNAT) published a national basic diagnostic for integrated solid waste management, which compiles the most complete and up-to-date data on solid waste reported by municipalities, states, and the national census to provide a comprehensive overview of the status of SWM in the country.

According to this study, as of 2017, the annual MSW generation for Mexico was 2,447,596.58 tons, which equates to 120,128 tons per day and 0.944kg per capita per day (SEMARNAT, 2020). As in most parts of the world, waste generation in Mexico has increased dramatically in the past several decades. In the year 2000, annual solid waste generation was 30.0 million tons and by 2015 it had risen 73% to 53.1 million tons (SEMARNAT, 2019, 2015 in Salazar-Adams, 2021). This increase is due both to population growth and to increasing per capita waste generation (Botello-Álvarez et al., 2018). When disaggregated by municipality, the data show that the smaller the municipal population, the lower the per capita waste generation (SEMARNAT, 2020). In other words, waste generation is strongly concentrated in urbanized areas.

With respect to composition of MSW, organic wastes represent the largest share, with an estimated 46.42%, followed by recyclable wastes with 31.56% and finally other non-recyclable wastes with 22.03% (SEMARNAT, 2020). Figure 11 presents a more detailed breakdown according to the 26 subproducts from NMX-022.



Category	Subproducts	Percentage
Recyclable	Cardboard	4.55
	Closed cardboard container	1.51
	Rubber	0.54
	Synthetic fibers	0.34
	Aluminum	0.98
	Ferrous metal	0.88
	Non-ferrous metal	0.57
	Paper	5.07
	PET	2.63
	Plastic-rigid or film	7.66
	Styrofoam	1.55
	Polyurethane	0.55
	Colored glass	1.6
	Transparent glass	3.13
Organic	Leather	0.46
	Hard vegetable fibers	0.73
	Bone	0.52
	Wood	0.79
	Food wastes	33.07
	Yard wastes	10.84
Other	Cotton	0.15
	Ceramics	0.46
	Construction materials	0.7
	Disposable diapers	6.75
	Fine wastes	2.25
	Rags	2.82
	Other	8.9

Figure 11. Percent composition of MSW by subproduct, adapted by author from (SEMARNAT, 2020).

The collection and treatment of this waste varies significantly from one area to another. According to the municipal government census, 92.3% of municipalities provided waste collection service in 2018. However, only 61% of the population was served (Salazar-Adams, 2021). According to SEMARNAT, on a national level 100,751 tons of MSW is collected daily, which represents 83.87% of the daily generation. Almost all this waste is collected in one single stream with only 5% being collected separately to facilitate subsequent recycling or composting. There are 127 transfer stations in the country of which the majority simply transfer MSW onto larger trucks. At 37 of these stations separation of recyclable materials is carried out, either formally or, more commonly, informally (SEMARNAT, 2020).

The Mexican constitution establishes that municipal solid waste collection is the responsibility of municipal government, and of all the MSW collection services, the vast majority are operated directly by the municipal government (SEMARNAT, 2020). However, in recent decades, the poor quality of municipal service has led some municipalities to subcontract waste collection (Salazar-Adams, 2021), and about 13% is now being offered by either the private or nonprofit sectors (SEMARNAT, 2020). Evidence suggests these privatized services are slightly more efficient and of higher quality than those offered directly by the municipalities (Salazar-Adams, 2021). MSW collection is currently offered at no charge, meaning it is paid for by the already strained municipal budgets (SEMARNAT, 2020).

In municipalities with absent or inadequate collection services, open burning and open dumping of wastes is particularly common, though such practices are by no means limited to that context. An estimated 1,788,349 tons of MSW was openly burned in Mexico in 2015, and 11.4% of households identified open burning as one of their practices to dispose of waste. Another 2.1% of households confirmed the use of burying or open dumping as disposal strategies (SEMARNAT, 2020).

Even waste that is collected by the official public or private disposal service is not necessarily disposed of safely. The scarcity of data on the country's 2,203 final disposal sites does not permit an accurate count of how many meet the requirements of a "sanitary landfill," a "controlled dumpsite," or an "uncontrolled dumpsite." However, an assessment of the infrastructure determined the percentage that have the following:

- Scale for weighing wastes – 8.62%
- Leachate capture system – 16.30%
- Leachate treatment system – 25% of those who have capture systems.
- Biogas capture system – 9.67%
- Geomembrane to isolate wastes from the soil – 14.80%
- Perimeter fencing – 43.35%
- Compaction and covering of wastes – 43.35%

A significant portion (40.08%) of the sites do not have any of the above protections (SEMARNAT, 2020). Due to the inadequate collection service and disposal infrastructure, open dumping and burning continue to be significant challenges in Mexico (Sharma & Jain, 2020).

The various other waste treatment strategies described in section 2.3 are not commonly practiced. Waste to energy technology is in its infancy, with only five biodigestion facilities nationwide. Recyclables collection centers are more common, with 1,060, but these are very unevenly distributed, and have only been documented in 21 of the 32 states. Similarly, the 47 waste treatment or reuse plants are located in just 15 states (SEMARNAT, 2020).

As in most developing countries, most of the resource recovery from MSW is performed by the informal sector. One study estimated that informal waste pickers, known in Mexico as *pepenadores*, were responsible for 71.69% of recyclables recovery (Botello-Álvarez et al., 2018). Even SEMARNAT acknowledges that waste picking, or *pepena*, is likely the country's main resource recuperation method (SEMARNAT, 2020). *Pepena* is ubiquitous, despite being formally prohibited in solid waste legislation. Rather than putting a stop to the practice, outlawing it only seems to have made quantifying the role of the informal sector more difficult (SEMARNAT, 2020).

The work of Mexico’s *pepenadores* is quite precarious, and their living conditions have been deemed 87% less favorable than for the rest of the population. They generally live in marginalized conditions with inadequate housing, education, and access to good and services (Botello-Álvarez et al., 2018). Despite Mexican society not serving them, they provide a significant service to society. Because of their labor, Mexico is the largest recycler of PET in Latin-America. The quantity recovered surpasses the domestic reprocessing capacity, and Mexico sells the PET it cannot process abroad, mostly to the United States and China. Significant amounts of paper and cardboard are also recovered, most of which is processed domestically, with a small amount sold overseas (Botello-Álvarez et al., 2018).

4.1.2. National Legislation

Mexican national solid waste legislation comes from several sources (Figure 12). The highest authority is the Mexican Constitution, followed by federal laws (*Leyes Generales*). Supporting and providing detail on federal laws are the regulations (*reglamentos*) derived from specific laws, which provide obligatory procedural guidance on the content of the law. Official Mexican Norms (*Normas Oficiales Mexicanas*, NOMs) and Mexican Norms (*Normas Mexicanas*, NMXs), also provide detailed procedures but may have relevance to multiple laws. The difference between the two is that NOMs are mandatory, while NMXs are suggested standards and are only obligatory if specifically stated in a *Ley General* or a NOM.

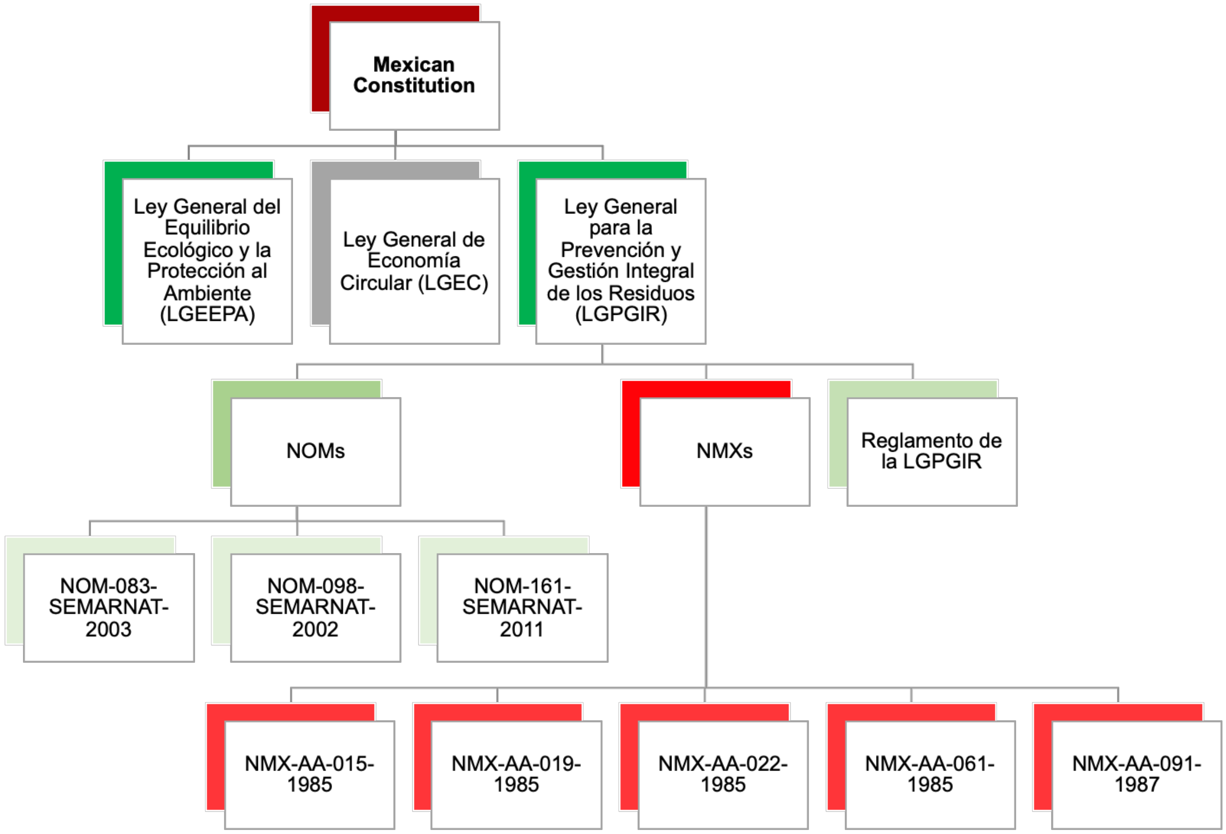


Figure 12. Structure of Mexican national solid waste legislation, by author.

4.1.2.1. *Ley General Para la Prevención y Gestión Integral de los Residuos*

Since 2003, the primary national solid waste legislation has been the General Law for the Prevention and Integrated Management of Wastes (LGPGIR). Its aim is to prevent and minimize the generation of solid waste, its release into the environment, its transfer from one medium to another, and to promote ISWM. It is based on the idea that the responsibility for the cost of waste management and reparation of harm caused by wastes lies with the party who generated the waste (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003). The LGPGIR establishes key definitions and responsibilities for ISWM.

First, as previously described, it establishes the classification of solid wastes and defines each category as follows (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003):

- **Hazardous wastes** (*Residuos Peligrosos,* RP) – Those that possess characteristics of corrosivity, reactivity, explosivity, toxicity, flammability, or that contain infectious agents, as well as containers or soils that have been contaminated by such wastes when they are transferred to a different location.

- **Wastes of special management** (*Residuos de Manejo Especial,* RME) – Those generated in productive processes that do not exhibit hazardous characteristics or characteristics of RSU, or that are produced by large generators of RSU.
- **Municipal solid wastes** (*Residuos Sólidos Urbanos,* RSU) – the wastes generated in homes by domestic processes, or wastes generated in public spaces that have the same characteristics.

Second, it classifies waste generators by size based on the quantity of waste generated (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003):

- **Micro-generator** – industrial, commercial, or service establishment that generates a quantity of up to 400 kilograms of RP per year.
- **Small generator** – natural or legal person who generates a quantity greater than or equal to 400 kilograms and less than 10 tons in net weight of wastes per year.
- **Large generator** – natural or legal person who generates a quantity greater than or equal to 10 tons in net weight of wastes per year.

Third, based on these definitions, it assigns the responsibilities corresponding to the national, state, and municipal authorities. Broadly, the federal government is responsible for RP and mining wastes, and for promoting the development of SWM infrastructure. State responsibilities include developing State Plans for the Prevention and Integrated Management of Wastes (*Programa Estatal para la Prevención y Gestión Integral de los Residuos*, PEPGIR), managing RME and RP generated by micro-generators, collaborating with the federal government to develop SW infrastructure, and promoting municipal ISWM programs (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

Municipalities bear the responsibilities related to RSU. They are required to develop Municipal Plans for the Prevention and Integrated Management of Wastes (*Programa Municipal para la Prevención y Gestión Integral de los Residuos*, PMPGIR), offer waste management services to the public, including collection, transport, and disposal, and maintain an up-to-date register of large generators of RSU (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

Finally, it outlines what must be included in the PEPGIRs and PMPGIRs. All such programs must be based on a diagnostic study which captures the current states of waste generation and infrastructure. Specific instructions for conducting this study are also provided. In addition to the results of this study, the programs must also include state or local policies, objectives, goals, strategies, timelines, sources of financing, mechanisms for forming partnerships with other states or municipalities, and the technical assistance needed from SEMARNAT. The programs must be designed to prevent the generation and encourage the recuperation of value from solid wastes, as well as promoting ISWM in more environmentally, technologically, economically, and socially effective ways (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

In the LGPGIR, ISWM is defined as follows:

> *"The articulated and interrelated set of regulatory, operational, financial, planning, administrative, social, educational, monitoring, supervision, and evaluation actions for management of waste, from its generation to final disposal, in order to achieve environmental benefits, economic optimization of its management, and its social acceptability, responding to the needs and circumstances of each locality or region."*

ISWM in Spanish is *Gestión Integral de los Residuos Sólidos*. A similar but distinct term defined in the LGPGIR is *Manejo Integral*:

> *"All the activities of sources reduction, separation, reuse, recycling, co-processing, biological, chemical, physical, or thermal treatment, collection, storage, transport, and final disposal of wastes, conducted individually or in combination to obtain value from wastes, maintain sanitary, environmental, technological, economic, and social efficiency."*

Both *gestión* and *manejo* translate to "management" in English, but as can be seen from the two definitions, *gestión* can be interpreted as being more like coordination or governance, while *manejo* is closer to management or direct handling of wastes. The importance of this distinction is that the law promotes integrated *gestión*, meaning it is not only concerned with the direct handling of wastes, but with the supporting governance system that can shift the way waste management is approached (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003).

Despite its 20-year history, the LGPGIR is still not fully implemented. As of 2020, all 31 states and Mexico City had developed PEPGIRs, but nine states still did not have state solid wastes laws. In SEMARNAT's own words, based on the results of the diagnostic study described earlier in this chapter show that "the definition of ISWM is far from fulfilled. What exists in most municipalities is a management system that is restricted to the basic activities of collecting the waste generated, transporting it, and depositing it in final disposal sites" (SEMARNAT, 2020).

4.1.2.2. NOMs and NMXs

Several NOMs and NMXs provide specific requirements or guidance on aspects of SWM. Those most relevant to ISWM of MSW are the following:

Normas Oficiales Mexicanas

- *NOM-083-SEMARNAT-2003, Especificaciones de protección ambiental para la selección del sitio, diseño, construcción, operación, monitoreo, clausura y obras complementarias de un sitio de disposición final de residuos sólidos urbanos y de manejo especial*
  - Provides the specifications and requirements for final disposal sites of RSU and RME.
- *NOM-098-SEMARNAT-2002, Protección ambiental-Incineración de residuos, especificaciones de operación y límites de emisión de contaminantes.*
  - Provides specifications and requirements for the incineration of wastes.
- *NOM-161-SEMARNAT-2011, Que establece los criterios para clasificar a los Residuos de Manejo Especial y determinar cuáles están sujetos a Plan de Manejo; el listado de los mismos, el procedimiento para la inclusión o exclusión a dicho listado; así como los elementos y procedimientos para la formulación de los planes de manejo.*
  - Provides the classification criteria for RME, the method for determining which require management plans, and the requirements for the content of the plans.

Normas Mexicanas

- *NMX-AA-015-1985 Protección al Ambiente - Contaminación del Suelo - Residuos Sólidos Municipales - Muestreo - Método de cuarteo*
  - Describes the quartering method for sampling of MSW.
- *NMX-AA-019-1985 Protección al Ambiente - Contaminación del Suelo - Residuos Sólidos Municipales - Peso volumétrico "in situ"*
  - Describes the method for determining the density of MSW during sampling,
- *NMX-AA-022-1985 Protección al Ambiente -Contaminación del suelo -Residuos Sólidos Municipales -Selección y cuantificación de subproductos*
  - Describes the subcategories into which MSW should be divided during sampling for classification and quantification.
- *NMX-AA-061-1985 Protección al Ambiente - Contaminación del Suelo - Residuos Sólidos Municipales - Determinación de la generación*
  - Describes the procedure for sampling to quantify the generation of MSW.
- *NMX-AA-091-1987 Protección al Ambiente - Calidad del Suelo – Terminología*
  - Provides definitions for important terms used throughout the other NMXs.

4.1.2.3. *Ley General de Economía Circular* (LGEC)

A new national law is in process, that would take the principles of the LGPGIR a step further. The objective of the General Law of the Circular Economy (LGEC) would be to "promote efficiency in the use of products, services, materials, energy, water, secondary raw materials, subproducts though clean production, reuse, recycling, redesign, or any criteria of the circular economy, as well as energy recovery from waste to comply with Zero Waste policies." The main instruments through which the LGEC intends to accomplish this are a National Circular Economy Program, with corresponding state and municipal programs, Circular Economy Plans for organizations, and economic incentive programs for those engaged in activities that favor a circular economy (Proyecto de Decreto CS-LXV-I-LP-038 Por El Que Se Expide La Ley General de Economía Circular, 2021).

In a similar manner to how the LGPGIR promotes ISWM through PEPGIRs and PMPGIRs, the LGEC would promote the circular economy by requiring certain types of organization to develop Circular Economy Plans (*Planes de Economía Circular*, PECs). These PECs are based on the principle of shared responsibility between manufacturers, distributors, and users and would outline the actions to be taken to comply with circular economy principles (Proyecto de Decreto CS-LXV-I-LP-038 Por El Que Se Expide La Ley General de Economía Circular, 2021).

Other noteworthy provisions of the law include article 18, which states that only wastes that cannot be reincorporated into productive use may be used in waste to energy facilities, and article 19, which requires all final disposal sites to capture and obtain energy from the biogas they generate. The LGEC would also require the development of economic incentives for activities that promote the transition to a circular economy and establishes a Circular Economy certification program in which organizations can choose to participate. Finally, very importantly, it would require municipalities to include the informal sector, including *pepenadores*, ambulatory vendors, and other informal economic actors, in their Municipal Circular Economy Programs (PMECs) and to formalize the work of any *pepenadores* working in final disposal sites to improve their working conditions and the efficiency of materials recovery (Proyecto de Decreto CS-LXV-I-LP-038 Por El Que Se Expide La Ley General de Economía Circular, 2021).

The requirements of the LGPGIR already made monitoring solid waste generation prudent for organizations (Armijo de Vega et al., 2008), but with upcoming passage of the LGEC there will be even more potential benefits to having complete and accurate SWM data, and more potential consequences for neglecting to do so.

4.2. STATE LEVEL: THE SAN LUIS POTOSÍ SOLID WASTE CONTEXT

4.2.1. Background and Challenges

San Luis Potosí is a predominately arid and semi-arid state in the central region of Mexico (Figure 13). The state is divided into four regions—*Altiplano, Centro, Media,* and *Huasteca*—and further into 58 municipalities. As of the 2020 census, the population was 2,822,255 with an average population density of approximately 50 inhabitants per square kilometer. Thirty-five percent of the population lives in moderate poverty and 9.5% in extreme poverty (Gobierno de México, 2020). The population is mostly concentrated in urban areas, with 67.2% living in cities, and this percentage has been increasing steadily (*Plan Estatal de Desarrollo: Programa especial de población 2022-2027*, 2022).

Figure 13. Map of the four regions of the state of San Luis Potosí and its location within Mexico (MIRPROCS, 2012).

The state-wide generation of RSU is 963,600 tons per year, or 2,640 tons daily (SEMARNAT, 2020). As of 2012, when a state-wide waste composition study was published, the majority of RSU was made up of organic material (57.81%), followed by paper and cardboard (15.58%), and plastic (14.63%) (MIRPROCS, 2012). According to SEMARNAT, the overall RSU collection rate for San Luis Potosí is 70.83% (SEMARNAT, 2020). RSU is collected in one single stream without separation at the source. In most cases, mixed RSU is placed in plastic bags, which are left in front of homes and businesses to await collection (MIRPROCS, 2012). There is only one transfer station in the state of San Luis Potosí, which is in the capital city and is discussed further in section 4.3.1.

The most prevalent final disposal practices in the state are open dumping, open burning, uncontrolled dumpsites, and landfills (controlled or sanitary). The prevalence of each practice varies significantly by region, with the Centro region having the highest landfill rate (70%), and the lowest open dumping and burning rates (both 3%), while the Huasteca region has the highest uncontrolled dumpsite usage (60%) and the highest open dumping and burning rates (both 8%) (MIRPROCS, 2012). This can me mainly attributed the higher degree of urbanization in the Centro region as compared to the Huasteca. Of the 58 municipalities, 6 do not have any type of final disposal site. Of the 57 final disposal sites in the state, 33 are considered type D, receiving fewer than 10 tons of wastes per day, 21 do not have any of the required infrastructure, and 18 do not perform any of the required processes to protect environmental and human health (SEMARNAT, 2020).

4.2.2. Legislation

San Luis Potosí is one of nine states that do not have specific solid waste legislation (SEMARNAT, 2020). Instead, solid waste is addressed as part of the state's general environmental law, (*Ley Ambiental del Estado*, LAE) and its corresponding regulation (*Reglamento de la Ley Ambiental del Estado de San Luis Potosí en materia de Residuos Industriales No Peligrosos*). The LAE first went into effect in 1999 and has since been updated several times, most recently in March, 2021 (Ley Ambiental del Estado de San Luis Potosí, 1999). The regulation, however, has not been updated since 2005 and still contains outdated terminology for RSU and RME (Reglamento de La Ley Ambiental Del Estado de San Luis Potosí En Materia de Residuos Industriales No Peligrosos, 2005).

The state environmental authority is the Secretariat of Ecology and Environmental Management (*Secretaría de Ecología y Gestión Ambiental*, SEGAM). In accordance with the LGPGIR, the state, with leadership from SEGAM, is required to develop a PEPGIR. The program for the state of San Luis Potosí was developed in 2012 by a contracted consulting company, MIRPROCS, and is targeted toward RSU and RME (MIRPROCS, 2012).

The LAE establishes additional responsibilities of the state government in accordance with the LGPGIR (Article 7), including regulating collection, transport, storage, management, treatment, and final disposal of RSU and RME and the selection, determination, and authorization of final disposal sites. The state must also advise municipalities on the development of their PMPGIRs if requested and certify the viability of the design, construction, operation and closure of final disposal sites, selection and treatment plants, and transfer stations (Ley Ambiental del Estado de San Luis Potosí, 1999).

Article 8 of the LAE establishes the municipal responsibilities, which include authorizing and regulating the management and final disposal of RSU and RME. In 2010, the requirement to develop PMPGIR was added, seven years after the LGPGIR went into effect. Municipalities are also responsible for offering or granting concessions, authorizations, licenses and permits for the provision of public services of cleaning, collection, transport, treatment and final disposal of RSU and RME, as well as the construction, operation and maintenance of landfills or other final disposal and treatment sites (Ley Ambiental del Estado de San Luis Potosí, 1999).

The state and municipal governments must collaborate to promote the manufacturing and use of packaging for all types of products whose material facilitates waste reduction, as well as the separation, classification, and recycling of solid wastes. Commercial establishments who provide disposable bags are also required to ensure these are made of at least 80% biodegradable or 100% post-consumer recycled material (Article 104) (Ley Ambiental del Estado de San Luis Potosí, 1999).

The LAE also bans certain practices relevant to SWM. Article 74 establishes that the burning of any type of solid waste should be “avoided,” and article 82 calls for the “prevention and control” of the burning of solid and liquid wastes. Article 104 states that the state and municipalities should seek to eliminate the use of plastic bags, and article 107 explicitly prohibits open dumping and incineration of RSU and RME. As of 2020, article 107 also prohibits the use of plastic straws in commercial establishments. Other recent additions to the LAE include Article 109.V, which calls for public communication to promote solid waste separation and a culture of caring for the environment (2021), and article 113.IX, which calls for the installation of recycling collection centers that offer food and household staples in exchange for recyclables (2018) (Ley Ambiental del Estado de San Luis Potosí, 1999).

A revision of the updates made to the LAE suggests that the passing of the LGPGIR prompted significant reform with respect to solid waste but with significant delay. In the original version, the approach to SWM was oriented toward disposal and the prevention of environmental contamination due to inadequate SWM. Recent modifications show a slight shift in approach toward waste prevention and resource reclamation from waste. The responsibility for implementing these new approaches is either shared with or completely assigned to the municipalities (Ley Ambiental del Estado de San Luis Potosí, 1999).

4.3. MUNICIPAL LEVEL: WASTE MANAGEMENT IN THE CAPITAL CITY

4.3.1. Background and Challenges

San Luis Potosí (SLP) is the capital city of the state of the same name. It is located in the arid *Centro* region of the state, and the municipality of San Luis Potosí is the state's most populous. It is an important city, centrally located, in a region with significant agricultural, mining, and manufacturing activity. The industrial zone on the southeast side of the city has attracted various new businesses, even transnationals, to the city because of its strategic location and growth potential (DEAP, 2021).

In recent decades SLP has experienced rapid population growth, increasing by 18% between 2010 and 2020 to a population of 911,908 (Gobierno de México, 2020b). During the same period, the city experienced significant economic growth, and the capital has higher levels of economic prosperity in general than the rest of the state, with only 18.7% living in moderate poverty and 1.6% in extreme poverty, as compared to state levels of 35% and 9.5%, respectively (Gobierno de México, 2020b).

The rapid increase in population and prosperity in the capital city has put a serious strain on municipal SWM (DEAP, 2021). As of the 2012 state-wide waste characterization study, the per capita RSU generation rate in municipality of San Luis Potosí of 0.422 kg was nearly twice that of the other municipalities in its region (MIRPROCS, 2012). By 2021, this rate had more than doubled, with the municipality reporting a per capita generation of 0.968 kg (DEAP, 2021).

In May 2021, a diagnostic report titled "Diagnostic of the Integrated Management Municipal Solid Waste" (*Diagnostico del Manejo Integral los Residuos Sólidos Urbanos*) was sent by the Director of the Directorate of Ecology and Public Cleaning (*Dirección de Ecología y Aseo Público*, DEAP) to the municipal comptroller with a letter affirming the DEAP's ability and willingness to attend to any recommendations stemming from the revision of the report (DEAP, 2021). The 42-page report consists mostly of background information about the challenges associated with SWM, the applicable legislation, and the demographics of the municipality. This is because, as the report itself states,

> *"To understand how to confront the challenges of waste production in the capital of San Luis Potosí it is necessary to expose the conditions of its generation and management. No detailed studies exist that reveal information about the generation and composition of the municipal solid waste."*

According to the LGPGIR and the LAE, municipalities are required to create PMPGIRs based on basic diagnostic studies. The requirements are outlined in the law and include basic generation and characterization data. Perhaps creating this clearly non-compliant diagnostic report and sending it to the municipal comptroller, the DEAP Director was attempting to underscore the urgency of the SWM crisis in hopes of funneling more funds to address it. The report alludes numerous times to the insufficient funding caused by increasing demand for services, and the public expectation not to pay for said services. Whatever the purpose of the report, the municipality clearly still lacks the basic information necessary to develop the legally required PMPGIR, and each year that passes without a systematic approach to curbing this emergency, the capital becomes more and more overwhelmed by its own waste.

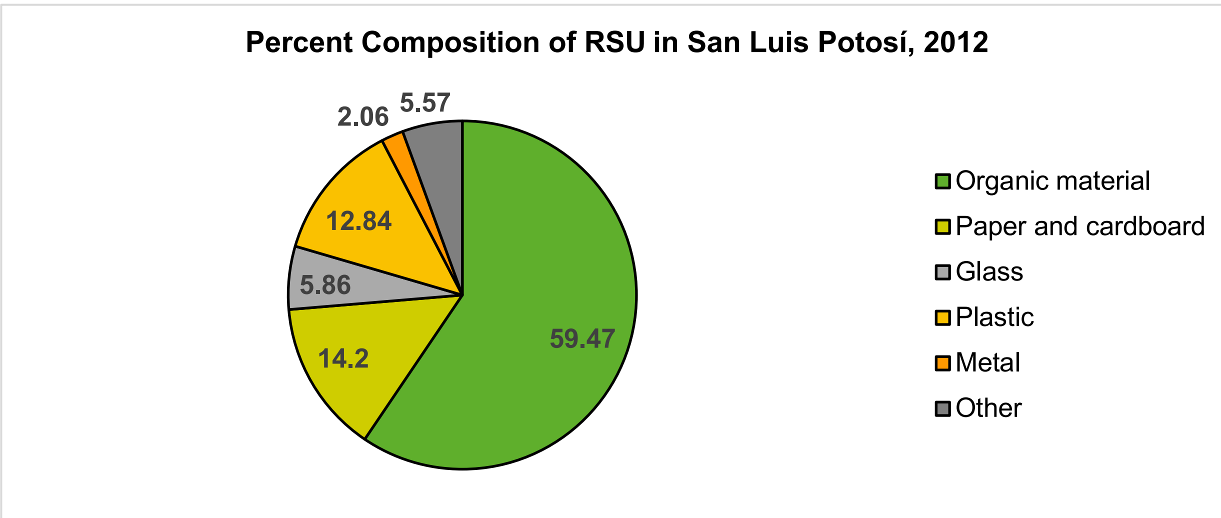


Figure 14. Percent composition of RSU in San Luis Potosí as of 2012 (MIRPROCS, 2012).

As noted above, the generation of waste has increased significantly since the 2012 state diagnostic study, but because no municipal studies exist, it is the best information available. As of 2012, the composition of RSU in the municipality was majority organic material followed by paper and cardboard, plastic, glass, and finally metals and other waste (Figure 14). Based on the general tendencies described in chapter 2, as urbanization and economic prosperity increase, the composition of wastes shifts away from organic material and toward inorganic recyclables, especially plastics. Thus, while it is likely that the waste stream of SLP has followed this same trajectory, the fact remains that most of the RSU could be diverted from landfills and dumpsites to recycling, composting, or other resource recovery methods.

Currently, no formal resource recovery services are offered by the municipality. In fact, most of the services related to SWM are not offered by the municipality itself. When it became clear that the municipality was unable to keep up with the demand for services, the decision was made to use competitive public tendering to contract collection, transfer, and final disposal services through a private company, Red Ambiental (DEAP, 2021;

Ramirez Guevara, 2010). The key RSU disposal sites for the municipality are shown in Figure 15. Of these, Red Ambiental operates the Peñasco Transfer Station (Peñasco) and the San Juanico Sanitary Landfill (SJ). It also provides the RSU collection service in most areas of the city. The process consists of door-to-door collection of mixed RSU, transfer to Peñasco, loading onto larger trailer trucks, and transfer to SJ for final disposal.

The Peñasco site has a complex past, present, and future. It was once the municipal dumpsite, a controlled dumpsite that would not have met today's legal standards (NOM-083) (Bernache Pérez, 2011). During that time, an active community of *pepenadores* developed at the site, manually removing recyclable materials, and selling them by weight to nearby material buyers. They built a livelihood around the site and settled in the surrounding area. Eventually, Peñasco exceeded its capacity, and the construction of a new landfill was necessary, this time under the new LGPGIR and NOM-083, which bans *pepena* inside sanitary landfills. Fearing they would no longer have access to the waste stream on which they based their livelihood, the *pepenadores* decided to organize (Guzmán Chávez & Macías Manzanares, 2012; Ramirez Guevara, 2010). They formed the Single Organization of Waste Pickers (*Organización Única de Pepenadores*, OUP) and demanded continued access to the city's waste (MIRPROCS, 2012). The current Peñasco transfer station is the compromise that resulted from the OUP's demands. On any given day, over 50 *pepenadores* can be observed working in Peñasco's *plancha de pepena* (waste picking field) (MIRPROCS, 2012). With over 500 members, the OUP has become so influential that the municipality is obliged to consult it before making any decision that would influence Peñasco (DEAP, 2021).

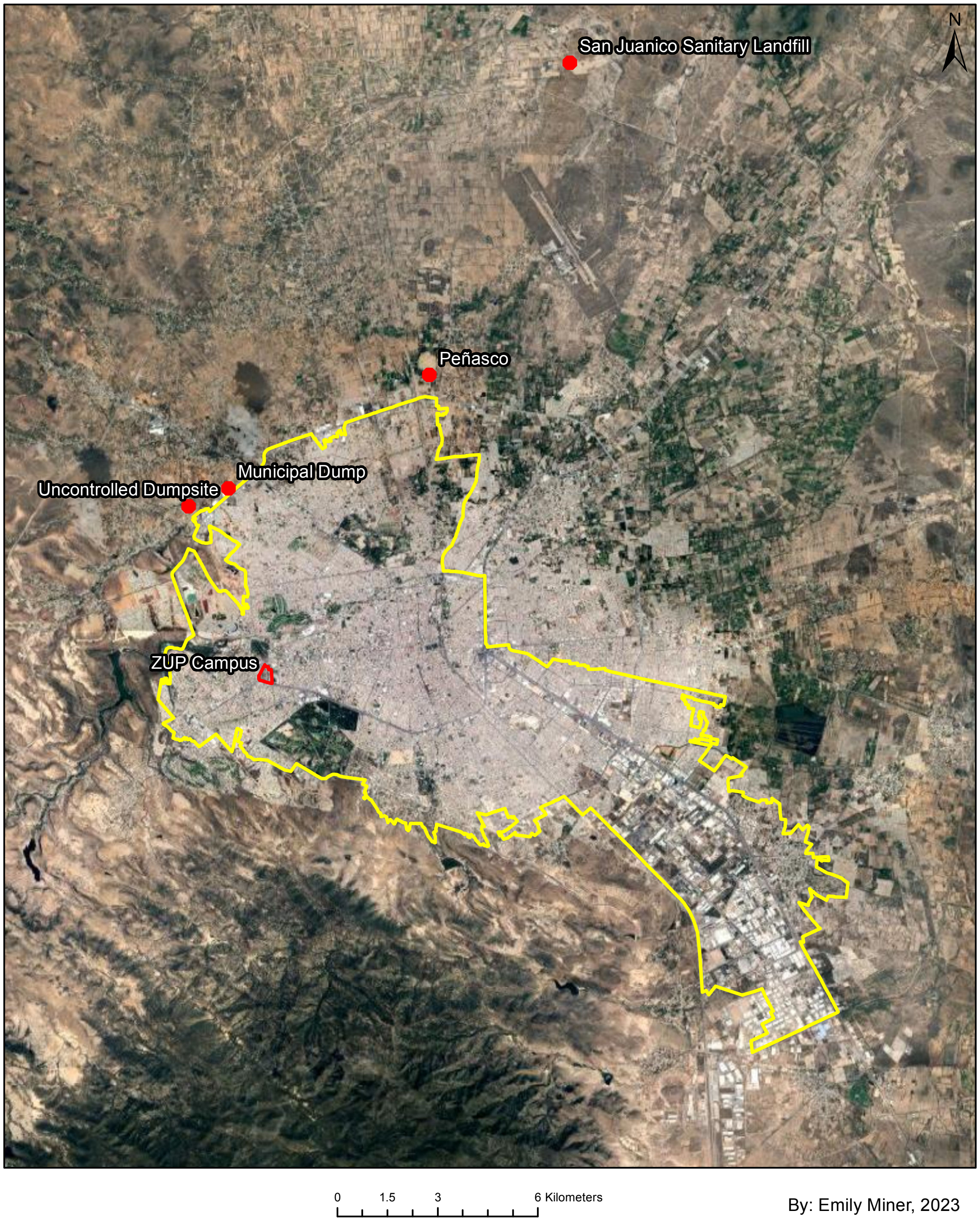


Figure 15. Final Disposal sites available near the SLP urban zone, by author.

On one hand, the *pepenadores* are informally providing an important resource recovery service that the municipality is simply unable to provide. On the other hand, although conditions at Peñasco have improved somewhat, it continues to present significant environmental, safety, and human health problems such as dispersal and open burning of wastes, conflicts over access to the best waste picking areas, and proliferation of disease vectors (Bernache Pérez, 2011; Guzmán Chávez & Macías Manzanares, 2012; Ramirez Guevara, 2010). At times *pepenadores* have become so insistent on access to valuable waste materials that they have stopped trucks on the road to SJ and insisted they enter Peñasco instead, threatening the safety of the drivers (Humberto & Agustín, personal communication, March 29, 2023).

4.3.2. Legislation

There is still much work to be done to bring the municipality into compliance with the national and state solid waste management legislation. Regulations related to SWM exist in SLP, but they need updating, and as at the state level, there is no dedicated SWM law (DEAP, 2021). The local legislation with bearing on solid waste management includes the Ecology Regulation (*Reglamento de Ecología para el Municipio de San Luis Potosí*, RE), the Regulation on Public Cleaning (*Reglamento de aseo público para el municipio de San Luis Potosí*, RAP), and the Edict on Policing and Good Governance (*Bando de Policía y Buen Gobierno del Municipio de San Luis Potosí*, BPBG).

4.3.2.1. *Reglamento de Ecología para el Municipio de San Luis Potosí*

The RE is the broadest municipal law pertaining to environmental protection, including not only provisions relevant to RSU and RME, but also to water, air, land use, and other environmental concerns. Its RSU provisions include the following:

- Article 5. The municipal government is responsible for
  - Article 5. V. Formulating a PMPGIR in correspondence with the PEPGIR.
  - Article 5. XII. The integrated management of RSU including collection, transport, treatment, and final disposal, as well as authorizing systems for such services.
  - Article 5. XIII. Establishing and maintaining a registry of large generators of RSU.
- Article 27. The DEAP will establish an environmental management plan, which will include at a minimum.
  - Article 27. I. A diagnostic of the state of the environment, including RSU.
- Article 66. The burning of any type of solid or liquid waste for any purpose without explicit approval is prohibited.

Chapter IV. On the management of municipal solid waste

- Article 76. With respect to management of RSU, the municipality is responsible for the following:
    - Article 76. I. Developing a PMPGIR as an integral part of the municipal environmental management plan.
    - Article 76. III. Operating the integrated management of RSU.
    - Article 76. IV. Collaborating with neighboring municipalities to receive or send RSU.
    - Article 76. V. Controlling authorized final disposal sites.
    - Article 76. VI. Promoting public education about the recovery of resources from RSU to promote reduction, recycling, and reuse.
    - Article 76. X. Establishing and maintaining a registry of large generators of RSU.
- Article 78. Depositing solid wastes on public or private lands, public spaces, drainage systems or bodies of water is prohibited.
- Article 81. Those who generate or otherwise manage RSU are obligated to promote its reduction, reuse, or recycling.
- Article 84. Those who are authorized to collect, manage, or transport RSU must report the following information semi-annually:
    - Article 84. I. Name and address of the waste generator.
    - Article 84. II. Activity performed by the waste generator.
    - Article 84. III. Quantity and type of wastes collected.
    - Article 84. IV. Type of recyclables separated and what is done with them.
    - Article 84. V. Frequency of collection.
    - Article 84. VI. Site in which the RSU are disposed.

4.3.2.2. *Reglamento de aseo público para el municipio de SLP*

The RAP is specifically dedicated to the municipality's duty to provide public cleaning and SWM. The municipal office in charge of these matters is the DEAP. The RAP outlines its responsibilities as well as those of the residents of SLP. The following is a selection of the most important articles and those most relevant to the university RSU management context (Gallardo Juárez & Aranda Martínez, 2017).

- Article 4. RSU may be deposited in the municipal sanitary landfill with prior authorization and the corresponding permit issued by the DEAP and paying the corresponding fee.

- Article 7. II. The DEAP will institute a system of public recognition for schools and other establishments that contribute to educating the residents of SLP about the importance of participating in keeping the city clean.
- Article 16. The public cleaning service for the municipality includes:
    - Article 16. I. Sweeping of designated public areas.
    - Article 16. II. Collecting RSU from public spaces and residences.
    - Article 16. III. Collecting RSU from commercial establishments in exchange for payment.
    - Article 16. IV. Transporting RSU to authorized disposal sites.
    - Article 16. VI. Designing instruments and systems for storing, transporting, recycling, treating, and disposing of RSU.
    - Article 16. VII. Granting permits to those who wish to make use of final disposal sites.
- Article 20. The collection and transportation of RSU from residences, buildings, markets, parks, and municipal public roads will be done a minimum of twice a week.
- Article 21. The collection of residential RSU will be carried out by the municipality, and users of this service are required to separate RSU into organic and inorganic.
- Article 30. The RSU collected by the cleaning personnel of the DEAP and by contracted individuals is the property of the municipality. The Municipality may take advantage of them commercially or industrially, directly, or indirectly.
- Article 32. In order not to prevent the procreation of microorganisms that are harmful to health and to avoid the emission of unpleasant odors, all productive and commercial establishments specified in this regulation are required to have closed containers for temporary storage of their waste.
- Article 33. Schools and educational centers in general, organizations, unions and various associations, may operate collection centers for non-hazardous recyclable materials, and allocate the collected material for the benefit of the community. The collection centers must have the authorization of the municipality.
- Article 34. The institutions indicated in the previous article, will promote environmental education and a culture of environmental concern among their students, users, partners, or affiliates, making them aware of the problems associated with improper SWM. The institutions will collaborate in municipal campaigns to promote cleanliness in general.

- Article 35. RSU may only be transported to authorized final disposal sites. Throwing RSU in any unauthorized place is cause for sanction.
- Article 38. The services of cleaning, collection, transport, and final disposal of non-domestic RSU generated in businesses, industries, and services, is the responsibility of the owners or managers of said establishments through contracted service or by their own means. The establishments must obtain a permit from the DEAP for the final disposal of the RSU and make the corresponding payment to the municipal treasury.
- Article 41. RSU produced by shops, industrial establishments, workshops, restaurants, stables, private offices, shows, or any other similar activity, whose weight exceeds 25 kg, must be transported by the owners or managers to an approved final disposal site unless a specific agreement is made with the municipality.
- Article 42. The owners or managers in such cases must bear the costs of the collection and transportation of RSU to the authorized sanitary landfill and must separate it into organic and inorganic.
- Article 52. Within sanitary landfills, the following is not allowed:
    - Article 52. I. For authorized waste workers to remain on the premises outside the hours established by the DEAP.
    - Article 52. II. The installation of any type of housing.
    - Article 52. III. The entry or permanence of minors under 16 years of age.
- ARTICLE 67. Waste picking of RSU is allowed only at the transfer station and subject to the guidelines established by the managers of the station.
- ARTICLE 73. The following are obligations of the inhabitants of the Municipality of San Luis Potosí:
    - ARTICLE 73. XIV. Separate residential RSU into two classes: organic and inorganic, in bags or containers that show their content, properly closed to prevent spillage and dispersion.
- ARTICLE 81. Individuals or legal entities with productive industrial, commercial, and service activities such as clinics, hospitals, workshops, and any type of service to the public, must separate their RSU, classifying it into organic and inorganic for it to be collected by the municipal collection service.

The RAP establishes inspections and sanctions as the corresponding enforcement mechanisms. Inspections can be initiated by the DEAP or by citizen complaints. Sanctions and security measures can be implemented based on the results of the inspection. Article 99 identifies the following possible security measures—full or partial closure, seizure of material goods, execution of actions or works at the expense of the party in violation, any other measure necessary to protect public health and safety. Article 110 lists the possible sanctions—reprimand with warning, fines, administrative arrest of up to 36 hours (exchangeable for a fine), suspension of authorization or license, and temporary or definitive closure of the establishment (Gallardo Juárez & Aranda Martínez, 2017).

4.3.2.3. *Bando de Policía y Buen Gobierno*

Finally, the BP briefly address RSU management in its article 14. I., which states that not sweeping and collecting garbage from one's property or the corresponding section of street, as well as throwing RSU on public roads or on any other property is an offense against public health (Bando de Policía y Buen Gobierno del Municipio de San Luis Potosí, S.L.P., 1999).

4.4. UASLP BACKGROUND AND CONTEXT

The UASLP was officially established on January 10th, 1923. Over its one-hundred-year history the UASLP has pursued research, academic freedom, and the dissemination of knowledge and culture. Both its academic offerings and geographical reach have grown substantially, and it currently has campuses in eight different municipalities across the state of San Luis Potosí (Figure 16), offering education from the high school to the doctoral level (UASLP, 2023).

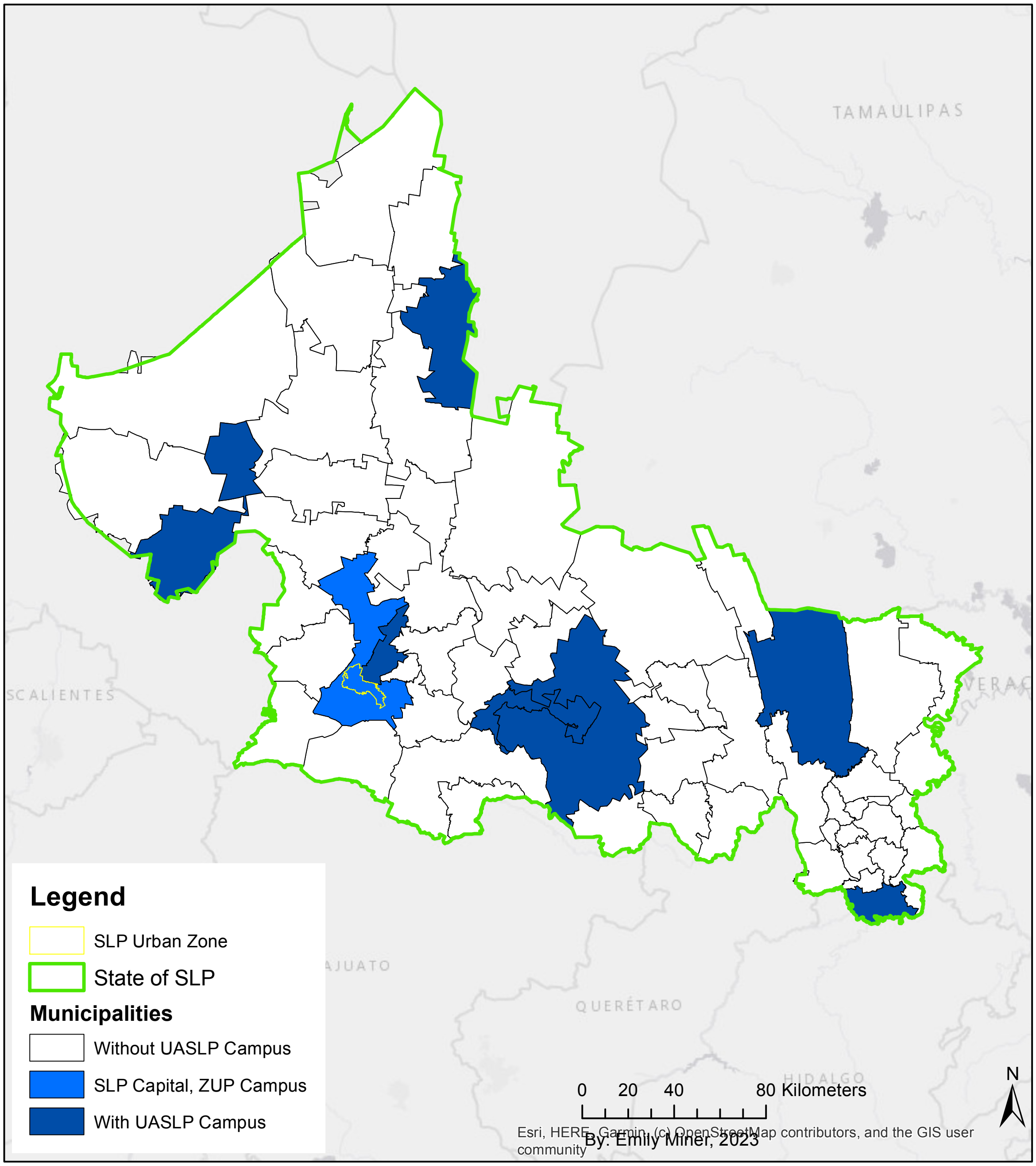


Figure 16. Geographical distribution of UASLP campuses in the state of San Luis Potosí, by author.

The ZUP campus is one of several campuses in the municipality of San Luis Potosí. The main faculties with activities on the campus are Habitat, Engineering, Geology, Physics, Languages, Oral Medicine, Nursing, and Chemistry, but it also houses several cafeterias, various administrative offices, the university health center, and a campus garden. The student population is approximately 12,000, with around 1,000 faculty and staff (estimation based on data reported in *Segundo Informe Indicadores,* 2022).

4.4.1. University Bylaws (*Estatuto Orgánico de la UASLP*)

The University Bylaws (*Estatuto Orgánico de la UASLP*) establish the internal regulations of the UASLP, including the organizational structure and the rights, roles, and responsibilities of university community members. Article 13. VI guarantees the right of all members of the university community to "facilities with a safe, healthy, and sustainable environment." The bylaws also indicate the creation of an institutional development plan, whose realization and monitoring is the responsibility of the university administrative secretary (Estatuto Orgánico de la Universidad Autónoma de San Luis Potosí, 2020).

4.4.2. *Plan Institucional de Desarrollo Estratégico* (PIDE)

The UASLP Institutional Development Plan for 2013-2023 (PIDE for its acronym in Spanish) describes 15 pillars of the 2023 vision for the university. Pillar number 14, "Environmental Perspective," involves the active participation of the entire university community, to promote a culture of environmental protection, connection to nature, and sustainable use of natural resources, incorporating environmentally responsible practices and mindsets into all university activities, from teaching and research to management and community outreach.

The PIDE lays out twelve institutional programs to implement the 2023 vision, the twelfth of which is Environmental Management. The aim of the EMS is to significantly reduce the environmental impact of university activities, including promoting the separation of solid waste. It calls for a system of indicators to monitor environmental performance and seeking ISO 14001 certification. It imagines the UASLP acting as a national and international example of successful environmental public policies (UASLP, Secretaría de Planeación, 2014).

The plan, written in 2013, also provides a general diagnostic assessment of the strengths and weaknesses in each of the 15 areas. With respect to the environmental perspective, it notes "the adoption of the environmental programs by the university community is not optimal" (UASLP, Secretaría de Planeación, 2014).

4.4.3. Agenda Ambiental

The entity responsible for promoting said environmental programs and the incorporation of a sustainability perspective into the university activities is the *Agenda Ambiental* (AA). Created in 1998, it is a transversal coordinating body which works in close collaboration with the other university entities on its programs in the areas of environmental education, extension and communication with the broader community, as well as through its postgraduate program in environmental sciences and the environmental management system, which is described in more detail in the following section (UASLP, Secretaría de Planeación, 2014).

One challenge of the AA is that its niche within the UASLP has not been formalized. The term *agenda* is not defined in the university bylaws. Like an institute, it promotes research, postgraduate programs, and education, but unlike an institute it cannot directly academically coordinate its own postgraduate programs. In institutes, the director is appointed by the rectory for a period of four years, and the rectory decides whether to renew the appointment for a maximum of 8 years total (Article 88) (Estatuto Orgánico de la Universidad Autónoma de San Luis Potosí, 2020). The director of the AA is also appointed by the rectory, but there is no established period of service. Like a secretariate, it has broad administrative responsibilities, but unlike a secretariate it does not have the authority to establish enforceable norms. The AA is more like a consultancy, providing information, support, training, education, and recommendations, but dependent upon the decisions of each university entity and the authority of the administrative secretary and the rectory for its recommendations to be implemented.

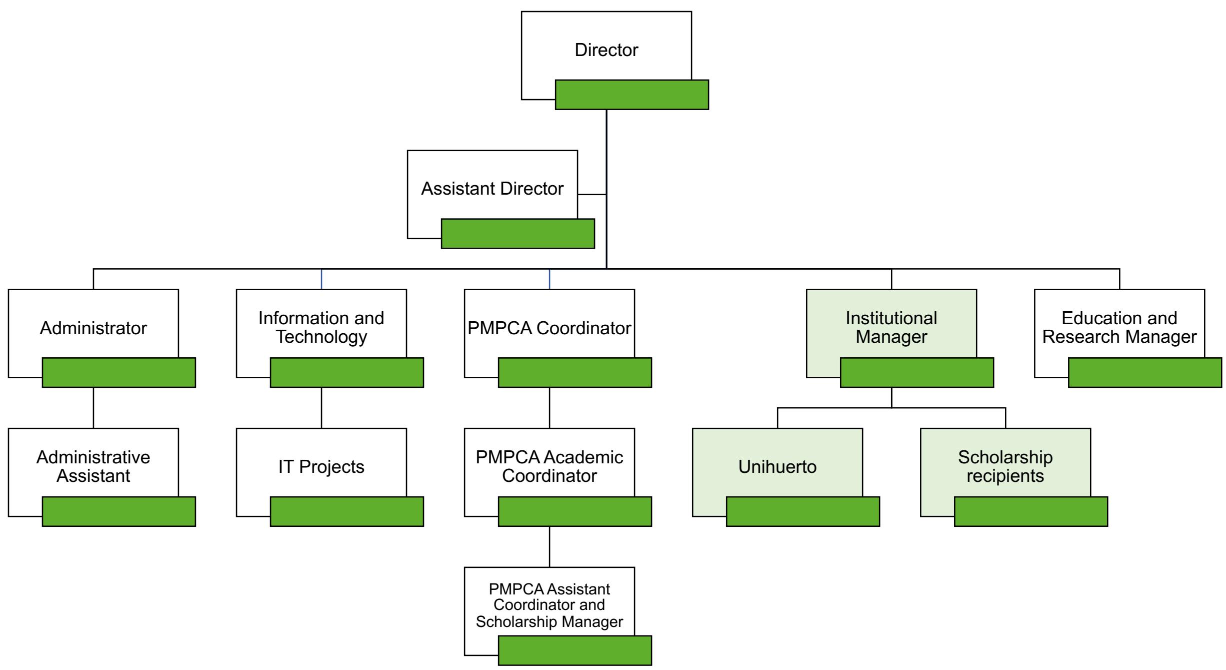


Figure 17. Agenda Ambiental organization chart, by author with information from (UASLP, n.d.)

Currently the AA staff consists of the director, assistant director, ten other staff members, and a small rotating group of scholarship recipients who support its activities as part of required social service (Figure 17). The institutional manager oversees the environmental management system, with support from scholarship recipients and collaboration of the UniHuerto (campus garden) director.

4.4.4. Environmental Management System (*Sistéma de Gestión Ambiental*)

The Environmental Management System (SGA for its acronym in Spanish) is one of the four strategic programs of the AA. The approach of the SGA is to use the ZUP campus, where the AA office is located, as a sort of living laboratory for sustainable practices and then systematically diffuse those practices throughout the rest of the university. It is a broad system, including twelve performance modules. Seven are specific focused modules, and five are cross-cutting modules that relate to all the others (UASLP, Secretaría de Planeación, 2014). The SGA module which encompasses the PROSEREM is module two, "Wastes, discharges, and emissions." This module monitors environmental discharges to air, water, and soil to prevent negative environmental and health impacts, and to ensure compliance with emissions limits (Agenda Ambiental, n.d.).

Table 7. Performance modules of the UASLP SGA as related to GreenMetric categories, by author.

GreenMetric Categories	Related SGA Performance Modules	SGA Performance Modules
Setting and Infrastructure	3, 4, 6, 7, 9, 10	Management of hazardous materials and substances
		Wastes, discharges, and emissions
Energy and Climate Change	4, 6, 7, 9, 10	Appropriate and efficient use of water
		Appropriate and efficient use of energy
Waste	1, 2, 10	Appropriate and efficient use of office supplies
		Vegetation and landscape architecture
Water	2, 3, 6, 7, 10	Bioclimate and sustainable construction
		Administration and purchasing
Transportation	4, 9, 10	Risks and contingencies
		Maintenance
Education and Research	12	Norms, standards, and certification
		Communication and environmental education

Within the SGA are various university programs, and each includes manuals, guidelines, plans, forms, and administrative procedures to promote actions in the university community that help meet the objectives of the twelve performance modules. Comparing these to the GreenMetric categories reveals that each GreenMetric category relates to one or more SGA performance module (Table 7), indicating that the SGA at least addresses all the necessary categories to perform well in the GreenMetric rankings. Though improvements are needed to meet the specific criteria in each category and to eventually seek ISO 14001 certification, this comparison illustrates a promising foundation for the SGA.

4.4.5. University Waste Program (*Programa Universitario de Residuos*)

Given the large variety and amount of waste the UASLP ZUP campus produces, it is considered a large generator and is required to develop an integrated solid waste management plan (Rosales Guzmán, 2018). According to the LGPGIR such plans should include waste minimization strategies in addition to responsible management, treatment, and disposal practices (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003). Minimization strategies could include policies to reduce paper use or acquisition rules that restrict the purchase of non-recyclable materials, for example (Espinosa et al., 2008).

The university waste program (PUR for its acronym in Spanish) seeks to meet this requirement by properly managing regulated substances, RP, RME, RSU, emissions, and discharges to the air, water, or soil. In doing so, it protects the safety and health of the university community, prevents environmental contamination, and ensures that the university complies with environment, health, and safety regulations (UASLP, n.d.). Based on the review of national, state, and municipal law in the preceding sections, the university’s responsibilities with respect to RSU could be summarized as follows:

1. Develop an integrated management plan for RSU including a diagnostic study.
2. Promote waste reduction, reuse, and recycling, and ensure final disposal in approved sites to prevent negative environmental impacts.
3. Acquire permit to collect and transport RSU to approved final disposal site or contract a permitted company to provide this service.
4. Store RSU in closed containers.
5. Separate RSU into organic and inorganic portions.
6. Promote awareness of environmental stewardship and problems associated with waste management in the student body and broader university community.

4.4.5.1. Objectives of the PUR

The general objective of the PUR is to create a participative institutional culture of appropriate integrated waste management (UASLP, n.d.). It is supported by the following specific objectives:

1. Show the university community the means and tools available to properly dispose of its regulated substances and materials according to regulations and with the university's expertise.
2. Influence the mitigation of the negative impacts that the incorrect disposal of waste can generate on health and the environment.

3. Reduce and monitor waste, discharges, and emissions generated according to the limits established by experts and by regulations.
4. Motivate the university community to initiate a new culture of purchase, consumption, treatment, and disposal of regulated substances and materials, promoting changes in society and thus contributing to the reduction of waste.
5. Participate in preventive training, minimization, recovery of resources, reduction, reuse, selective collection, recovery, and recycling of waste.
6. Reinforce practices in laboratories and workshops from the design of practices to management plans and treatment updates.

Several subprograms have been developed within the PUR focusing on each of the LGPGIR waste classifications, as well as certain wastes of special relevance to the university context such as fluorescent lightbulbs and confidential documents.

4.5. PROSEREM

The subprogram of the PUR focusing on RSU is the Material Separation and Recycling Program (*Programa de Separación y Reciclaje de Materiales,* PROSEREM). It was developed for the ZUP campus in 2018 by the AA and focuses explicitly on the separation and proper management of RSU. Its main components include the separation of wastes generated on campus and monthly collection events called Responsible Consumption Spaces (*Espacios de consumo responsable*). At the monthly events, university members or other community members can drop off compostables, recyclables, used electronics, and used books for proper recycling. Other waste types are managed by other subprograms of the PUR. At the time of writing, formal PROSEREM guidelines have only been published for the ZUP campus, but the eventual scope of the program encompasses all campuses of the UASLP.

4.5.1. Vision, Mission, and Objectives

The vision of the PROSEREM is to support the UASLP guiding pillar of “environmental perspective” by promoting the adoption of responsible consumption habits and closing the life cycles of various materials to prevent them from becoming wastes. The program mission is to “be an efficient, replicable university program and a model of urban solid waste management to reduce the social and environmental impact caused by these wastes, as well as to serve as an evaluative tool for the environmental performance of this educational institution” (Rosales Guzmán, 2018). The stated objectives of the PROSEREM are as follows:

General objective:

- Have an efficient program for the separation and recycling of materials which involves the commitment of the entire university community in its different entities and at all levels.

Specific objectives:

1. Establish guidelines for the disposal of each category of RSU in all the generating areas of the university.
2. Create a commitment with the society to guarantee the proper management of wastes generated by the university.
3. Promote a positive culture of separation and recycling which maximizes the capturing of value and minimizes the generation of wastes in the university community, which transcends from within to outside the university.
4. Contribute to the UASLP becoming certified by international organizations for the implementation of integrated solid waste management best practices.

Finally, the specific goals established include the following:

1. By 2023, reduce the wastes being disposed of in the improperly managed municipal dump from the university by 70%.
2. By 2023, increase the coverage of the PROSEREM to 90% of the UASLP campuses statewide.
3. Develop key practices and procedures to ensure the appropriate management of wastes.
4. Fully consolidate the program by closing the cycle at the source (Translated by author from Rosales Guzmán, 2018).

4.5.2. Roles and Responsibilities

For various reasons, the PROSEREM is based on the principle of shared but differentiated responsibilities. In part, this is because of the way financial resources are distributed and managed at the UASLP. Each academic entity has its own budget, hires its own janitorial staff, and pays for the maintenance of its own facilities. Another reason is that the AA is a coordinating body without administrative authority over other university programs or departments. Finally, the PROSEREM aims not only to manage RSU but to transform the university culture, which requires an inclusive participatory approach (Rosales Guzmán, 2018).

Table 8. Roles and responsibilities of the PROSEREM. Adapted by author from Rosales Guzmán (2018).

Role	Description	Responsibilities
Agenda Ambiental	Coordinating entity focused on promoting environmental sustainability in all university activities	Prepare PROSEREM guidelines. Schedule and conduct PROSEREM trainings. Provide posters for labeling micro-stations.
Mixed Hygiene and Safety Commission	Formal commission of the UASLP whose mission is to ensure compliance with the collective hygiene and safety agreement	Monitor the compliance with the PROSEREM. Submit monthly progress reports to the Agenda Ambiental.
Generating Entities	Academic departments with their own self-managed budgets who produce RSU.	Conduct diagnostic study of waste generation in the entity. Share the responsibility of maintaining and cleaning the assigned transfer station. Submit weekly maintenance log to the Agenda Ambiental.
Administrator of the Generating Entity	Director of the academic department who acts as the responsible party for complying with the PROSEREM	Attend PROSREM training. Promote the PROSEREM program. Manage the resources and actions needed for each phase of the program. Appoint a responsible technician for the generating entity. Collaborate with the other administrators to ensure the cleaning of the transfer station to which they are assigned.
Responsible Technician of the Generating Entity	Other employee of the department designated by the administrator	Coordinate the cleaning and maintenance of the micro-stations.
Collection Staff	Full-time UASLP staff members from the maintenance department who drive the UASLP pickup trucks	Attend PROSEREM training. Follow the designated collection route for the transfer stations. Wear personal protective equipment

Janitors	UASLP and contracted employees assigned by academic department to clean the buildings including removing the waste.	Attend PROSEREM training. Keep the micro-stations clean. Close the plastic bags properly. Bring the closed bags to the transfer stations.
Maintenance Department	UASLP department in charge of maintaining campus grounds and facilities.	Ensure the collection route of the transfer stations is completed daily.

The SGA has only one full-time staff member (see Figure 17). With respect to the PROSEREM, this means there is no dedicated staff, but rather the roles and responsibilities (Table 8) are assumed by staff members who also play other roles in various other capacities and who do not officially report to the AA.

4.5.3. Phases of Implementation

Because of the extensive coordination, purchasing, installation, and training required to roll out the program, its implementation was planned in phases (Figure 18).

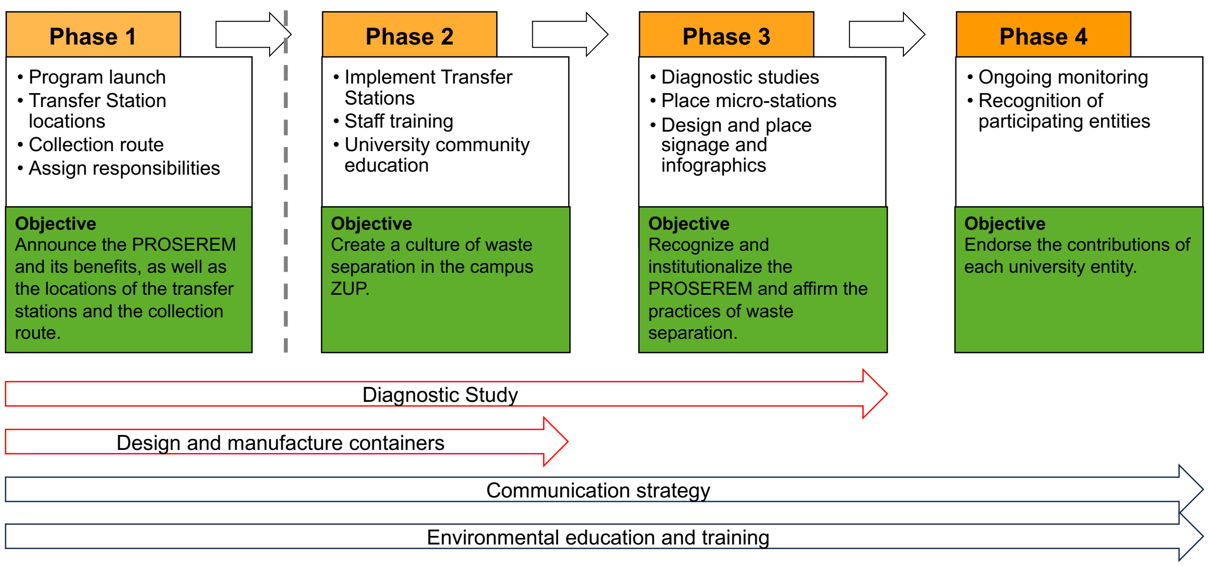


Figure 18. Planned implementation phases of the PROSEREM, adapted by author from Rosales Guzmán (2018). The gray dotted line represents the status of implementation at the time of writing.

4.5.3.1. Phase 1

The launch of the program was conducted via an email to the directors and administrators of each generating entity. The email served to introduce the program concept, explain the responsibilities, and describe the next steps. Also, during this phase, the locations of the transfer stations (collection points) (Figure 19) were agreed upon and the collection route was established (Rosales Guzmán, 2018).

4.5.3.2. Phase 2

In the planned second phase, the containers at the transfer stations are installed. Also, training is provided by the AA to offer information and begin to generate a culture of separation of wastes as well as promote health and safety in the collection process. Staff members involved in the collection of wastes receive specialized safety and health training, while the general university public receives education promoting the habit of waste separation (Rosales Guzmán, 2018).

4.5.3.3. Phase 3

The phase three plan involves the placement of the micro-stations within each waste generating entity of the ZUP campus. Before placing these stations, it is the responsibility of the entity administrator to conduct a basic diagnostic study to assure the appropriate size and location of the containers. The administrator must also assign staff to maintain the micro-stations, making sure that the containers are lined with clear plastic bags, keeping them clean and orderly, and reporting instances of incorrect waste separation (Rosales Guzmán, 2018).

4.5.3.4. Phase 4

In phase four, the ongoing sustainability of the program is reviewed within each entity. To encourage entities to reach this phase, the *Agenda Ambiental* publicly congratulates those that complete the first three phases (Rosales Guzmán, 2018).

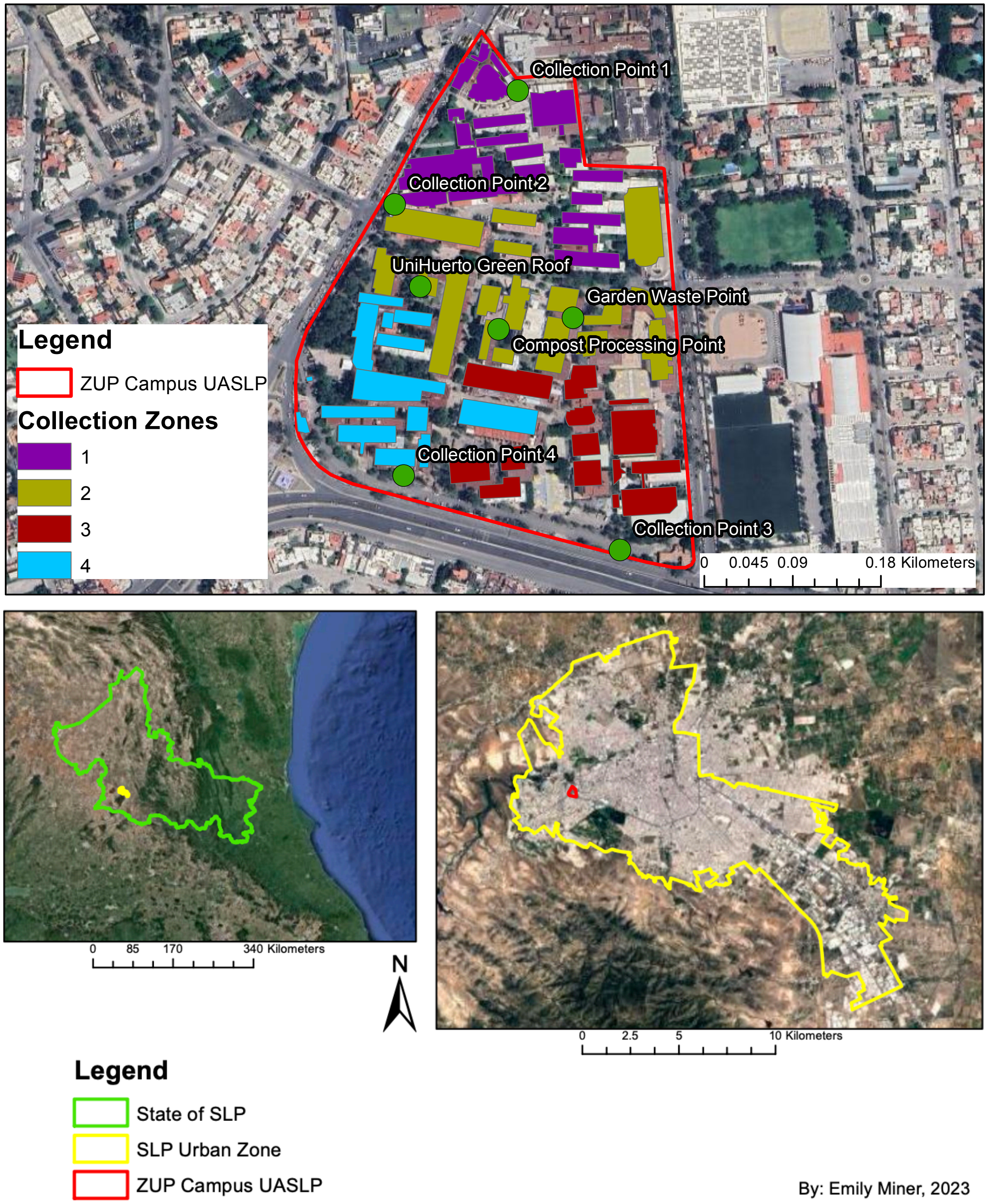


Figure 19. Map of ZUP Campus showing PROSEREM collection zones, collection points, compost processing point, and campus garden locations, by author.

4.6. PROBLEM AND NEED

The UASLP is a large and highly visible public institution in the capital city with the potential to influence and act as an example as for the municipality (Armijo de Vega et al., 2008; Uhl & Anderson, 2001). Its duty to promote sustainable development by doing so is acknowledged in the UASLP institutional development plan (UASLP, Secretaría de Planeación, 2014). Sustainable development is traditionally considered to encompass, environmental, social, and economic sustainability. Despite the existence of the PROSEREM guidelines and the launch of the program in 2018, the PROSEREM is unsustainable in all three areas. In other words, it remains neither efficient nor effective, neither lean nor green.

ISWM is considered an essential environmental service, but the PROSEREM is not currently doing much service to the environment. The UASLP continues to employ the same collect-transport-dispose model it followed before PROSEREM existed. The only recuperation of recyclable materials on campus is due to the efforts of *pepenadores* and the few university community members who choose to bring their recyclable wastes elsewhere. Wastes that could be diverted are taken either to Peñasco, where open burning, waste dispersal, and the proliferation of vectors and pests present environmental and human health risks, or to SJ where they generate additional greenhouse gases and cause the landfill to fill more rapidly.

Implementation phases 1 and 2 remain incomplete (Figure 18). This means that on paper the UASLP is meeting its legal obligation as a large generator to draft an integrated management plan for RSU (Ley General Para La Prevención y Gestión Integral de Los Residuos, 2003), but only on paper. It is also not fulfilling the requirement of separating organic form inorganic waste (Gallardo Juárez & Aranda Martínez, 2017). The upcoming passage of the national circular economy law will only increase the pressure for institutions such as the UASLP to manage waste more sustainably (Proyecto de Decreto CS-LXV-I-LP-038 Por El Que Se Expide La Ley General de Economía Circular, 2021).

In terms of the social impact, the PROSEREM has the potential to minimize health risks faced by waste collection workers and *pepenadores*. Numerous complaints have been filed with the AA of RP being mixed with the RSU at collection points. This risk is especially acute because personal protective equipment is sometimes not available even for the university-employed waste collectors. *Pepenadores* working informally on campus and at Peñasco almost never have such equipment (Barford & Ahmad, 2021; Ramirez Guevara, 2010).

The mismanagement solid waste also has economic costs in terms of the university's public image and financial expenditures. In 2021 UASLP ranked 527th overall in Green Metric Rankings and 447th in the waste category. Of the 25 participating universities in

Mexico, UASLP ranked 13th (*Overall Rankings 2021 - UI GreenMetric*). The mediocre environmental performance ranking shows that UASLP is not keeping pace with other universities. Staffing, fuel, and maintenance costs are also expended for the daily hauling of solid wastes, approximately half of which could be recycled at no cost to the university if only they were properly separated.

Thus, with the aim of promoting the environmental, social, and economic sustainability of the UASLP, the study investigates whether making the PROSEREM leaner can also make in greener, and thereby more sustainable.

CHAPTER 5. APPLYING AN ADAPTED LEAN MANAGEMENT STRATEGY

In this study, an adapted VSM strategy was executed in four stages (Figure 20) described below.

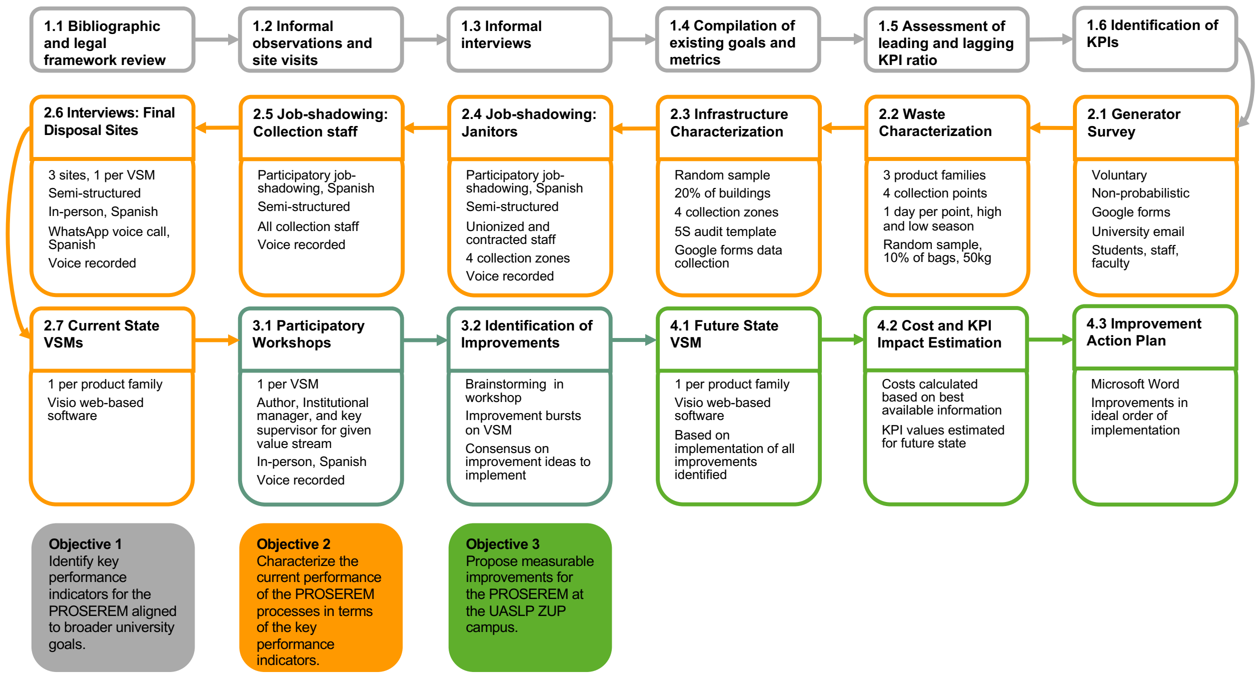


Figure 20. Overview of adapted VSM strategy with key methods, tools, and information for each step, by author. The four main phases are indicated by numbering, the corresponding specific objectives by color, and the sequence by arrows.

5.1. BACKGROUND INFORMATION

Phases 1.1 and 1.2 served to contextualize the PROSEREM within the academic literature on each of the topics previously described in Chapter 3, as well as understand its history, current state, relevant stakeholders, and perceived problems within the ZUP campus study area. In addition to extensive literature review, informal meetings were held regularly with the institutional manager, the significant locations such as micro-stations, collection points, and landfills were visited, and informal interviews were conducted with various members of the campus community including professors, students, janitors, and drivers.

5.1.1. Identify Key Performance Indicators

The original stated goals of the PROSEREM described in section 4.5.1 were written at a time when baseline data about waste generation was not available. Thus, the first goal of reducing wastes disposed of in municipal dumps by 70% was based on rough estimates (Rosales Guzmán, 2018). To support this goal, it was first necessary to quantify how much waste was being disposed of in dumps and the percentage of that waste that could be diverted for composting or recycling. The Key Performance Indicators (KPIs) selected for the PROSEREM in support of this thesis aimed to fill that data gap.

To support the second and third goals, the ZUP campus is being used as the pilot campus for the PROSEREM, with the idea that best practices developed there will be implemented on the rest of the UASLP campuses throughout the state and adapted as necessary according to local conditions. Therefore, it is necessary to meet the third goal first by developing effective practices and procedures at the ZUP campus and documenting those best practices in a way that makes them easily transferrable to other campuses to support the second goal of 90% coverage. Clearly it was also necessary to revisit the timeline for these initial goals, given that the goals were not met by 2023. Collecting more complete baseline data allowed a realistic timeline to be proposed.

The context provided by the PROSEREM goals and preliminary information gathering permitted the identification of KPIs. According to lean principles, KPIs should "measure what matters" to drive continuous improvement and be differentiated between "leading" and "lagging" indicators (*entradas* and *salidas*, respectively, in Spanish). Lagging indicators measure results, while leading indicators measure inputs or behaviors that lead to those results (The Shingo Institute, 2021). For a simple example, if a person's goal is to lose weight, the lagging indicator would be that person's weight, while leading indicators might be the number of calories consumed or the time spent exercising. Leading and lagging KPIs for the PROSEREM (

Table 9) were informed by the existing PROSEREM goals and guidelines, indicators from the GreenMetrics ranking system, and waste characterization and recycling behavior studies at other university campuses.

Table 9. Leading and lagging KPIs for PROSEREM with corresponding data collection method, by author.

		Key Performance Indicator	Data Collection Method
		Leading	
E	1	Incident reports at collection points per month	Incident reports submitted to PROSEREM email or to Institutional Manager
E	2	% ZUP Campus community who believe separating organic waste is important	Generator Survey
E	3	% ZUP Campus community who believe separating recylable waste is important	Generator Survey
E	4	% ZUP Campus community aware of PROSEREM	Generator Survey
E	5	% ZUP Campus community who correctly identify organic waste container	Generator Survey
E	6	% ZUP Campus community who correctly identify recyclable waste container	Generator Survey
E	7	% ZUP Campus community who correctly identify non-recyclable waste container	Generator Survey
E	8	PROSEREM participation score for ZUP campus community	Generator Survey and calculation
E	9	% of containers with cross-contamination of wastes	Infrastructure Audit
E	10	% of cleaning staff trained on PROSEREM	Semi-structured job shadowing
		Lagging	
S	1	Organic compostables volume/day	Waste characterization at collection points
S	2	Organic compostables mass kg/day	Waste characterization at collection points
S	3	Organic compostables volume m3/day	Waste characterization at collection points
S	4	Inorganic recyclables mass kg/day	Waste characterization at collection points
S	5	Inorganic recyclables volume m3/day	Waste characterization at collection points
S	6	Inorganic non recyclables mass kg/day	Waste characterization at collection points
S	7	Inorganic non recyclables volume m3/day	Waste characterization at collection points
S	8	Total RSU to Peñasco mass kg/day	Receipts (boletas) vs. waste characterization at collection points
S	9	Total RSU to San Juanico landfill mass kg/day	Receipts (boletas) vs. waste characterization at collection points
S	10	Total RSU to Peñasco volume m3/day	Estimate from reciepts vs. Estimate from waste characterization at collection points
S	11	Total RSU to San Juanico landfill volume m3/day	Estimate from reciepts vs. Estimate from waste characterization at collection points
S	12	RSU to Peñasco mass kg/capita	Receipts (boletas) and ZUP campus population; calculation
S	13	RSU to San Juanico landfill mass kg/capita	Receipts (boletas) and ZUP campus population; calculation

These leading and lagging KPIs are appropriate given the current state of the PROSEREM to guide improvement efforts and monitor the results and performance on an ongoing basis. KPIs should be monitored over time to assure targets are met and performance is maintained, but they may also be adapted or adjusted as needed as the performance of the process improves and new goals emerge. For example, the initial focus is on participation and assuring the correct separation of waste, but in the future, reduction of generation may become more relevant, thus requiring different leading KPIs.

5.2. CURRENT STATE VALUE STREAM MAPPING

After the background information was gathered and the KPIs were established, data collection for current state value stream mapping began.

5.2.1. Waste Characterization

In the application of VSM to the PROSEREM, the waste can be understood as the product passing through the value stream. The waste subproducts outlined in Mexican law, NMX-AA-022-1985 (Norma Mexicana NMX-AA-022-1985-Protección al Ambiente-Contaminación Del Suelo-Residuos Sólidos Municipales-Selección y Cuantificación de Subproductos, 1985), were classified into product families of wastes that receive the same treatment and final disposal (Table 10) (Nash & Poling, 2008).

Table 10. Product Matrix, applied by author to the waste categories from NMX-AA-022-1985 based on the strategy described by Nash & Poling (2008).

Waste Subproduct	Collection (Janitors)	Collection (Gardeners)	Transport (Maintenance)	Transport (GW, Maint.)	RECICLO	Peñasco	UniHuerto
Cardboard	X		X		X		
Waxed cardboard	X		X		X		
Cans (Aluminum)	X		X		X		
Ferrous material	X		X		X		
Non-ferrous material	X		X		X		
Paper	X		X		X		
Plastic – rigid and film	X		X		X		
Colored glass	X		X		X		
Transparent glass	X		X		X		
Stryrofoam - clean	X		X		X		
TetraPak	X		X		X		
Cotton	X		X			X	
Leather	X		X			X	
Fine wastes	X		X			X	
Synthetic fibers	X		X			X	
Bone	X		X			X	
Rubber	X		X			X	
Pottery and ceramics	X		X			X	
Wood			X			X	
Disposable diaper y sanitary waste	X		X			X	
Rags	X		X			X	
Styrofoam - dirty	X		X			X	
Other			X			X	
Hard vegetable fiber	X		X				X
Food waste	X		X				X
Gardening waste		X		X			X
Construction materials			X				
Polyurethane			X				

The waste characterization was conducted based on these product families at PROSEREM collection points 1, 2, 3, and 4 and repeated on two separate occasions, once when the semester was in session (April and May 2023), and once when it was not (July 2022) to capture periods of higher and lower waste generation, respectively (Armijo de Vega et al., 2008). For a detailed description of the characterization procedure and data collection table see the work instructions in Appendix A.

5.2.2. Infrastructure Characterization

To quantify the degree of implementation of the PROSEREM, an audit of the micro-stations was conducted based on the lean 5S audit checklist tool (Gupta & Jain, 2015). This audit was conducted during the period of high waste generation in April 2023 using a standardized digital data collection form (see Appendix B). Micro-stations were classified according to their corresponding building or outdoor location and collection point. Then their accordance with PROSEREM guidelines and degree of cross-contamination were assessed. A random selection of buildings from each collection zone (Figure 19) was chosen by assigning each building a number and using a random number table to select a sample of three buildings from each collection zone, representing 20% of the buildings on campus.

5.2.3. Incident reporting

The only KPIs that could be obtained by compiling existing information were S1, S8, S9, S10, S11, S12, and S13 (Table 9). For several years, since the four collection points were established, the PROSEREM coordinator has been receiving incident reports formally via email and informally via WhatsApp messenger. The official process is to fill out an incident report form in a Microsoft Word document and send it as an email attachment to the PROSEREM email account. However, because this is a somewhat time-consuming process and difficult to complete in the field, it has also become common practice for staff to send messages and pictures to the PROSEREM coordinator via WhatsApp to report instances of non-compliance with the PROSEREM guidelines.

The number of incident reports per month (S1) was obtained by first searching the PROSEREM email account to locate all the incident reports officially received during 2022 and 2023. Then the PROSEREM coordinator exported the WhatsApp conversations with staff members who use that method of reporting for 2022 and 2023. The author and a scholarship recipient assigned to help in the AA then reviewed each report and used a Google Form (see Appendix C) to pass the information into an excel worksheet so that it could be more easily analyzed and presented.

5.2.4. Tonnage data

To complement the data obtained from the waste characterization and obtain averages over a longer period, the tonnage data was requested from both Peñasco and San Juanico for the years 2022 and 2023. Both facilities have a scale, over which all trucks entering and exiting must pass to obtain the tonnage used for billing. The mass of waste delivered by university trucks to each disposal site was calculated in tons by subtracting the weight of the empty truck leaving the facility from the weight of the full truck entering the facility. The data requested was provided by Red Ambiental, the company contracted by the municipality to manage both facilities.

KPIs S8, S9, S10, S11, S12, and S13 are all based on this data. However, only the mass of the waste is measured, so the volumes for S10 and S11 were estimated using the average density of the waste obtained during the waste characterization. The per capita values for S12 and S13 were obtained considering an estimated ZUP campus population of 12,626. The estimated campus population was calculated by totaling the student, professor, and staff populations for all the university departments on the ZUP campus for which data were available (*Segundo Informe Indicadores*, 2022). Several smaller departments did not have data, but the largest faculties did, and though the final value is certainly an underestimate, it accounts for the majority of the campus community.

5.2.5. Draft Current State Map

Based on initial informal observations and data collected, a draft current state VSM was created for each product family using the Microsoft Visio software. Traditional VSM symbology and layout was used. Data visualized on the VSM included the following from both the PROSEREM KPIs and traditional VSM mapping data illustrating the efficiency of the workflow (Table 11). The current state map for each product family can be seen in Appendix H.

Table 11. Value stream mapping terms and definitions used, by author based on Nash & Poling (2008).

Symbol	Name	Meaning
P	People (*personas*)	Number of personnel who perform the task
TC	Cycle time (*tiempo de ciclo*)	Active time required to complete the process step once
L	Batch size (*tamaño de lote*)	Number of items processed in one instance of the process step
TE	Wait time (*tiempo de espera*)	Time the product must wait before being processed
TD	Uptime (*tiempo disponible*)	Percentage of time the process step is available to be performed
PNC	Defects (*productos no conformes*)	Percentage of flawed or incorrectly processed products
I	Inventory (*inventario*)	Products or material inputs in the value stream
TVA	Value added time (*tiempo de valor agregado*)	Total time the product is actively processed to transform it into the final product
TNVA	Non-value added time (*tiempo de no valor agregado*)	The total time the product is in the value stream but not being actively processed
LT	Lead time (*plazo de entrega*)	The total time the product takes to pass through the entire value stream

5.2.6. Identification of Value Stream

Nash & Poling (2008) recommend observing the value stream in action as well as physically and verbally walking through the processes with the people who perform each step. These are the true "subject matter experts" (SMEs) who can provide the most valuable information about how a process is performed and possible opportunities for improvement (Nash & Poling, 2008). While it is important to be systematic, it is equally important to leave open opportunities for the SMEs to share unexpected information. The following is a description of the semi-structured information gathering for each of the identified processes.

5.2.6.1. Final Disposal

Qualitative semi-structured interviews were conducted with responsible parties from the three final disposal destinations of the RSU from PROSEREM, including the coordinator of the campus garden, UniHuerto, which processes the compostable organics, the directors of RECICLO, the recycling company who receives the inorganic recyclables, and a responsible representative from Red Ambiental, the company that manages the Peñasco transfer station and the San Juanico landfill on behalf of the municipality and receives the remaining RSU. Interviews were conducted in Spanish following a pre-made semi-structured interview guide as described by Hernández Sampieri et al. (2014) (see Appendix D). In the VSM, the final disposal companies represent the customers to which the products are delivered. Therefore, the goal of the interviews was to better understand the customers' needs, including the desired characteristics, quantities, and collection frequency of waste to be received.

5.2.6.2. Loading and transfer

With each of the drivers who collect waste from the collection points, a semi-structured interview and participative job shadowing were conducted, also using a pre-made guide (see Appendix E). The aim of the job shadowing was to document what work was being performed, and how. The interview provided understanding of the generalities of the work that may not have occurred during the observation, the workers' feelings and opinions about their work, and their perceptions of how the process could be improved. Based on the informal observations conducted in phase one, the "ride-along" was identified as the most convenient format, conducting the interview in the truck on the way to the various destinations along the route. At each stop, participative job shadowing was conducted both to gather information and build trust and empathy with the drivers (Scharmer, n.d.).

5.2.6.3. Collection and transport

The next preceding steps in the value stream involves the janitors (*personal de intendencia*) who collect the RSU from the micro-stations and transport it to the collection points. The same method of semi-structured interviews combined with participatory job shadowing using an interview guide was applied to this process (see Appendix F). The only difference is that in the step described above, the sample size was the entire population, whereas in this case, sampling the entire janitorial staff was not feasible. Because the data supports a qualitative not a quantitative objective, it was not necessary for the sample size to be statistically significant. However, it was important to avoid bias and account for a variety of perspectives. To obtain a non-probabilistic but representative sample of the staff who perform this work, staff were selected from each of the four collection zones and from both hiring modalities—unionized university staff and outsourced staff from a private contract cleaning company. The sampling approach was a combination of sampling of experts, typical cases, and extreme cases, with a quota of at least two staff members from each collection zone and each work modality (Hernández Sampieri et al., 2014). In total, interviews and job shadowing were conducted with ten janitorial staff members.

5.2.6.4. Generation and disposal

To better understand the intention and behavior of the waste generators, a survey of the ZUP campus community was conducted. Though in theory the campus is open to the public, most of the waste generators are current students, faculty, and other university staff, and therefore that was the population sampled. The objective of the survey was not experimental but rather a qualitative assessment to guide future improvement proposals. Therefore, the sample was a non-probabilistic sample of voluntary respondents. General sample size recommendations for a large-scale survey are 100 respondents for the group of greatest interest and 20 – 50 respondents for other groups (Hernández Sampieri et al., 2014). Because most of the campus population consists of students, the survey aimed for at least 100 student responses, at least 20 staff, and at least 20 faculty.

The voluntary questionnaire assessed the awareness of PROSEREM, recycling intention, and recycling behavior in the ZUP campus community. The goal of the questionnaire was to obtain baseline information about the leading KPIs E2, E3, E4, E5, E6, E7, and E8 (see Table 9). Demographic information such as age, gender, role within the university, and time at the university were also gathered. The list of the survey questions can be found in Appendix G.

5.2.7. Adjust Current State VSM

Throughout the data collection process, the current state VSM was adjusted and adapted as needed to accurately reflect the processes for each of the product families. After all the data was collected, the current state VSM was finalized in preparation for use as the basis for the following steps.

5.3. FUTURE STATE VALUE STREAM MAPPING

The original intent was to conduct steps 3.1 and 3.2 (Figure 20) via large group workshops including members of each of the following stakeholder groups: waste generators, janitors, drivers, final disposal site representatives, and entity administrators from each collection point. However, organizational dynamics within the university made the larger workshop dynamic impossible (see section 6.3.1). Instead, for each of the three waste types a small participative session was held with the key decision-making stakeholder and the PROSEREM coordinator.

Workshops were conducted in-person in Spanish and facilitated by the author with visuals projected on a screen. The meetings began with a presentation of baseline information and KPI data. Then, the current state VSM and associated symbology and data were explained. According to Nash & Poling (2008), the purpose of presenting this information before proceeding to improvement suggestions is for the parties involved to arrive at a shared understanding that can act as the basis for change. With the consent of the participants, the sessions were voice recorded to ensure all results were accurately documented.

5.3.1. Brainstorm Improvements

VSMs are “living documents” that are revised as new information is obtained or circumstances change. It is common for additional information to emerge when various stakeholders come together to view a VSM (Nash & Poling, 2008). According to best practices, any adjustments to the VSM were made as necessary to achieve acceptance of the current state VSM by all the participants.

Similarly, improvement ideas were documented by adding numbered “kaizen burst” icons directly onto the VSM. A list of the improvement ideas was also kept in a separate document. Between 30 and 45 minutes of the workshop time was dedicated to brainstorming improvements (Nash & Poling, 2008). The VSMs with numbered kaizen bursts can be seen in Appendix I.

5.3.2. Draw Future State VSM

The future state VSM shows the desired future functioning of the value stream. Sometimes this state can be directly envisioned, with improvement bursts being identified to reach the future state. More commonly, a back-and-forth process emerges between identifying improvement opportunities, and envisioning certain aspects of the future state, which is continuously adjusted as more improvements are identified. Regardless of how it is developed, the idea of the future state VSM is that it acts as a guiding plan or “blueprint” for improving the process (Nash & Poling, 2008).

The kaizen bursts were added to the current state VSMs in real time during the participative workshops using the Visio program. After the workshops, the author reviewed the ideas listed, listened to the recording, and added any missed ideas to the list and VSM. Then the future state VSM was drawn based on implementation of all the proposed ideas and made available to the workshop participants. The future state VSMs can be seen in Appendix J.

5.4. IDENTIFICATION OF IMPROVEMENTS

Next, the improvements ideas gathered throughout the data collection and VSM process and those proposed during the small group workshops were analyzed in more detail to determine which KPIs they impacted and quantify to what extent. When possible, their impact on KPIs was directly calculated (for example, the increase in the percentage of micro-stations with the correct set of containers achieved by installing new containers). When impossible to calculate, the expected impact was estimated. Next the expected material cost of implementation for each improvement was calculated or estimated. Based on the calculated and estimated costs and potential impacts, the improvements were prioritized and compiled into a proposed improvement action plan, as described by Nash & Poling (2008). The proposed improvement action plan is available in Appendix K.

CHAPTER 6. RESULTS

6.1. CURRENT PERFORMANCE OF PROSEREM BASED ON KPIS

After establishing the KPIs, the second specific objective was to characterize the performance of the PROSEREM based on the KPIs. The following subsections discuss each KPI in greater detail, and an overview of the PROSEREM's performance at the time of writing compared to the goals for the year 2030 is shown below (Table 12).

Table 12. KPI Scorecard for performance of PROSEREM as of June 1st, 2023, versus goals for 2030, by author.

		Key Performance Indicator	Current 2023	Goal 2030
		Leading		
E	1	% ZUP Campus community who believe separating organic waste is important	89.4	98
E	2	% ZUP Campus community who believe separating recylable waste is important	96.9	98
E	3	% ZUP Campus community aware of PROSEREM	20.7	50
E	4	% ZUP Campus community who correctly identify organic waste container	84.4	90
E	5	% ZUP Campus community who correctly identify recyclable waste containers	74.4	90
E	6	% ZUP Campus community who correctly identify non-recyclable waste containers	80.0	90
E	7	PROSEREM participation score for ZUP campus community	24.8	50
E	8	% of micro-stations with correct set of containers	2.7	25
E	9	% of containers with cross-contamination of wastes	75	50
E	10	% of cleaning staff trained on PROSEREM	0	50
		Lagging		
S	1	Incident reports at collection points per month	3.6	2.0
S	2	Organic compostables mass kg/day	92.94	92.94
S	3	Organic compostables volume m3/day	0.39	0.39
S	4	Inorganic recyclables mass kg/day	193.82	193.82
S	5	Inorganic recyclables volume m3/day	6.05	6.05
S	6	Inorganic non recyclables mass kg/day	321.82	96.55
S	7	Inorganic non recyclables volume m3/day	9.78	2.93
S	8	Total RSU to Peñasco mass kg/day	*0.23	0.00
S	9	Total RSU to San Juanico landfill mass kg/day	*0.40	0.32
S	10	Total RSU to Peñasco volume m3/day	6.16	0.00
S	11	Total RSU to San Juanico landfill volume m3/day	10.63	9.78
S	12	RSU to Peñasco mass kg/capita/day	0.018	0.00
S	13	RSU to San Juanico landfill mass kg/capita/day	0.032	0.001

6.1.1. Waste characterization

The waste characterization established baseline data about the waste composition and the lagging KPIs S2, S3, S4, S5, S6, and S7 (Table 12). Based on the two characterizations conducted in July 2022 and May 2023, the estimated average daily generation of RSU by volume, mass, and collection point was obtained (Figure 21). Inorganic non-recyclables represent most of the waste stream, both by volume (61.5%) and by mass (53.1%), overall and at all the collection points, except by mass at collection point 2. Overall and at all collection points, organic compostables represent the minority of the waste stream by volume and by mass, despite having the highest density of the three waste types (Figure 22).

In terms of volume, an average of 16.22 m^3 is being transported to Peñasco daily, of which 6.44 m^3 (38.5%) could be redirected to composting or recycling (Figure 21). By mass, 608.58 Kg is being transported to Peñasco on average each day, and 286.76 Kg (46.9%) could be diverted (Figure 21). Volume is the limiting factor of the university truck currently used for transporting wastes, but cost is determined by mass.

More waste is generated in collection point 1 (35%) than in any other collection point, followed by point 2 (27%), and finally points 3 and 4 (19% each) (Figure 21). The composition of wastes varies slightly by collection point while maintaining the general trend of majority inorganic non-recyclable waste.

The total waste generation was significantly greater in the high season (May 2023) as compared to the low season (July 2022), except at point 3 (Figure 23). However, this is almost certainly due to wastes having been brought to point 3 from other campuses on the day of the low season characterization. Thus, it is likely that the low season generation measured at point 3 is artificially high.

During the waste characterization it was also possible to make qualitative observations that informed subsequent improvement suggestions. First, the use of black opaque trash bags was still very common, despite the PROSEREM guidelines requiring the use of transparent bags (Figure 24). Secondly, at all collection points and on all occasions, scattered loose waste was observed surrounding the collection point. Wastes of other types, including RME, RP, and RPBI were also found at all collection points and on all occasions, which confirms information obtained from incident reports (see section 6.1.7). Wastes were also delivered to the collection points continuously throughout the day, rather than only in the designated hours before collection. In all cases, a significant proportion of the inorganic non-recyclable waste was used toilet paper and paper towels used for drying hands in the bathrooms. Finally, evidence of compiling various smaller bags into one large bag could be easily observed, and this practice was confirmed by the job shadowing conducted with the janitors (see section 6.1.5). The result was large bags containing a layer of toilet paper, a layer of mixed food and office waste, and a layer of dirt, leaves and dust resulting from sweeping. This practice optimizes the use of trash bags but makes separating the recyclable and compostable wastes very challenging.

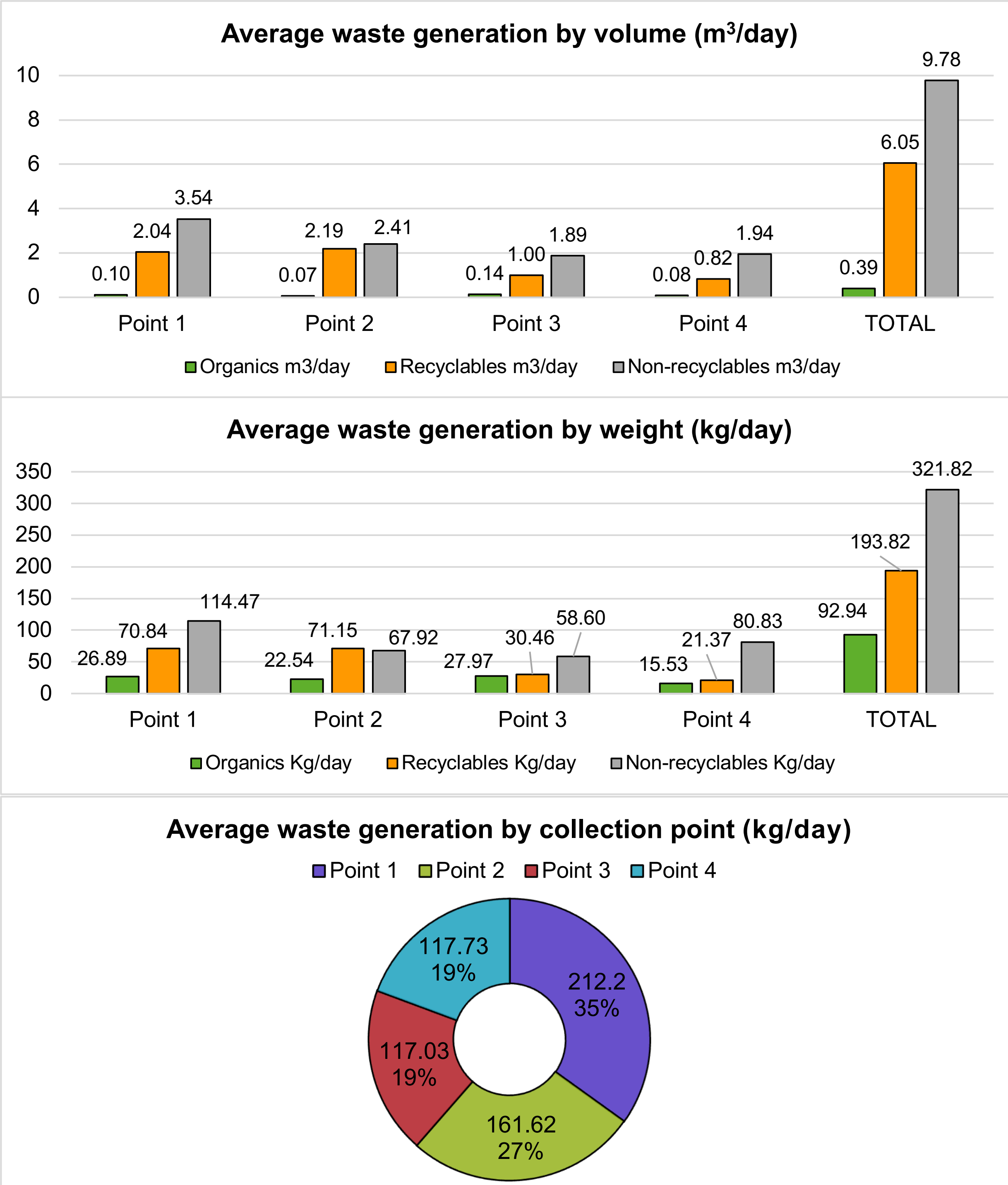


Figure 21. Weight and volume of waste generation by category and collection point, by author.

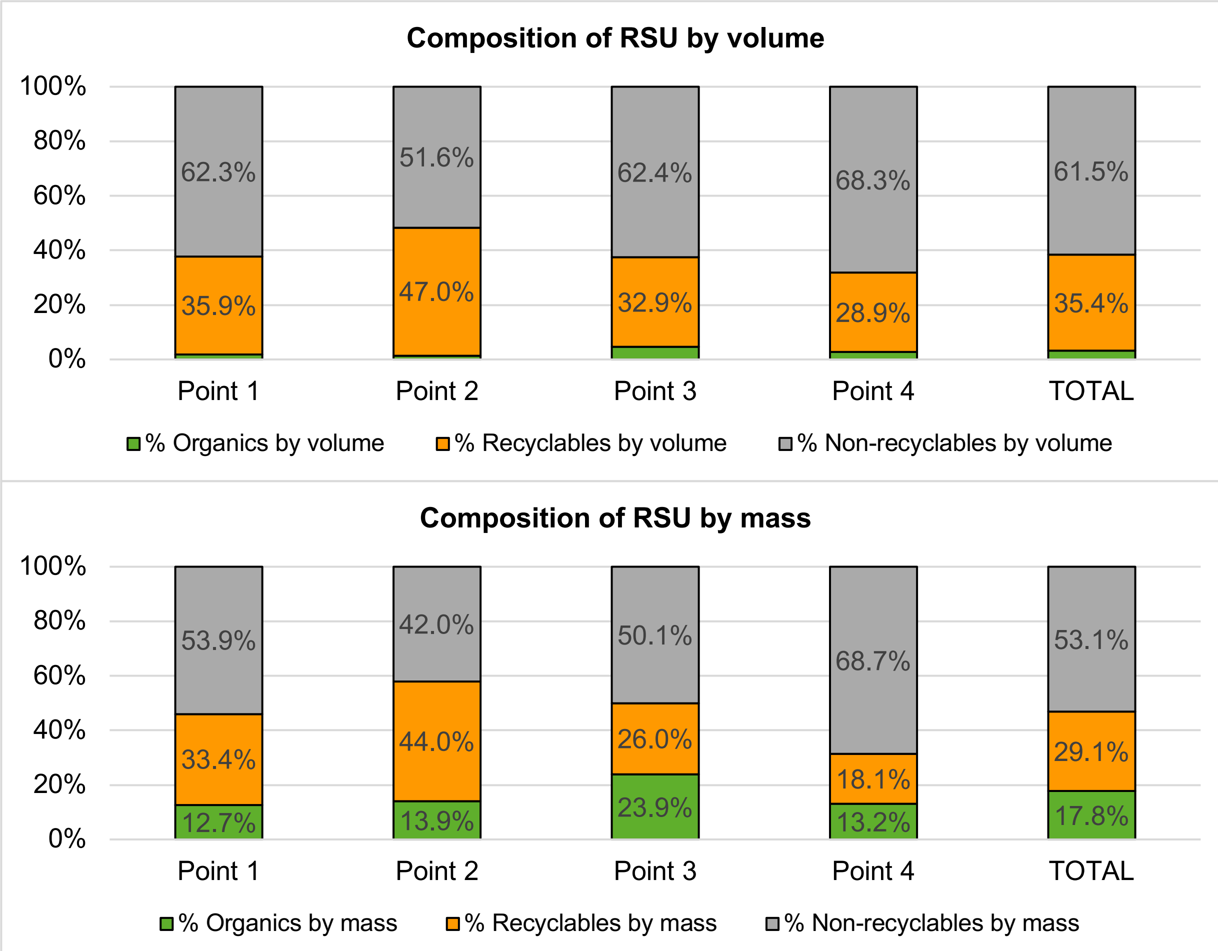


Figure 22. RSU composition as percentage of mass and volume, overall and by collection point, by author.

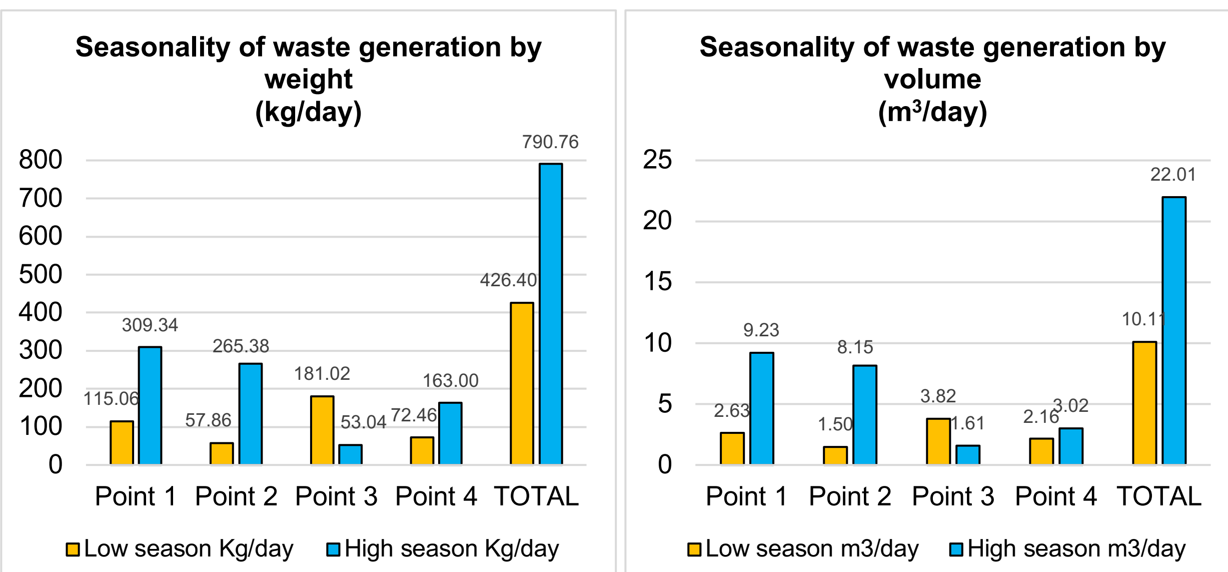


Figure 23. Seasonality of RSU generation overall and by collection point, by author.

Figure 24. Starting state photos of collection points 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right) before the low season waste characterization in July 2022, by author.

6.1.2. Tonnage data from Peñasco Transfer Station and San Juanico Landfill

To complement the data obtained from the waste characterization and obtain averages over a longer period, the tonnage data was requested from both Peñasco and San Juanico for the years 2022 and the first half of 2023. This data provided values for the lagging KPIs S8, S9, S10, S11, S12, and S13 (Table 12).

Interestingly, other than the vacation periods in April, July, and December, there is no notable seasonality in the data. What is very notable is the sudden cease of dumping at Peñasco in January 2023 (Figure 25). The reason for this sudden change was discovered during the job-shadowing conducted on that waste collection route (see section 6.1.6.1).

The data also show a high degree of variation in the frequency of drop-offs and the amount of RSU dropped off. Creating more predictability and stability in the collection system should lead to a decrease in this variation over time.

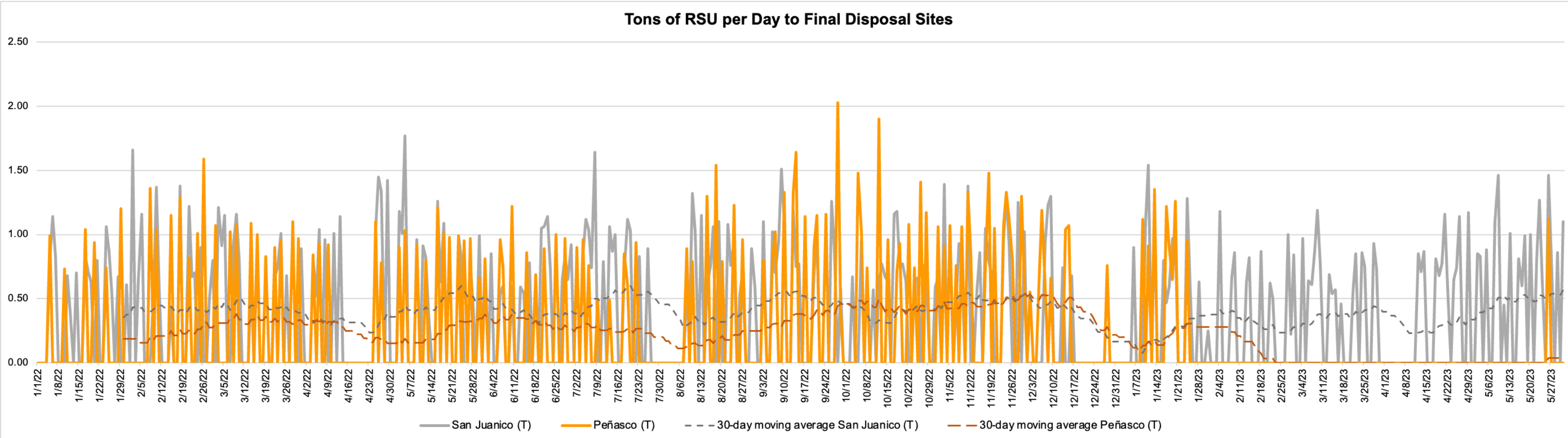


Figure 25. Tonnage data for San Juanico Sanitary Landfill and Peñasco Transfer Station, by author.

6.1.3. Infrastructure Characterization

The goal of the infrastructure characterization was to obtain baseline data for the leading KPIs E8 and E9 (Table 9). Based on previous observation, it was expected that almost none of the micro-stations would meet the PROSEREM guidelines, and the random sample confirmed this expectation. Of 31 micro-stations sampled from 12 randomly selected buildings in the four collection zones, not one met the PROSEREM guidelines. Therefore, to observe waste separation practices in the presence of the correct set of containers, compliant examples were sought.

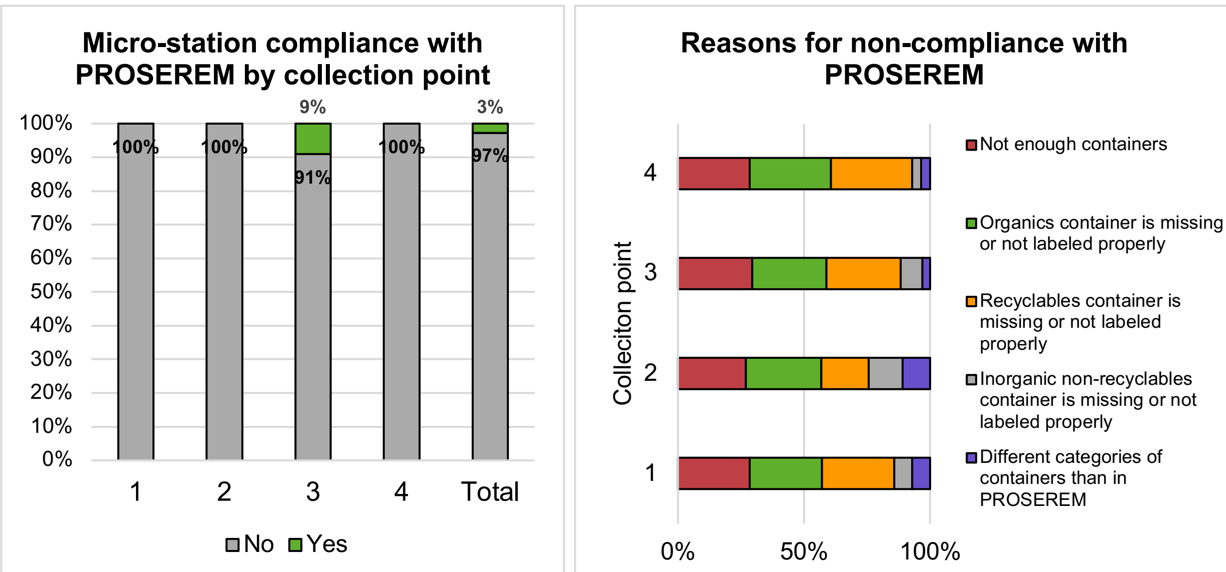


Figure 26. Percentage of micro-stations compliant with PROSEREM guidelines and the reasons for non-compliance, by collection zone, by author.

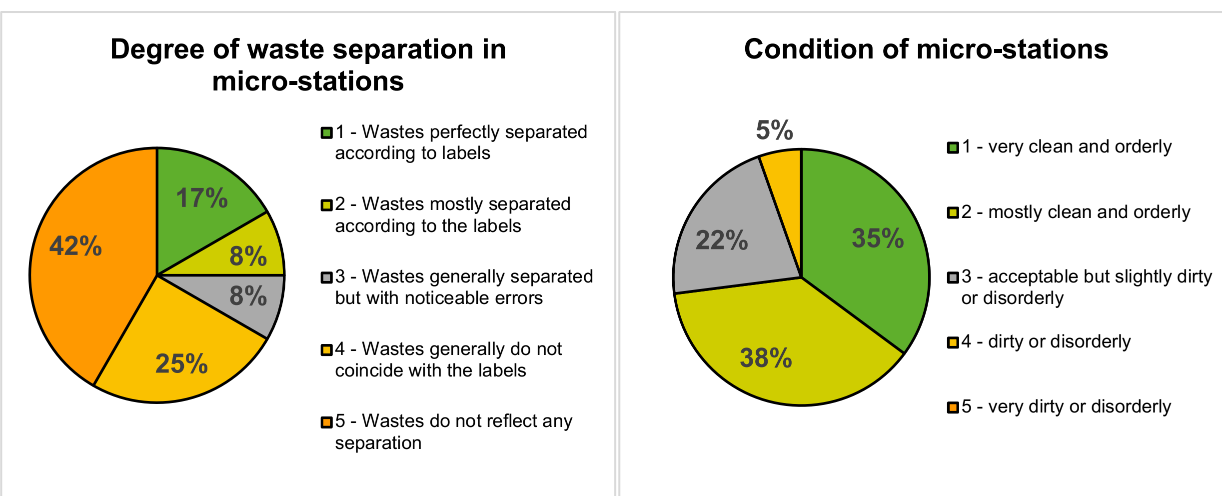


Figure 27. Degree to which wastes were correctly separated and the condition of the micro-stations, by author.

Figure 28. Examples of the variety of containers and micro-stations observed on the ZUP campus, by author.

The university library system has shown notable interest and initiative in implementing the PROSEREM. At the time of the infrastructure characterization in April 2023, micro-stations had been recently implemented in the larger of the two libraries, and therefore that building was also included in the otherwise random sample.

A large variety of micro-stations was observed (Figure 28). The most common type was a single unlabeled container, which was classified as “not enough containers,” “organics container is missing or not labeled properly,” and “inorganics recyclables container is missing or not labeled properly” (Figure 26), but there were also various arrangements and labels for different categories. Some micro-stations consisted of only one container for a different category, such as PET, paper, or batteries. Others consisted of two or three containers for categories specific to the use area but were missing one or more of the PROSEREM categories.

Of the 12 micro-stations that had more than one container, whether they followed the PROSEREM or not, the accordance of waste separation with the labels on the containers was assessed using a scale from one to five, one being perfectly separated according to the labels, and five reflecting no regard for the labels. Seventy-five percent of these micro-stations either reflected no regard for the labels or generally did not coincide with the labels (scores of five or four respectively) (Figure 27).

Although the micro-stations mostly did not follow the PROSEREM guidelines, and the separation generally did not follow the labels, the overall condition of the micro-stations was clean and orderly. On a scale from one to five, 95% of the stations scored a three or better, meaning their condition was either acceptable (22%), mostly clean (38%) or very clean (35%) (Figure 27). This suggests that the micro-stations are being serviced by the janitors with sufficient frequency.

6.1.4. Generator Survey

The main goal of the generator survey was to obtain baseline data for the leading KPIs E1, E2, E3, E4, E5, E6, and E7 (Table 9, Table 12). Of the 160 respondents, the majority, 65.6%, were women, and 51.2% were between 18 and 24 years old. Sixty-four percent were undergraduate students, 5% master's students, 12.5% academic staff, and 15.6% administrative staff. Those with more than 6 years of familiarity with the UASLP ZUP campus represented 33.8%, and those with less than 1 year only 18.8%. The vast majority, 71.3%, attend the ZUP campus four days per week or more. Their responses show a high level of concern for the environment and of importance of recycling and composting, but very low awareness of and participation in PROSEREM.

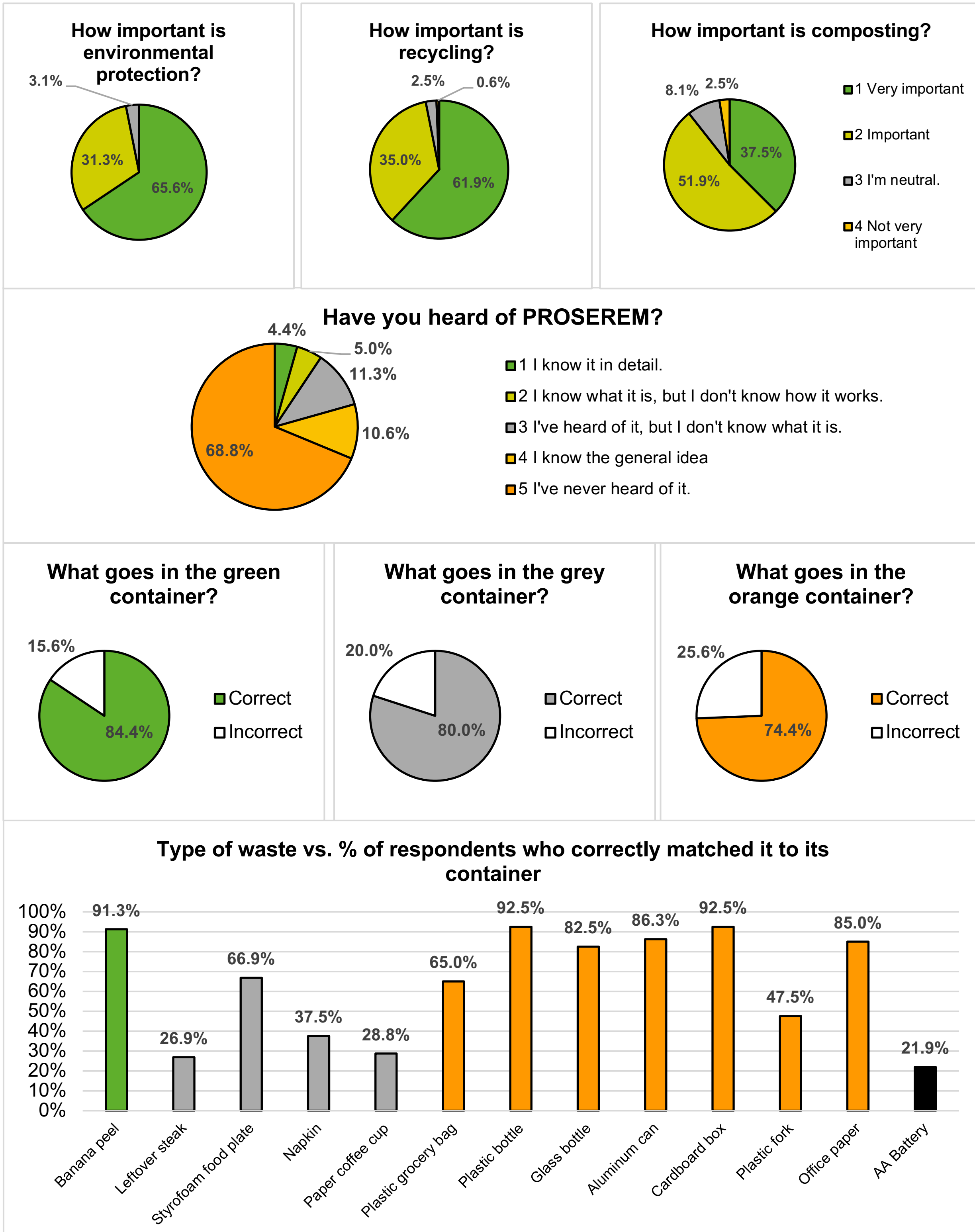
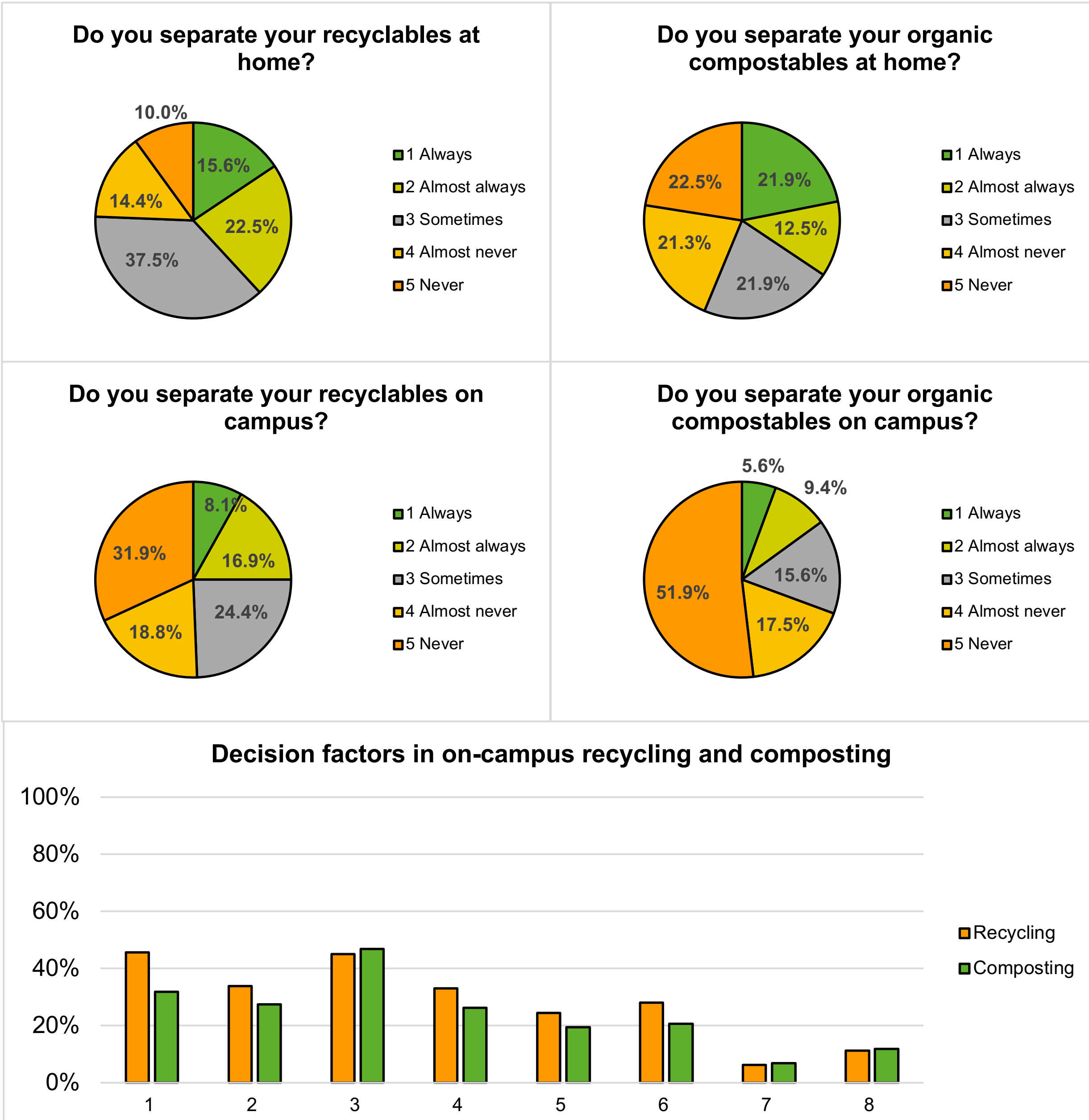


Figure 29. Beliefs about the importance of waste separation and knowledge of how to correctly separate wastes on the ZUP campus, by author.



1	My concern for the environmental impact
2	If I know whether the item is recyclable/compostable or not
3	If I know where the correct container is
4	The proximity of the container
5	The condition of the container (full, dirty, smelly)
6	If I trust that the wastes will be properly managed after putting them in the container
7	If I see other people separating their wastes
8	Other (specify)

Figure 30. RSU separation habits at home and on the ZUP campus and the factors influencing the decision to separate RSU, by author.

To understand the attitude of the university community towards the environment, recycling, and composting, respondents were asked to rate their importance on a scale of one to five, with one being very important, three being neutral and five being not important. Environmental protection was rated as important or very important by 98.9% of the respondents (Figure 29). Similarly, recycling and composting were rated as important or very important by 96.9% and 89.4% of the respondents, respectively. The importance rating did not vary significantly according to years of familiarity with the ZUP campus.

Only 9.4% of the respondents said they knew what PROSEREM was. The vast majority (68.8%) said they had never heard of PROSEREM (Figure 29). Despite reporting high levels of concern for the environment and belief in the importance of recycling and composting, respondents were not aware of the university's program related to those issues.

Despite not being aware of PROSEREM, when asked to match the categories to the corresponding colors of containers, the respondents mostly answered correctly. The green container was correctly matched with organic compostables by 84.4% of respondents, the grey with inorganic non-recyclables by 80%, and the orange with inorganic recyclables by 74.4% (Figure 29). The ability to match the colors to the waste categories greatly exceeded the stated awareness of PROSEREM, suggesting that perhaps the colors selected are intuitive or that the same colors are used in other waste separation schemes with which the respondents are familiar.

The next part of the survey, focused on waste separation habits, both at home and on the ZUP campus. The frequency of waste separation varied in both settings but was lower overall on the ZUP campus than in the home. At home, 75.6% of the respondents stated that they separate their recyclable waste sometimes, almost always, or always, and 56.2% stated the same for their compostable organic waste (Figure 30). In contrast, on the ZUP campus, only 49.3% separate their recyclable waste at least sometimes and 30.6% their compostable organic waste (Figure 30). In both settings, academic staff separate their waste more than undergraduate students.

The participation ratings provided by the respondents can be transformed into a participation score (Table 9) by the following formula:

$$\left(1 - \frac{\sum ratings}{5n}\right) \times 100 = \%Participation\ Score$$

By applying this formula to the composting and recycling ratings, the following participation scores were obtained:

- Composting participation score = 19.5%
- Recycling participation score = 30%

By applying the following formula to the composting and recycling ratings, the overall participation score was obtained:

$$\left(1 - \frac{\sum compost\ ratings + \sum recycling\ ratings}{10n}\right) \times 100 = \%Overall\ Participation\ Score$$

Even at home, not all respondents who consider recycling and composting to be important separate those types of waste, but fewer still on campus, and the results indicate that this could be due to a lack of both knowledge and infrastructure. Among the factors that influence the decision whether to separate waste on the ZUP campus or not, the most noted were concern for the environment, knowledge of the location of the appropriate container, and knowledge of which types of waste are recyclable and compostable (Figure 30). Regarding the knowledge of the location of the appropriate container, it is important to note that 53.1% of the respondents had never seen the appropriate containers on the ZUP campus or were not sure whether they had seen them. This is unsurprising given the results of the infrastructure characterization described previously. If the infrastructure does not exist, or if the campus community does not know where to find it, they cannot reasonably be expected to separate their RSU on campus.

Finally, respondents were asked to identify which would be the appropriate container for various examples of commonly generated waste. The wastes correctly sorted by the most respondents were plastic bottles (92.5%), cardboard boxes (92.5%), and banana peels (91.3%). The wastes with the most errors were AA battery (21.9%), leftover steak (26.9%), and paper coffee cup (28.8%) (Figure 29). The waste types most incorrectly sorted were those that either go against intuition or are likely to be inconsistent with systems used in other contexts. For example, leftover steak is organic, which would make one assume it would correspond to the organic compostables container, but, due to the specific limitations of the UniHuerto, the PROSEREM indicates that it goes in the grey container, which is labeled inorganic non-recyclables.

6.1.5. Job Shadowing – Janitors

In addition to understanding the flow the of the value stream, job shadowing was conducted with janitors (cleaning staff) to determine the starting condition for leading indicator E10 (Table 9). In total, 14 janitors were job-shadowed, 10 unionized and four contracted, as well as one *pepenador*. The experience of the staff ranged from three weeks to 25 years, with a general trend of unionized staff having more years of experience than contracted staff. The cleaning work is organized into two shifts. The day shift is from approximately 7:00 am until 3:00 pm, and the evening shift is from 2:00 pm until 10:00pm. However, exact start and end times vary from person to person. Each staff member has an assigned area of responsibility, which may include laboratories, classrooms, offices, bathrooms, or outdoor areas. Cafeterias are handled separately by the contracted food service company. Some staff collect as many as five bags of RSU per day, while some take multiple days to fill up one bag, depending on the generation in their assigned area. Most staff wait for the bag to be full before bringing it to their collection point.

There were some universal practices and observations in all fourteen cases. All agreed that there were almost no separate containers for organic, recyclable, and non-recyclable waste, and that in the cases where there were separate containers, the students and staff do not dispose of their waste accordingly. All commented that there was not enough education for students or staff about waste separation, nor had they themselves received any training on how to handle wastes. They said they learned on the job from their colleagues. The waste collection procedure is to complete the rounds of the assigned area, emptying the contents of small containers into one large bag of RSU. When that bag is full, it is taken to the collection point.

In addition to these generalities, there were various challenges specific to certain areas. Those in collection zone one, which includes the Oral Medicine faculty, struggle consistently with the separation of RPBI. Sometimes, new sharps containers or bags are not immediately available to replace the RPBI container when Orlando collects it, which contributes to students disposing of RPBI in the RSU containers. The staff from points one and two all noted time pressure as a challenge as well, especially those that are assigned areas with laboratories, who must clean the lab multiple times daily between each class session. The staff from collection zone two all noted that point two is not well located, and there is a major problem with loose trash. In some cases, janitors are assigned to clean up the collection points or remove RME or RP that do not belong.

Finally, there was variation in the extent to which the janitors conducted waste separation. Some do not separate any waste at all, while others pull out easily accessible recyclable materials, either for themselves or to set aside for the *pepenador*.

The famous campus *pepenador*, nicknamed “La Pizca” (the pinch), is actually a contracted janitor in the large parking ramp and has been for 14 years. His parking ramp corresponds to collection point three (Figure 19), and part of his work is to bring the waste to the collection point. On the way, he passes by all the micro-stations picking out recyclable materials that are easily visible. The transparent bags make picking out wastes much easier, but even so he does not reach deep into bags because he has been cut by broken glass doing that in the past. He spends approximately one hour every day doing this and lately has been able to collect 8-10 kg of PET and 1kg of aluminum daily. He sells it on his way home from work and gets 5 pesos per kg of PET and 22 pesos per kg of aluminum.

When asked what the biggest challenge of their job was, some answers could be classified under the description given by one staff member, “*Todo se va revuelto*” (everything goes all mixed together). This category of responses included observations such as the students do not separate their waste, people pour liquids in the trash cans, people throw cigarette butts in the trash cans, and there is no time for janitors to separate wastes. Some said time pressure itself of keeping up with the generation of waste was the biggest challenge. Others said the communication chain for getting the necessary supplies was the biggest complication. Finally, the newest staff member said, “*Pues, es trabajo*” (well, it’s work), meaning there were no challenges beyond what one would normally expect from a job.

Many said they wished there could be more consciousness and respect for waste separation and following the labels on the separate containers. One suggestion was to have the janitors lead a talk or workshop at the beginning of each semester to explain the importance of waste separation. Several mentioned wanting a “*riesgo de trabajo*” (hazard pay) for having to handle hazardous wastes that do not fall within their job descriptions. Others said installing the separate containers at the micro-stations and at the collection points would make the most difference. One staff member from collection zone two suggested having two collection shifts per day just like there are two cleaning shifts per day to prevent what he perceives as excessive waste accumulation at collection point two.

6.1.6. Job Shadowing – Collection staff

Conducting job shadowing with the collection staff provided a more complete and accurate understanding of the flow of RSU within and from the ZUP campus. The flow of RSU is much more complicated than it first appeared and is influenced by various factors both on and off campus.

The two main routes servicing the PROSEREM collection points on the ZUP campus are the Internal Route and the Garden Waste Route (Figure 31). The internal route collects RSU from points one, two, and four and brings it to Peñasco, while the garden waste route collects the waste from point three and the garden waste point and brings it directly to San Juanico (SJ). However, there are also various routes not dedicated to the ZUP campus that influence the waste collection process of these two main routes.

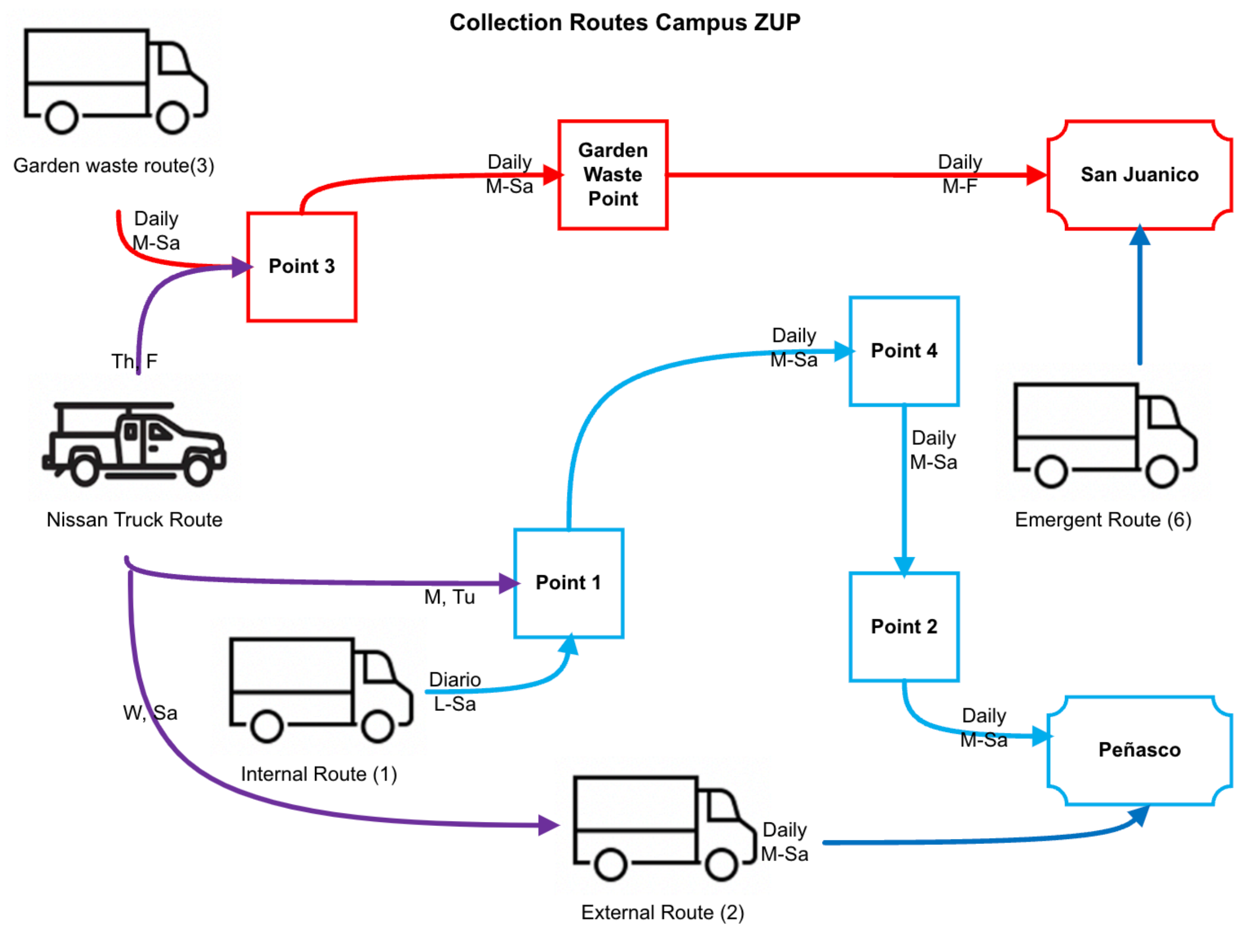


Figure 31. RSU collection routes related to campus ZUP, by author.

6.1.6.1. Internal Route

Jesús is the driver in charge of the internal route, which collects the RSU from points one, two, and four on the ZUP campus and transports it to Peñasco (Figure 31). He has worked as a driver for the maintenance department for 11 years and at the UASLP for a total of 15 years. His position is unionized, and his work hours are Monday through Friday 7:30am to 4:00pm and Saturdays from 7:30am to 1:00pm (J. Rangel, personal communication, March 24, 2023).

During the job-shadow, the prescribed internal route was not followed, which Jesus explained is quite normal due to various factors. Truck maintenance, fuel availability, quantity of waste at the collection points, availability of an assistant to load the waste onto the truck, and access to the collection points are all factors that consistently influence whether and how quickly Jesús can complete the internal route (J. Rangel, personal communication, March 24, 2023).

Collection point 2 (Figure 19) has the most frequent access problems because it is accessed through a gate that is only used for trash collection and emergencies and opens to a very busy road. Because the gate is usually closed, people commonly park their cars in front of it, blocking access to the collection point. In such cases, Jesus must skip point 2, which causes a greater accumulation of waste for the following day (J. Rangel, personal communication, March 24, 2023).

He also explained that fuel availability almost always becomes an issue toward the end of the work week. According to him, he is given 35 liters of fuel per week, exactly enough to complete the prescribed route once a day, but then he is often asked to run other errands, which are not accounted for in the fuel allowance. By Thursday or Friday there is often not enough fuel to make the trip to Peñasco, and he must follow a formal process to request an additional fuel credit, which can be very time consuming. Due in part to the issue of lack of fuel and in part due to safety concerns at Peñasco, he searched for a work-around and found an uncontrolled dumpsite as an alternative location to dump the RSU (Figure 15).

The internal route to Peñasco as planned is approximately 20 km, and during an informal ride-along in the background information gathering phase, took about two hours to complete, including significant wait time in traffic. During the job-shadow, the alternative route used was recorded using the smartphone application Strava. According to the Strava data, the total distance of the route was 12.43km, the total elapsed time was 53 minutes and eight seconds, and the moving time was 35 minutes and 39 seconds.

In Jesús' opinion, the AA is changing a lot of rules and procedures for no reason. He said he did not receive any real training when PROSEREM was launched. He was only told not to collect fluorescent bulbs, and if he saw them at the collection point, he should try to find out who left them. He was unaware that fluorescent bulbs were legally classified as RP. He said he does not report these types of incidents because he does not think they listen or even really know who is reporting.

When asked what he thought was the biggest challenge, Jesús' first response was "*ellos*" (them), referring to the Agenda Ambiental. He explained that they add requirements and change things without understanding how things really work. Another serious problem he talked about was a lack of accountability. He said before PROSEREM, it was much easier because he would just call the janitors for each faculty when he was passing by with the truck, and they would bring out their trash. Sometimes this caused longer wait times, but loading the truck was easier, and he could see what waste each faculty was delivering. With the four shared collection points, if someone leaves waste that is not RSU, there is no way to find out who left it. The root of this challenge is that wastes other than RSU are being left at the collection points, and Jesús views knowing who is leaving what wastes as the way to correct this behavior.

Jesús said if there were two things he could change, he would move point two to an easier to access location, and he would stop having routes bring wastes from other campuses to ZUP campus. To him that seems like a waste of gas, time, and energy to drive it all to ZUP, unload it, and later load it on the other truck again.

6.1.6.2. Garden Waste Route

The garden waste route (*ruta de poda*) collects the RSU from point three and the garden waste point (*punto de poda*) and transports it directly to SJ. Two staff members are assigned to the route, Agustín and Humberto. They work Monday through Friday from 7:00am until 3:00pm and Saturday from 7:00am to 12:00pm. Each morning, they start by loading all the RSU from point 3 into their truck. Then they move the truck to the garden waste point and fill whatever space is left with garden waste. By 8:30am they are usually on their way to SJ. At SJ they pass by the scale upon entering, drive out onto the working front to empty the truck, and pass by the scale again upon leaving. The only exception is that on Saturdays they load the truck but do not go to SJ because of the time constraint of having a shorter day.

Agustín and Humberto have been with the UASLP for eight and six years, respectively, and neither was hired to collect RSU. Agustín was hired as a gardener (*jardinero*) and later promoted to a general laborer (*peon de albañil*), and Humberto is a gardener. They described their job on the garden waste route as "leaving the points clean," and neither does other work besides the collection route.

They mentioned several challenges to completing their work, the first being variation and unpredictability of the workload. Besides serving the two points on the ZUP campus, they also pick up waste, mostly sawdust used in lab animal cages, from *Medicina* (the medical campus) that does not contain hazardous substances. Though the established frequency is once a week, sometimes they are asked to go twice due to high generation. They are also sometimes asked to collect garden waste from other campuses on an as-needed basis. The Nissan route contributes more variation to the garden waste route because it leaves RSU from other campuses at point 3 on Thursdays and Fridays (see following section). Sometimes this means there is so much RSU at point 3 that there is no room left in the truck for garden waste, and it starts to accumulate. Finally, there is seasonal variation in the generation of garden waste based on natural seasons and the school calendar. For example, in the rainy season trees are trimmed more often.

Another category of challenges that was mentioned was insufficient supervisory planning and oversight. First, with respect to gasoline, 45 liters per week is allotted to their vehicle, which is sufficient to make their planned trips to SJ, but sometimes they are asked to collect from other campuses or run other errands, and they run out of gas. In such cases they have to request an additional gas credit, which can present a significant delay. Second, under their previous supervisor, they were required to fill out a form confirming they had collected the waste from their assigned points and had left the points clean, but with the recent change of supervisors, this practice was lost. Third, they used to be given a paper receipt at the scales at SJ, which they were required to submit to their supervisor, but since the pandemic SJ no longer gives physical receipts. Agustín and Humberto did not know for sure how, to whom, or whether receipts were still being sent, but their supervisor does not request any documentation from them.

They also noted a recurring problem with wastes other than garden waste being left at the garden waste point. The example they gave was tires being left there, and the day of the job-shadowing there was a tire at the point. They attributed this problem to professors bringing wastes from elsewhere and leaving it at the point. In their opinion more education and awareness campaigning directed at professors would be helpful.

When asked what they would change if they could change just one thing, Humberto responded he would improve the corrective and preventive maintenance of the vehicles. Their vehicle is not in safe working order. It lacks a hand brake, and in general the brakes do not work well. For that reason, their truck is not allowed to go to the *Pedregal* campus which is at the top of a steep hill. The truck is designed to have two side by side rear tires on each side because of the heavy loads it carries, and there been cases of prolonged periods without the second tire. Agustín echoed these observations but said he would provide more and better equipment for the tasks. He said, "*no hay la maquinaria para hacer el trabajo*" (there is not equipment to do the job). The day of the job-shadowing, only one of the two had gloves, and those had large holes in them. Before loading the garden waste onto the truck, they spent several minutes repairing their one rake. They said there is often a long delay in getting the materials they request.

6.1.6.3. External Route

Eduardo is in charge of the external route (*ruta externa*). He collects wastes from other campuses besides ZUP and takes the RSU to Peñasco. Because he does not collect from ZUP, no formal job-shadowing was conducted, but a ride-along to Peñasco during the background information phase in March 2022 provided useful context to understand Peñasco.

Upon arriving to Peñasco, Eduardo weighed in at the scales and then drove out to what he explained was his usual spot on the *plancha de pepena* (waste picking field). He explained that different groups of *pepenadores* have different territories on the field and changing the location of drop-off can cause conflicts. He has a long-running arrangement with the group in his usual spot, and they know generally what composition of wastes to expect from Eduardo’s truck. He said they complain when there is more garden waste than usual in the load, or less valuable material.

On the way out, he passed over the scale again but was not given any receipt. He explained they used to give paper receipts but have stopped since the pandemic.

6.1.6.4. Nissan Truck Route

The Nissan Truck Route is driven by Juan José and services three other smaller campuses in the city of San Luis Potosí, accounting, law, and the central campus (Juan José, personal communication, April 27, 2023). Due to time constraints and because this route does not service the ZUP campus, an interview was conducted with Juan José instead of a full job-shadow.

During the interview, Juan José explained the schedule he follows and the reasoning behind it. The Nissan Truck is smaller than the trucks used on the other routes, which allows it easier access to the central campus in the historic center of the city, which has more traffic and narrower streets. Both because it is small and because it is also used for other purposes, it is not the best use of the Nissan for Juan José to drive the wastes to Peñasco or San Juanico. Instead, he delivers them to one of the other routes (Figure 31) and then proceeds with his other assigned errands (Juan José, personal communication, April 27, 2023).

The Nissan has a capacity of approximately one-half ton, and according to Juan José, he fills it daily (Juan José, personal communication, April 27, 2023). The result is that an additional one-half ton of RSU is added to the garden waste route two days per week, the internal route two days per week, and the external route two days per week. Two days per week the RSU from this route is disposed of in San Juanico, and four days per week in Peñasco.

6.1.6.5. Emergent Route

The emergent route (*ruta emergente*) is a variable route with some regular collection points and some as needed. Regardless of which points are collected, the waste is taken to San Juanico. Two unionized staff members are assigned to the route. Ezequiel was hired as a gardener, then promoted to carpenter, and two years ago was assigned to the collection route. Alan previously worked as janitor for a different university department, and one year ago changed to the maintenance department with the title of gardener. The two have been working the emergent route together for one year. In addition to RSU collection, they also perform other tasks, such as moving furniture.

Alan's shift starts at 7:00 am, and Ezequiel's at 8:00 am. They said they report to the maintenance department, but usually end up just waiting for their supervisors to arrive at 8:30 am to get instructions for the day. Every Saturday they collect from campus Pedregal and take the RSU to SJ. Sometimes they make one or two other trips to SJ during the week as well, depending on how much RSU they collect. Interestingly, although their route is the least predictable, they said they do not have any problem with running out of gas, although they are allotted only 20 liters at the beginning of each week. They said there is no requirement to keep a register of the odometer readings to document their distances or destinations. They also commented that they have plenty of time to complete their tasks, and even have time to tidy up the collection sites. Like the garden waste route workers, they described their job as "leave the points clean."

Ezequiel commented that when he sees fluorescent bulbs at the collection points, he brings them to SJ with the rest of the RSU. He did not know they required special treatment. This provides further evidence that PROSEREM trainings are either not being offered or not being offered frequently or thoroughly enough.

The biggest challenge Ezequiel and Alan identified was that other drivers do not clean the points completely. They said they are often called to go clean up points that have been left dirty for weeks because the other drivers only take the RSU that is in bags, but they leave the loose trash there to accumulate. After a while, when the point is full of loose trash, they call the emergent route to come clean up. Along the same lines, they said if they could change one thing it would be to implement a way to make sure the drivers are accountable for leaving their scheduled points clean.

6.1.7. Incident reports

The incident reports were used to calculate the lagging indicator S1. A total of 65 incident reports were compiled in the 18 months from January 2022 through June 2023. Most of these were received via WhatsApp, and the only reports received via email were submitted by employees of the Agenda Ambiental. This demonstrates the preference for quick, in-field reporting via cell phone rather than via the Microsoft Word form. Neither form of reports had previously been compiled or systematized in an accessible way for record keeping or data analysis.

After compiling the data, it was possible to identify certain trends. First, the point with the most incident reports was point 1. It was followed by points 2 and 4, then point 3, and finally the UniHuerto and the garden waste point (Figure 32). The most commonly occurring incident was the use of opaque trash bags. The next most reported incident was loose waste at the collection points, followed by excessive accumulation of waste or missed or incomplete waste collections.

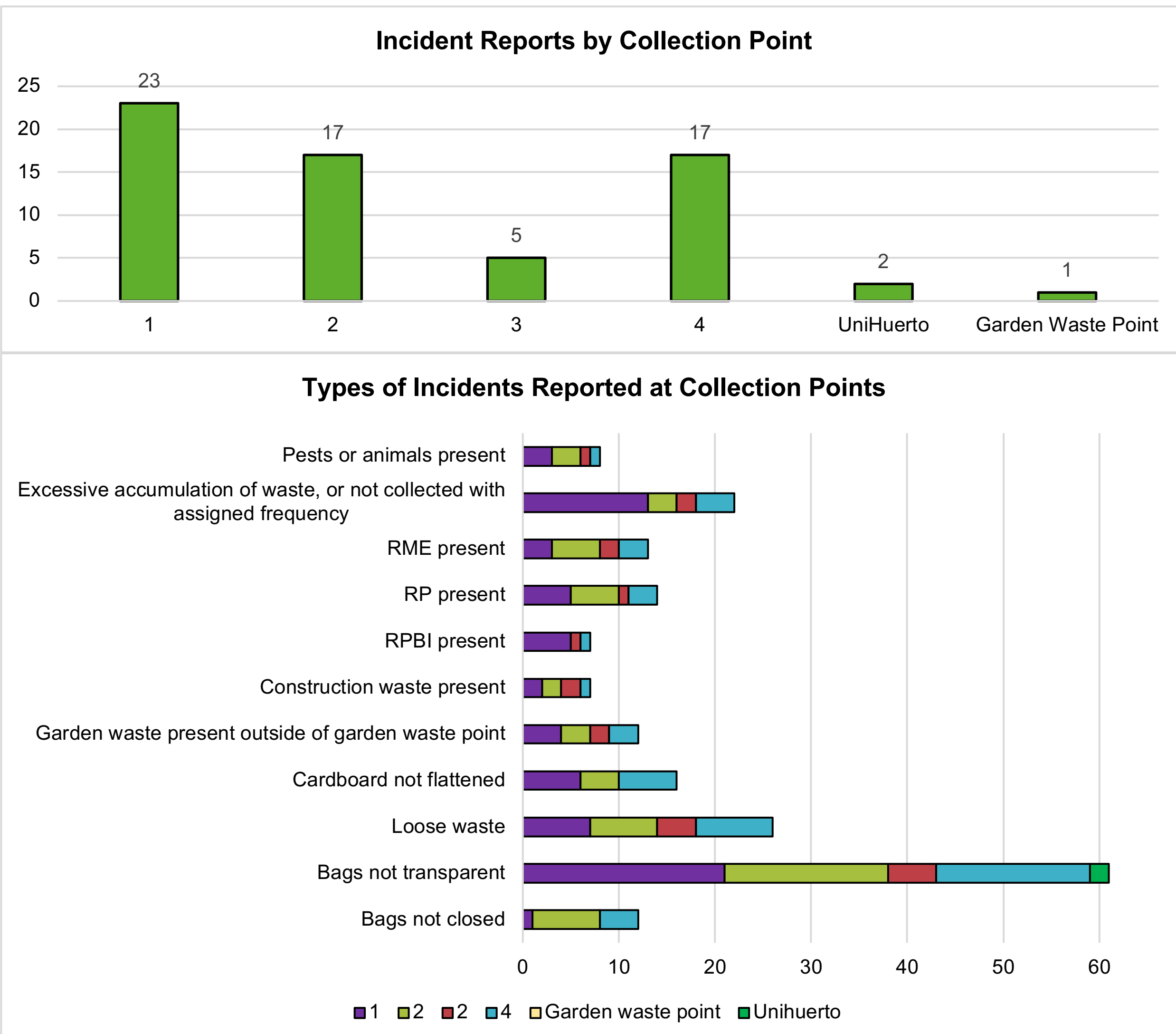


Figure 32. Number of incident reports per collection point and frequency of different types of incidents, by author.

It is important to consider that these reports by no means provide a complete account of the incidents that have occurred since the beginning of 2022. During interviews and job shadowing, numerous workers involved in the collection, loading, and transport of wastes stated they do not report incidents either because of inconvenience or because of lack of trust that there will be a response.

6.1.8. Interviews – Final Disposal Sites

The final step in understanding the value stream was interviewing responsible parties from the final disposal sites, who are analogous to customers in this lean application. The customer for non-recyclable waste is *CIPRES San Juanico* (San Juanico Sanitary Landfill, SJ) owned by the municipality and operated through concession by the private company, Red Ambiental. CIPRES stands for Ce*ntro Integral de Procesamiento de Residuos* (integrated waste processing center), and it receives RSU and RME. RedAmbiental refers to all their sanitary landfills across the country by this acronym to reflect their shift in mindset toward ISWM. They have pilot projects at other CIPRESs on different forms of composting and on using WtE to power cement plants, but so far there are no such projects at SJ.

According to the Operations Manager at SJ, it is more difficult to initiate these types of projects in SLP because of the contract arrangement with the municipality. Red Ambiental is only paid to offer services that are approved by the municipality, and all the waste collected through the contracted service or disposed of in SJ is property of the municipality. Those who bring their own RSU/RME to SJ, such as UASLP, must have a permit from the municipality. The customers pay the municipality, and the municipality pays Red Ambiental based on tonnage. Red Ambiental must consult the municipality about any initiatives undertaken on its property. They also operate the Peñasco Transfer Station under the same type of contract.

At the Peñasco site, the OUP has significant influence over the decisions of the municipality, meaning Red Ambiental is also subject to the will of the *pepenadores* to some extent. The manager of Peñasco was not available for an interview, but the manager of SJ explained that for the UASLP to transition from bringing RSU to Peñasco to brining only non-recyclable RSU to SJ, it would need to explain the change to the OUP to avoid conflicts.

Red Ambiental also offers waste collection service to industries outside its contract with the municipality. This service includes containers and collection, which are paid to Red Ambiental, and disposal at SJ, which is paid to the municipality. Red Ambiental expressed interest in winning a contract with the UASLP for this service as well as in partnering with the university to develop ISWM pilot projects if the university can obtain permission from the municipality.

The customer for the recyclable waste stream is RECICLO México, which was founded in 2019. It is a small business with only eight employees and receives plastics (PET, HDPE, bags), Tetra Pak, cardboard, paper, metals (iron, aluminum, metal spray bottles, etc.), Styrofoam, glass, electronic wastes, and used clothing through a collection center, the monthly university collection events at the responsible consumption spaces, and a residential collection service. They bring the waste collected to their warehouse where their employees sort it by hand. After enough is amassed, the sorted material is sold to recyclers. Some materials are much more profitable than others, but overall, the profit margin is not very large. The most profitable material for them to sell is aluminum, which sells for 24 pesos per kg, followed by PET, other plastics, and cardboard. Some materials, such as contaminated cardboard or Styrofoam do not general any income but are simply given to recyclers for responsible processing.

RECICLO's point of contact with the UASLP is the AA. The agreement in place is that the AA puts RECICLO's logo on the advertisements for the monthly responsible consumption space events, and RECICLO collects the recyclables from the events for free but keeps the profits from selling the recovered materials.

The UniHuerto is the customer for the organic compostable waste. It has existed since 2012 and has had a full-time coordinator since 2020. On the ZUP campus, the UniHuerto spaces include the UniTecho green roof, and the UniHuerto with its compost processing point (Figure 19). The compost processing point currently uses cold composting piles to process organic wastes from individuals and university entities, which it mixes with garden waste from the garden waste point. Because the UniHuerto does not have a shredder or a hot composting system, it does not accept leftover food cooked with oil, meat, or heavy condiments, bones, napkins, coffee filters, or other paper products. It also requests that organic waste not be more than 4 days old when dropped at the processing point. In theory it accepts organic wastes from the campus cafeterias, but there is some resistance due to the effort required to separate the waste and the belief that it is not processed correctly anyway.

If the UniHuerto had a shredder machine, it could process compost faster, and receive more types of waste and in greater quantities. It could process larger garden waste materials like branches and receive the types of food waste it currently cannot, but the coordinator would still prefer not to accept paper products. With an increased capacity to accept and process waste, the UniHuerto could justify an institutional norm that the cafeterias must separate their organic waste for composting on campus. Since the cafeterias are operated on a contract basis, this requirement could be written into the contracts.

The coordinator's vision for composting at UASLP is smaller in-situ processing points, not transporting compost between campuses. He sees the ZUP campus as a pilot campus to demonstrate how it could be replicated at the other campuses across the state. In terms of communication with the university community, the coordinator described his approach by quoting the movie *Fight Club*, "The first rule of fight club is don't talk about fight club." He values putting actions over words and leading by example over publicity. For him, demonstrating sustainable actions is more important than communicating. The outreach to the university community consists of information provided through the SGA by the AA, direct contact with individual laboratories that generate large amounts of organic waste, and composting and gardening workshops, which have a cost to participate.

He said the biggest challenge for continuing and expanding the composting system is people who do not follow instructions. He gave examples of people throwing trash or cigarette butts in the compost piles to demonstrate his point that "*El ser humano es cochino*" (Human beings are gross). According to him, attempting to convince the masses to behave sustainably is a lost cause, and one should focus only on one's own locus of control. As he puts it, "*Para de llorar y ponte a cultivar*" (Quit crying and start sowing). When pushed to identify a system level priority for the PROSEREM, he said purchasing the shredder machine would be the next most important step.

6.2. CURRENT STATE VALUE STREAM MAPS

The information gathering described in the preceding section was done in service of the second lean principle, identify the value stream. The goal of the VSM is to capture as much objective information about the performance of the value stream as possible and present it in a quickly understandable to form the basis for continuous improvement conversations. The current state VSMs for the three value streams can be seen in Appendix H, and the main take-aways from each are described in the following subsections.

The three value streams were mapped separately according to their product families, but they are in fact interrelated. The inorganic non-recyclables value stream is the default, catch-all, business-as-usual process of the linear disposal-based model. The recyclables and organics value streams have the potential to divert material from this value stream and back into productive use. Many challenges and improvement ideas are applicable to all three value streams, and changes in any of the value streams impact the others.

6.2.1. Inorganic Non-recyclables

In traditional lean applications, time is money. In the adaptation of lean to the university ISWM context, flowing the waste through the value stream as fast as possible does not directly translate to more money, but the comparison of value-added to non-value-added time is still useful as an illustration of the efficiency of the value stream. In this case, less than 4% of the total time is value added time, illustrating the many inefficiencies in the process.

The first waste of lean is “Defects,” which is shown on the VSM by PNC. The PNC rate for the disposal step is 60%, meaning there are many items being incorrectly disposed into the non-recyclable value stream. Reducing the PNC for this step by improving waste separation would reduce the amount of inventory awaiting processing in all the subsequent steps. Unknown amounts of these recyclable and organic wastes are being harvested from this waste stream through *pepena* and the UniHuerto.

Both the scheduling managers emit daily schedule adjustments, which is both symptom and a cause of the high level of variation in the value stream. The PNC rate for loading on the internal route is estimated at 60%, because, as the driver explained, more often than not, something changes that prevents him from collecting all the waste from all the assigned collection points. A missed collection one day, leads to a schedule adjustment the next day, which creates unpredictability, instability, and the need for more schedule changes in a reinforcing loop.

The Nissan route is a source of additional variability, transportation, extra processing, and defects. Driving the waste to ZUP, unloading it, and loading it again is a waste of transportation and processing. The waste also occupies capacity in the garden waste and internal route trucks, which contributes to not successfully collecting all the waste from the assigned ZUP collection points.

Finally, the lack of communication between SJ, Peñasco, and the Maintenance Manager allows the high PNC in the internal route dumping step (50%) to go unnoticed, and waste to be illegally dumped.

6.2.2. Inorganic Recyclables

The VSM for the inorganic recyclables is quite obviously missing a flow from the ZUP campus generators to the customer, RECICLO. The only process that currently exists is for collecting waste from individual participants at the monthly responsible consumption space events. That system, like the non-recyclables VSM, is very inefficient, as shown by the comparison of value-added to non-value-added time. The main source of this inefficiency is the low frequency of the event, shown by the TD (uptime) of only 0.5% in the weighing and registering data step, which causes very long wait times.

The lack of data is also noticeable, represented by the question marks in the data boxes on the VSM. All the recycling currently performed is done either informally and against university policy, or individually, voluntarily, and off-campus, making the process non-standard and difficult to observe. For example, the transport step is different for each individual who participates in the collection event.

There is room for improvement in the loading step, which is currently performed in one large batch, shown by the inventory of 876 kg being equal to the L (batch size). There are no containers used to store the recyclables after they are received and waiting to be loaded. The recyclables are heaped in a disorganized pile, which must then be loaded by hand onto the RECICLO trailer at the end of the event. This requires the participation of all the event workers as well as the RECICLO drivers, takes fifteen minutes, and leads to errors, shown by the PNC of 5%, such as broken glass or light materials being taken by the wind.

Finally, similarly to the non-recyclable VSM, documentation is not being sent from RECICLO to the AA. This contributes to the need for the weigh and register data step, which is the only source of data on quantity received. This increases the number of workers required to run the collection events as well as the TE (wait time) and TC (cycle time) of the weigh and register data step.

6.2.3. Organic Compostables

There are two processes available for the organic wastes value stream. The upper process could be called “self-service” and the lower process “drop-off.” The drop-off process is quite obviously less efficient than the self-service process, adding three extra process steps and 422.5 extra minutes of non-value-added time, as well as TC (cycle time) and TE (wait time), creating a bottle neck of inventory at the unloading step.

As in the recyclable VSM, there is no process for capturing the daily generation of the campus community, only a system for individual participants. The existing system relies on direct face-to-face instruction from the UniHuerto director, which likely contributes to the low PNC rate, but is time-intensive and only feasible for a limited number of participants.

Finally, the only data on quantity of organic wastes processed is the yearly compost report. This figure includes not only the organic waste received from the self-service and drop-off processes, but also the garden waste mixed into the composting process. This data is not temporally or categorically fine enough to support planning or management decisions.

6.3. FUTURE STATE VALUE STREAM MAPPING

6.3.1. The Shingo Model in Action

The traditional VSM process involves the participation of the stakeholders from the value stream processes. Those who work in the processes are considered the subject-matter experts (SMEs) in how the processes work and how they could be improved. The SMEs often have more knowledge about the processes than their supervisors, and valuable ideas can be generated from dialogue between SMEs from different processes in the value stream and between SMEs and managers. Unfortunately, institutional politics of the UASLP made holding this type of workshop challenging and potentially threatening to the job security of those working in the process. The decision was made to host three smaller workshops with only the Institutional Manager, the author, and the supervisor of the key processes for the given value stream.

One of the advantages of this approach was that supervisors could have time to assimilate information that revealed opportunities for improvement without an audience. Employees could also remain more anonymous, reducing the possibility of negative repercussions. Finally, the ideas generated came mostly from the supervisors with some guidance from the author, which could promote a stronger commitment to implementing them in the future.

However, there were also significant disadvantages. Employees who had been asked for input in the VSM process and had been told about the workshops were excluded in the end, undermining the messaging of the importance of their participation. The ideas proposed in the workshops could not be immediately vetted for viability by those who perform the work. Not all the ideas that employees had shared during the data gathering could be incorporated into the workshops, and the opportunity to hear ideas that would have come from the dialogue between supervisors and SMEs and between SMEs from different process steps was missed.

Some of the ideas previously offered by employees also came up in the workshops, but in the end, 12 ideas from SMEs were not incorporated into the improvement bursts agreed upon in the workshops (Table 13).

Table 13. Improvement ideas not incorporated into the improvement action plan, by author.

Improvement idea	Source
Improve management of RP and RPBI to prevent contamination of RSU.	Administrator Point 3
Pilot project in one building or one faculty to prototype containers and separation process before expanding to rest of university	Administrator Point 3
Log distances and destinations in a logbook in the trucks; audit the log weekly when gas is given to monitor mileage and form part of a preventive maintenance program.	Emergent route drivers
Purchase one trash collection vehicle for ZUP and dedicate the other trucks to other tasks.	Emergent route drivers
Use dumpsters at the collection points and have one truck that can load the dumpsters directly onto the truck to bring them to SJ.	Emergent route drivers
Bring garden waste to municipal dump instead of San Juanico.	Emergent route drivers
Re-institute an accountability system for leaving the points clean after collection.	Emergent route drivers
Awareness and education campaign for professors about respecting the collection points.	GW Route Drivers
Preventive and corrective maintenance program for collection trucks.	GW Route Drivers
Provide more and better equipment for the drivers.	GW Route Drivers
More centralized micro-stations and fewer small containers in classrooms, offices, and labs.	Point 2 unionized janitor
Pilot project in one building or one faculty to prototype containers and separation process before expanding to the rest of the university.	Point 2 unionized janitor

6.3.2. Improvement Burst Maps

During the VSM workshops, improvement bursts were drawn on the VSMs identifying which part or parts of the value stream would be impacted by each of the improvement ideas discussed. The improvement burst maps for each of the value streams can be seen in Appendix I, and the numbered improvement bursts correspond to the following tables. To focus the discussion, participants were prompted to envision the medium-term future, and consider what was optimistically possible for the year 2025.

6.3.2.1. Non-recyclable wastes

In the non-recyclable waste workshop, only five improvement ideas were agreed upon, but the ideas are relatively broad, impacting multiple areas of the value stream. The ideas are listed in the order in which the participants agreed they would ideally be implemented (Table 14).

Table 14. Improvement ideas identified for the non-recyclables value stream, by author.

#	Improvement Bursts
N1	Require receipts or other confirmation that wastes are delivered to their assigned disposal site.
N2	Create a more specialized department or unit to be responsible for solid waste management, other than the maintenance department.
N3	Host an activity at the beginning of each semester to introduce the PROSEREM.
N4	Shred garden waste on campus rather than sending it to San Juanico.
N5	Remove points 1, 2, and 3. Consolidate non-recyclable waste collection at current point 4 with legally compliant container(s).

6.3.2.2. Recyclable wastes

Seven improvement ideas were agreed upon in the recyclables workshop, listed in ideal order of implementation (Table 15). As the value streams are interrelated, it is important to note that improvement ideas for one value stream have implications for the others. This workshop was conducted after the non-recyclables workshop, for example, and thus the plan to combine the four collection points into one (N5) was incorporated into the ideas. The collection point mentioned in R3, R4, and R5 is the same collection point described in N5.

Idea R2 has also significant implications for all three value streams and coordinates with idea C1 in the following section. In this workshop, it was agreed that separating the recyclable value stream into two categories would be ideal for conserving the quality of the recyclable material without adding too much room for confusion. The categories decided were based on those being implemented in the university library system. Orange for “recyclables” and blue for “paper and cardboard.”

Table 15. Improvement ideas identified for the recyclables value stream, by author.

#	Improvement Bursts
R1	Obtain receipts from RECICLO for each collection showing volume and date.
R2	Rework PROSEREM categories to include 4 categories, adding one for paper and cardboard.
R3	Collaborate with RECICLO to design and build the appropriate containers for the collection point.
R4	Purchase custom super sacks to be used only for the UASLP that can be interchanged inside the containers at the collection point and at the collection events.
R5	Place adequate containers at the collection point to keep the point orderly.
R6	Expand or adjust hours of the Responsible Consumption Space to accommodate those who work during the day.
R7	Increase and improve communication to the university community with murals, videos, better signage, and QR codes on containers.

6.3.2.3. Compostable wastes

The compostables workshop generated 13 ideas for the year 2025, and one additional longer-term idea that warranted mention in the action plan (C14) (Table 16). Ideas N4 and C3 are the same but have different benefits in their respective value streams. C1 corresponds to R2, in this case renaming the gray and green categories to generate less confusion. It was agreed that gray would correspond to “non-recyclable wastes” and green to “compostable wastes,” removing the terms organic and inorganic which, based on the generator survey, seemed to cause unnecessary confusion.

Table 16. Improvement ideas identified for the compostables value stream, by author.

#	Improvement Bursts
C1	Rework the PROSEREM categories (compostables, recyclables, non-recyclables).
C2	Collect garden waste generation data.
C3	Place sign or plaque at the compost processing point indicating not to smoke.
C4	Place containers for recyclables and non-recyclables at the compost processing point so people can dispose of their waste properly.
C5	Purchase shredder.
C6	Update list of compostable wastes accepted.
C7	Designate a space for hot composting in the processing point.
C8	Get rid of container drop-off system.
C9	Place appropriate infrastructure for separation of organic wastes on campus.
C10	Locate containers in ideal place to facilitate collection by the janitors.
C11	Educate directors about the importance of separating organic wastes.
C12	Increase the participation of the university faculties, offices, and other entities.
C13	Receive larger quantities of organic waste.
C14	Purchase biodigesters. *

6.3.3. Future State Value Stream Maps

The future state maps, showing how each value stream would function in 2025 after implementing the improvement ideas, are shown in Appendix J. An important gain for the PROSEREM in general from implementing the improvements to reach these future states is that doing so would bring the ZUP campus into compliance with its legal responsibilities discussed in section4.4.5. In all three value streams, the communication flow is improved, represented by the change from dashed lines to solid lines. However, data is still missing in all three cases for various reasons, including the addition of new processes that do not currently exist, the continued existence of informal processes, or the addition of the new waste classification. The table below shows the projected KPI values for June 1st, 2025, if all the improvement bursts are implemented as compared to the current state and the goals for the program. In the following section, each future state value stream is discussed in more detail.

Table 17. Projected KPI values for 2025 based on implementation of the agreed improvement ideas, by author.

Key Performance Indicator			Current 2023	Goal 2030	Projected 2025
Leading					
E	1	% ZUP Campus community who believe separating organic waste is important	89.4	98	92
E	2	% ZUP Campus community who believe separating recylable waste is important	96.9	98	98
E	3	% ZUP Campus community aware of PROSEREM	20.7	50	44
E	4	% ZUP Campus community who correctly identify organic waste container	84.4	90	87
E	5	% ZUP Campus community who correctly identify recyclable waste containers	74.4	90	80
E	6	% ZUP Campus community who correctly identify non-recyclable waste containers	80.0	90	83
E	7	PROSEREM participation score for ZUP campus community	24.8	50	30
E	8	% of micro-stations with correct set of containers	2.7	25	5
E	9	% of containers with cross-contamination of wastes	75	50	70
E	10	% of cleaning staff trained on PROSEREM	0	50	0
Lagging					
S	1	Incident reports at collection points per month	3.6	2.0	3.6
S	2	Organic compostables mass kg/day	92.94	92.94	92.94
S	3	Organic compostables volume m3/day	0.39	0.39	0.39
S	4	Inorganic recyclables mass kg/day	193.82	193.82	193.82
S	5	Inorganic recyclables volume m3/day	6.05	6.05	6.05
S	6	Inorganic non recyclables mass kg/day	321.82	96.55	321.82
S	7	Inorganic non recyclables volume m3/day	9.78	2.93	9.78
S	8	Total RSU to Peñasco mass kg/day	*0.23	0.00	0.00
S	9	Total RSU to San Juanico landfill mass kg/day	*0.40	0.32	0.30
S	10	Total RSU to Peñasco volume m3/day	6.16	0.00	0.00
S	11	Total RSU to San Juanico landfill volume m3/day	10.63	9.78	8.00
S	12	RSU to Peñasco mass kg/capita/day	0.018	0.00	0.00
S	13	RSU to San Juanico landfill mass kg/capita/day	0.032	0.001	0.001

6.3.3.1. Non-recyclable wastes

Implementing the improvement action plan for 2025 significantly reduces the lead time of the non-recyclable wastes value stream. The VAT is reduced by almost one hour, and the NVAT is reduced by 24 hours. This is due mostly to the enormous improvement in PNC rate in the loading, and transfer steps as a result of consolidating the collection points into one easily accessed point. The PNC rate of the dumping step is also improved from 50% to 0% by adding the requirement for receipts or confirmation for each load.

These improvements as well as the diversion of the garden waste to the compostables waste stream allows the collection to be done with fewer staff and with a much greater degree of predictability. Daily schedule adjustments are no longer needed, and the maintenance staff members currently doing the waste collection can return to working within the job descriptions for which they were hired. The new Department of Cleaning and Environmental Protection provides one or two specialized, well-trained staff members for waste collection.

The PNC rate for separation is still high but improved compared to 2023 due to the orientation activity. Worker safety is increased by not bringing wastes to Peñasco, but the incorrectly separated recyclables and compostables still in the value stream are lost to San Juanico. The total amount of waste brought to Peñasco and San Juanico, however, is reduced from 620 kg/day to 300 kg/day, assuming diversion of the garden waste and a PNC rate of 40% at the separation step.

6.3.3.2. Recyclable wastes

The VAT is increased in the recyclable wastes value stream in 2025, but that is due to adding an entire process that did not exist previously. The NVAT is significantly reduced due to the increased frequency of the responsible consumption space collection events and the corresponding reduction in wait time.

There is an increase in communication from the AA to the and campus community, cleaning managers, and janitors leading to an estimated improvement in PNC rate of the separation and transport steps as compared to the existing practices observed in the non-recyclables value stream.

The number of workers required to manage the responsible consumption space events is reduced because of the receipts sent form RECICLO and the use of super sacks to store and load the materials. *Pepena* inevitably still exists at the micro-stations and the collection point containers, but it is safer for those to engage in it because of the improved waste separation.

6.3.3.3. Compostable wastes

The compostable wastes value stream also has an increase in overall lead time, but two new processes were added, and the old, inefficient, drop-off process was removed. Individuals can still participate in self-service drop-off of their household compostable wastes.

Most of the additional NVAT comes from the wait time for the new transport-unload-shred process. The idea discussed in the workshop was to run the shredder once a week. Batching like this is not necessarily inefficient in this case, unless it causes other problems, like a reduction in the quality of the material or delays in being able to use the material in subsequent process steps.

TC and L (batch size) for shredding are not known. In the workshop, the idea of using the wheelbarrow to bring garden waste to the compost processing point for shredding was discussed, so the most precise unit available for the batch size would be the capacity of the wheelbarrow. The time required to process that amount cannot be known until the shredder is acquired.

The estimated value of 404 kg for daily organic waste processing in the hot composting area is based on estimations of the garden waste generated, the organic waste amounts from the waste characterization, and the estimated amount of compost currently being dropped off by individuals in the self-service system. This does not include the cafeteria food waste. While it is highly unlikely that all the organic waste generated on ZUP campus will be captured, this is the best available high-end estimate of the quantity that could be obtained without requiring cafeterias to participate.

6.4. IMPROVEMENT ACTION PLAN

The improvement ideas agreed upon in the workshops were compiled into a proposed improvement action plan (See Appendix K). Each improvement was assigned to a responsible party or parties, and target start and completion dates were established. The material costs for each improvement were estimated based on standard consumer prices found via an internet search. The university could likely obtain lower costs through its formal purchasing processes and through in-house services, such as printing of signage. Thus, the cost estimations are assumed to be high estimates. Quotes were requested through the university for signage and containers, but the information was not provided in time for inclusion in this thesis.

The only improvement for which it was unrealistic to estimate a cost was R7. There are so many possible strategies for improving communication to the university community, that the best strategy would be to determine a budget and select suitable strategies accordingly. Seven of the 26 improvements have no initial or ongoing cost, and eight cost only staff time.

Staff time is acknowledged as an investment but not calculated in the cost because the tasks fall within the existing duties of the responsible parties, the improvements are expected to save time in other areas to offset the time spent implementing them, and scholarship recipients can provide no-cost support, for example in R6 or C3. The creation of the new subdepartment is assumed to involve restructuring and retraining, not hiring of additional staff.

Of the improvements that have an initial financial cost, the most influential is C6, the purchasing of a shredder. This improvement affects all three value streams and allows for significant reduction in transfer costs. The next priority cost would be R3, the installation of recycling containers at the consolidated collection point, because this allows for recyclable wastes to be diverted from the non-recyclable waste stream and for the recyclable collection service to begin.

6.5. POSSIBILITIES FROM LEAN MANAGEMENT

The improvement action plan based on the improvements agreed upon in the workshops would represent significant progress for the PROSEREM. However, in addition to the ideas from SMEs that were not incorporated, the following improvement ideas identified by the author based on previous experience applying the principles of LM could also be incorporated into future improvement plans.

1. Provide an easier incident reporting method that can be quickly used in the field.
2. Perform a waste characterization on the garden waste.
3. Implement a Kanban pull system for consumable supplies such as RPBI containers, transparent trash bags, gloves, and face masks.
4. Conduct regular vehicle audits for collection vehicle(s) to ensure they are in good condition and stocked with the necessary supplies.
5. Schedule non-routine collections based on a pull system.
6. Pursue formal recognition by the municipality for proper RSU management (Gallardo Juárez & Aranda Martínez, 2017).

Lean is an organizational culture shift, not a one-time task. When implemented properly, it becomes a *continuous* system of improvement. The improvement possibilities identified in the workshops, by the SMEs, and by the author suggest that LM has significant potential impact. The following chapter discusses the considerations for doing so in the PROSEREM context and in the university ISWM context in general.

CHAPTER 7. THE APPLICABILITY OF LEAN MANAGEMENT

The theoretical framework (Figure 7) described in chapter three, provided a guide to adapting LM to the university ISWM context based on input from the fields of waste characterization and recycling behavior. The following sections discuss the adaptations that resulted from combining these concepts with LM.

7.1. WASTE CHARACTERIZATION

Applying LM to solid waste required performing a waste characterization in a “lean” way. As other universities have done (Lázaro, 2020), this study simplified existing methodology from NMX-AA-022 to provide only the data needed for management decisions, while working within the university’s staffing and funding limitations. The purpose of waste characterization is to facilitate informed waste management, so good practice is to base characterizations on categories that have the potential to be managed differently, which is context dependent and may evolve over time. In the starting case of the PROSEREM, this meant quantifying the waste types that would receive the same treatment, similar to how products processed the same way are grouped into product families in traditional lean applications (Nash & Poling, 2008). Quantifying the recyclable, compostable, and non-recyclable categories provided previously lacking baseline information about the amount of waste possible to divert from final disposal.

To save time and reduce the need for staff, the characterization was completed at the four collection points rather than upstream at the point of generation. This decision reduced the precision of the data from the building level to the collection zone level, but this level of detail was deemed sufficient to fill the basic knowledge gaps necessary for making early management decisions. However, compared to other universities, the characterization showed a lower percentage of recyclable and compostable waste. It became clear that there was a difference between the waste generated and the waste collected due to *pepena* occurring along the collection chain.

Other university waste characterizations conducted sampling further up the collection chain, or at the point of generation, which likely reduced the impact of waste picking on the resulting data. In Mexico, the Autonomous University of Baja California (UABC) found that recyclables and compostables represented between 55% and 88% of the waste stream depending on the building (Armijo de Vega et al., 2008), and Universidad Iberoamericano found that 52% of waste was compostable, 27% was recyclable and only 21% was non-recyclable” (Ruiz Moralez, 2017). One Nigerian university found the recyclable potential to be between 69% and 93% for different campus zones (Adeniran et al., 2017), and in Canada, another found it to be over 65% (Smyth et al., 2010). In contrast, at the ZUP campus collection points, only 46.9% of waste was found to be compostable or recyclable, excluding of course the garden waste and any waste picked along the collection chain.

The characterization was also conducted on only one day at each point in the low and high season. Later, it was discovered that waste was being brought from other campuses on certain days to certain points, influencing the total amount of waste on specific days. The job shadowing with janitors also revealed that some compile wastes over multiple days before bringing a full bag to the collection point. The ideal situation would have been to exclude external wastes from the ZUP campus characterization study and perform the study over several consecutive days to account for these fluctuations.

The information that came to light during the job-shadowing with collection staff and janitors informs future adaptation of the waste characterization strategy and illustrates the importance of understanding the complete value stream. This first ever waste characterization on the ZUP campus was imperfect but provided sufficient data of high enough quality to fill critical knowledge gaps and enable more informed decision making about composting capacity, collection frequency, and recycling potential. In the future, the procedure can be continuously improved and adjusted as the data needs change. Due to the decision to combine the four collection points, the first modification could be to perform the characterization over four days at the single point instead of one day each at the four points, thus achieving higher quality data without any additional staff or time requirements. It will also be important to characterize the garden waste and could prove useful to quantify sanitary waste separately to understand how much of the non-recyclable value stream cannot be eliminated through source reduction.

7.2. RECYCLING BEHAVIOR

To increase participation in the PROSEREM and create patterns of recycling behavior, it was necessary to consider the factors that influence behavioral intention, which in turn influences the probability of executing the behavior. According to the theory of planned behavior, these three factors are attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991).

There is a general perception among staff, faculty, and students on the ZUP campus that people do not recycle or compost because they don't care. The generator survey indicates this is not true. Rather, the combined results of the survey and the infrastructure characterization suggest even the people who care do not have the knowledge, infrastructure, or systems necessary to do it. The Shingo model assumes the best intentions in people and that if the desired behavior is made clear and easy, people will perform it. Rather than blaming people, it aims to fix the systems that prevent translating intention into behavior.

7.2.1. Generator Survey

The results of the generator survey indicate that the university community already has a well-established positive attitude towards environmental protection, recycling, and composting. Respondents stated that their concern for the environment influences their decision to separate their waste on campus, which is consistent with results from other studies showing that concern for the environment has a positive influence on recycling behavior (Chao et al., 2021a). This attitude should be monitored and maintained, but it is not necessary to invest many resources in imparting information or building understanding related to the importance of environmental protection or the separation of waste because these beliefs are already well established.

In the municipality of San Luis Potosí, there is already a legal norm that requires the separation of organic and inorganic waste to a minimum (Gallardo Juárez & Aranda Martínez, 2017). However, the existence of a legal norm does not mean it is followed. The infrastructure and systems are required to carry it out, and the intention to perform a behavior is usually influenced more by social norms than by legal norms. If one perceives that others separate their waste, or that the separation is viewed positively by others, one's intention to do so increases.

According to the theory of planned behavior, the perception that a behavior is acceptable, normal, or esteemed, positively influences the intention to do it (Ajzen, 1991). Therefore, the intention to separate waste tends to correlate with how common the practice is. The responses indicate that most of the respondents do not separate their waste on the ZUP campus and, perhaps for this reason, very few said that seeing other people separating their waste influenced their decision to separate theirs (Figure 30). The more people start to separate their waste, the more social pressure there will be for others to do the same. This will be reflected in the PROSEREM participation scores and will be a gradual cultural shift, but participation is not a yes-no phenomenon, and any increase in the degree of participation is beneficial.

The third factor of intention is the key to improving waste separation on the ZUP campus: perceived control. This refers to the perceived probability or ease of success, which includes separating the waste correctly, locating the correct container, bringing the waste to the container, and the waste reaching its appropriate destination for recycling or composting. As expected, the survey results show low perceived control. Many respondents identified a lack of knowledge on how to separate waste, on the location of the appropriate containers and even on the existence of such containers and of the PROSEREM (Figure 29). There was also a notable lack of confidence in the processing of waste once separated. Some respondents stating that, even if they separated their waste correctly, the janitors and collection staff would combine it, rendering their efforts useless.

It has been shown that a pro-environmental attitude is not enough to change behaviors (Alzaidi & Iyanna, 2021; Largo-Wight et al., 2012; Oke et al., 2021b). Still, the perception exists that explaining the importance of a behavior is the same as teaching it (Heimlich & Ardoin, 2008). To teach the behavior of separating the waste and turn it into a habit, it will be necessary to fill the gaps in the basic knowledge of PROSEREM. Almost all survey respondents noted that more specific education about how to separate waste would be helpful. Because there is no larger municipal recycling or composting collection or processing system, most university community members do not come to campus with previous experience separating waste. It is not a part of the broader SLP culture, and thus it needs to be explicitly taught within the university.

The community needs to know the program, the locations of the appropriate containers, and the types of waste that correspond to each one. They also need the opportunity to practice and improve their skills based on feedback. There are many ways to offer this possibility, for example, placing volunteers at new micro-stations during times of high generation to teach people how to properly separate their waste and answer their questions directly (Lin et al., 2016). The more experience and positive feedback the community receives, the more confident they will be when disposing of their waste, and therefore the more motivated they will be to do so.

7.2.2. Infrastructure Characterization

However, educating the university community about how to separate wastes priority will only increase perceived control if there is actual control to support it. Because the Municipality of San Luis Potosí does not have the systems or infrastructure in place to achieve ISWM, it is essential to install adequate containers for separation and establish separate collection systems to increase the control the of the university community over its own waste (Largo-Wight et al., 2013; Oke et al., 2021b). In the current state, there are almost no separate containers for compostables and recyclables on the ZUP campus, and no separate collection system. The containers that do exist are inconsistently labeled and not strategically located, making separating waste feel inconvenient, confusing, and pointless.

Adding adequate infrastructure to make separating wastes convenient and obvious has a greater impact than any other factor. Studies on other university campuses have shown that the most significant improvement in recycling and composting rates comes from simply pairing recycling and composting containers with trash containers, even without any accompanying education (Largo-Wight et al., 2013; Ruiz Moralez, 2017). This first characterization made it obvious that the infrastructure for separation is lacking, but that the collection frequency is adequate. Once the containers for the micro-stations are acquired, future infrastructure audits can assess the location of micro-stations, and the frequency of collection for the separate waste streams.

7.3. THE TWO SIDES OF LEAN MANAGEMENT

In this adapted application of LM, waste characterization was the foundation of system improvement, and recycling behavior the basis for the Shingo model (Figure 7). Lean management is the combination of these two approaches. One without the other is not only not lean but also not effective.

7.3.1. System Improvement

On the system improvement side, the lean principles previously described are applied to continuously improve by identifying and eliminating eight types of waste (Table 6).

7.3.1.1. Key Performance Indicators

Selecting the appropriate KPIs is essential for guiding this continuous improvement process. On the most basic level, the KPIs selected (Table 9) solved the common challenge of universities not knowing how much waste they really produce (Ruiz Moralez, 2017). They also served the purpose of informing management decisions by quantifying the relevant product families and including both leading and lagging indicators.

As circumstances change, priorities shift, and new information is obtained, KPIs should evolve to continue to inform process improvement decisions. Based on the outcomes of the value stream workshops, several adjustments to the KPIs will already be necessary. Indicators S8, S10, and S12 can be removed because wastes will no longer be brought to Peñasco, and two new lagging indicators will need to be added for the mass and volume of the new paper and cardboard subcategory of recyclables. A leading indicator about source reduction practices such as green purchasing, double sided printing, or use of refillable bottles should also be considered.

7.3.1.2. Principles of System Improvement

Based on the KPIs, the performance of the value stream can be characterized, and measurable improvement goals can be set. To meet the established goals, wastes are systematically identified and eliminated by applying lean principles. In this lean application, the five main principles of lean guided the identification of improvement opportunities, with only slight adjustments to their usual interpretation.

The first principle, “specify value,” traditionally means value for the customer. Any materials, features, or processing that does not have value for the customer is considered waste. This general principle is true in the ISWM context, except that the idea of “customer” needs to be seen more broadly. The final disposal sites are analogous to the customers in a traditional value stream, but they do not pay for the product and thus do not have as many demands about its quality or characteristics. However, it was still necessary to understand their perspective to facilitate acceptable separation of wastes and appropriate collection strategies. In addition to the final disposal sites however, the environment and the entire university community could also be considered customers of the value streams because they are also served. Thus, some processing steps that are not absolutely necessary for final disposal, are justified because they provide social or environmental value.

“Identify the value stream” is the second principle, and this was applied in the traditional manner of directly observing each of the processes involved in moving the RSU through the value stream. Through observing all the processes, the author and those who participated in the workshops gained a complete view of the functioning of the value streams, but in a full lean implementation, this principle also means that workers in each process step should understand the overall value stream and their role within it. Achieving this requires more systematic and ongoing communication than was possible within the scope of this thesis.

The next principles, “flow” and “pull” refer to the uninterrupted movement of RSU through the value stream and the way work is prompted. In the starting state value streams, there simply was no flow of recyclables or compostables from the generators on the ZUP campus, and the flow of non-recyclables was often interrupted by errors or waiting. Work was often scheduled by “pushing” rather than “pulling,” in that schedules were often adjusted in response to urgent situations. To promote pull, improvement ideas sought to stabilize the value stream and improve communication and information flow so that work can be triggered by predictable schedules rather than forced by emergent circumstances.

The final principle “pursue perfection” refers to the continuous improvement process. Lean management is not one isolated fix, but rather an ongoing systematic approach to improving the way work is done. This is traditionally done through the iterative practice of “Plan-Do-Check-Act,” referred to as “kata” or daily practice in the TPS (Marchwinski, 2003). This is a practice that needs to be systematized, and such a system does not currently exist for the PROSEREM. The steps initiated in this thesis can form the basis for establishing an ongoing monitoring and improvement system, but doing so will depend on the decisions of university authorities.

7.3.2. Shingo Model - Respect for People

The complement to system improvement is respect for the people who work in the system. This aspect of LM proved more difficult in this application. Many negative beliefs about people in various parts of the value stream needed to be combatted.

First, the generator survey aimed to understand the needs and beliefs of the university community with respect to recycling and composting to inform how to approach increasing participation in PROSEREM. The data refuted the belief that “people don’t care,” which helped shift the responsibility off individual people and onto the system itself.

Incident reports had not been systematically processed or addressed, which lead many employees to feel submitting them was pointless. Failing to take advantage of the knowledge and experience of SMEs in this way is neglected talent and a missed opportunity to make employees feel valued in the improvement process. The idea to improve the way incident reports are submitted and processed was not included in the final list of improvement ideas from the workshops, but it is the opinion of the author that it is important to do so.

Prioritizing the safety and health of workers above all else is the most fundamental way to show respect. In the current state, workers often work without the necessary PPE and tools to perform the collection safely, and some must enter the unsafe conditions of Peñasco daily. When the author requested to perform the job-shadowing with the internal and external routes, there was hesitation on the part university authorities to approve it. If the conditions at Peñasco are not safe enough for the author, then perhaps they should not be considered safe for the workers either. In the job-shadowing of several routes, drivers commented they found ways to avoid going to Peñasco, either going to San Juanico or uncontrolled dumpsites instead. The change in the future state to skip Peñasco is a first step toward showing the drivers their safety is valued.

The Shingo model advocates for accountability rather than punishment. Workers should be trained and responsible for doing the work correctly, rather than simply punished for doing it wrong. Systems of accountability are lacking in all the process steps in the current state. The improvement idea of tracking receipts from San Juanico is a first step toward accountability, but ideally it would be accompanied by monitoring gas and mileage to assure that there is in fact enough gas for workers to complete the route. Tracking the gas, mileage, and receipts would promote fairness and accountability.

Unfortunately, the culture of the university is not based on these principles. It tends more toward punishment, strict hierarchies, and an adversarial relationship between employees and managers. This atmosphere did not permit participatory meetings with all stakeholders at one time. Instead, a modified approximation of the workshop events was conducted so that anonymity and job security for the employees could be maintained. To move toward full LM, it will be important to create spaces for non-hierarchical interaction between all process stakeholders to that ideas and problems can be expressed without fear of repercussions.

Finally, respect for people and their abilities is essential for the development of in-house expertise, and in-house expertise is crucial for the decentralized decision-making structures that make LM most effective. For the continued improvement of the PROSEREM, more training must be offered, and it must be offered systematically. This involves not only providing training, but also standardizing and documenting how repeated tasks should be performed to enable staff and scholarship-recipients who support the program to be more self-sufficient. In settings with high turnover, documenting the work instructions is essential, and in settings with long-standing staff, ongoing training to maintain and develop expertise is necessary and valuable.

7.4. OBSTACLES TO LEAN IMPLEMENTATION

The potential measurable benefits have been shown of implementing the improvements identified in one workshop for each value stream, but one workshop is not LM, and it remains to be seen if the improvements will in fact be implemented. At the UASLP and at any organization, there are numerous obstacles to lean implementation.

In a systematic literature review, Chaple et al. (2021) investigated the reasons that attempts at LM often fail and identified 44 different obstacles to lean implementation, which were grouped into ten categories—knowledge, conflict, management, resources, technology, employees, financial situation, customers, culture, and past experience. These were then assessed based on their potential to drive change and degree of dependence on other factors.

The financial situation at UASLP was frequently noted as an obstacle to improvement of the PROSEREM. However, the experience from this LM application supports findings from other universities that institutionalization of waste separation behaviors is possible with very little financial investment (Smyth et al., 2010). Other than staff time, the UASLP invested only MXN 500 in this work, and many of the improvement ideas generated cost nothing to implement (see improvement plan in Appendix K).

Obstacles with high driving potential and low dependence on other factors are those that are most important to overcome. These include insufficient supervisory skills, lack of support from senior management, and shortage of management time (Chaple et al., 2021), all of which fall under the categories of knowledge, management, and culture.

Knowledge of LM and time shortage are both obstacles for the PROSEREM. Training and support for the Institutional Manager in learning and applying lean principles would facilitate lean implementation. The Institutional Manager has many competing responsibilities, very limited time, and very little support staff. Empowering the scholarship recipients to offer more support through improved procedures and more systematic approaches would allow her to delegate more responsibilities and free up more time.

Management, specifically support from upper management, is also a significant obstacle because, as described previously, the Agenda Ambiental does not have authority to require compliance with its initiatives. Some other universities whose environmental departments have more institutional clout have more robust environmental programs. For example, the Autonomous University of Nuevo León, the highest ranked Mexican university in the GreenMetric rankings, has an environmental secretariate with numerous sub-departments (Fernández Delgadillo, 2023). Without the commitment of upper management, it is unlikely that the AA will be able to generate the political will to improve the PROSEREM on its own. The AA can provide the tools, but implementing LM with only the tools is not possible (Yadav et al. in Chaple et al., 2021), the corresponding cultural shift is also necessary (The Shingo Institute, 2021).

The cultural shift is often the most challenging aspect of lean implementation. In a hierarchical structure such as at the UASLP, fostering open and equal communication and decentralizing decision-making power can be very difficult. Also, LM requires patience and consistency to achieve meaningful results, and maintaining political will for such extended periods of time is also complicated (Gaiardelli et al., 2019).

7.5. LEAN IN THE ISWM CONTEXT

Moving from poorly managed disposal-based systems to ISWM is an important first step along the continuum of sustainability, one of which many universities are in serious need, and one which LM can help accomplish. Although there can never be a directly transferrable formula for any management system because context must always be considered, some broadly applicable adaptations were identified in this study that could facilitate lean ISWM at other universities.

The first difference between the university ISWM context and the traditional lean manufacturing environment is that most of the people involved in a university system are students, not staff. The disadvantage of this is that the university has limited authority over their behavior. Employees can be given work instructions and their continued employment can depend upon following them, but students have only academic responsibilities at universities. This means their behavior changes must largely be voluntary. However, the advantage of working with students is that they tend to be quick to pick up on new, forward-thinking ideas, and they can be involved in improvement efforts for free. Any lean application at a university should utilize this free, highly capable labor, not only to reduce environmental impacts, but also as part of the learning process in ways that promote both inter- and intra-organizational learning (Agyabeng-Mensah et al., 2021; Vargas et al., 2015). Practices developed by or with students can be shared within the university, between different universities through systems such as GreenMetric, and between campus and off-campus life (Blok et al., 2015; Espinosa et al., 2008; Largo-Wight et al., 2012, 2013).

Any lean application to ISWM must also adapt its definitions of "products," and "customers." The product, the object flowing through the value stream, in traditional lean manufacturing is something for which the company makes more money for producing in higher quantities. In this case of ISWM, this is not generally the case. With recyclable and compostable value streams, the products do have some economic value, but very little, and in the non-recyclable value stream, the university actually has to pay for the "customers" to receive the "product." Thus, the traditional lean manufacturing goal of reducing lead time to get products to the customer as quickly as possible because time is money does not apply. Instead, other aspects of LM, such as safety, quality, and resource efficiency, become higher priorities than speed.

The traditional definition of value is based on customer demand. In an ISWM value stream, other values besides the customer expectations must be considered. For example, ISWM provides the value to the campus community of waste removal, or to the environment of reduced contamination. Thus, the "customer" in ISWM is not only the party at the end of the value stream, but also the environment and all the members of the campus community. In traditional value streams, one strategy to eliminate waste is to avoid over-production by not producing more product that the customer demands. However, unlike in traditional manufacturing value streams, in lean ISWM, the option to reduce the production to zero exists and even represents the ideal situation.

As discussed previously, KPIs evolve over time and must suit the needs of the management system. However, based on the experience of developing and measuring KPIs for the PROSEREM, the following guidelines are applicable for other university ISWM systems.

1. Consider the relevant municipal, state, and national legislation. Is certain data required to be reported or a certain classification scheme mandated? Select KPIs that support compliance and compatibility with the extra-university system.
2. Develop both leading and lagging indicators in approximately a one-to-one ratio that have a causal relationship to one another. To guide management, KPIs should provide information not only on what is happening, but also why.

3. Compare the indicators selected to international standards such as ISO 14001 or to those used by universities with similar characteristics via international ranking systems such as GreenMetric.
4. Measure what matters, no more, no less. Do not collect the most easily gathered information only out of convenience. Identify the data that is needed and then design the most convenient way possible to measure it.
5. Plan and document how the KPIs will be collected, how often, and by whom. Involve students and SMEs in their collection.
6. Adjust KPIs as the system changes and improves.

Applying LM in the university ISWM context in this way can be expected to produce measurable improvements in the functioning of the ISWM system, though the exact gains depend upon which KPIs are selected, which goals are set, and which obstacles are presented. Outcomes that are achievable in any university by following these principles include the following:

1. Selecting and obtaining baseline data on KPIs.
2. Systematizing the ongoing collection of KPIs.
3. Targeting education strategies more purposefully.
4. Justifying the installation of infrastructure (containers) or other financial investments based on measurable data.

Because LM is directly compatible with ISO 14001, it is also possible to use this adapted lean strategy as a baseline from which to pursue a fully-fledged EMS and seek certification.

7.6. LEAN AND SUSTAINABILITY

This study and others have provided evidence that LM can make processes and organizations "greener." However, given the responsibility universities have for driving societal change, the potential gains from applying LM to ISWM must be contextualized.

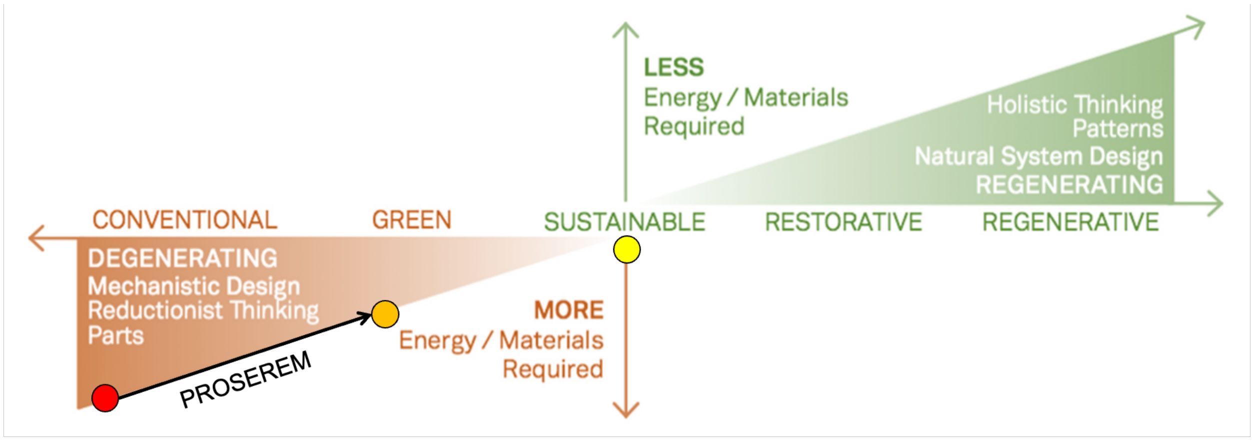


Figure 33. Continuum of sustainability from degenerating to regenerating systems, adapted by author from (Sonetti et al., 2019)

Originally from Bill Reed of Regenesis Group, and adapted by countless authors, Figure 33 shows the continuum from degenerative to regenerative systems. The bottom left position represents systems that consume resources and energy and diminish the functioning of natural systems. Moving upward to the right along the diagonal line represents a shift to using fewer resources and causing less damage, to a net zero state, which is considered sustainable, to regenerative systems that generate resources and repair natural systems.

7.6.1. Lean-green

Based on the KPIs, it is clear that making the PROSEREM "leaner" would also make it "greener." By implementing the improvements identified in the three workshops, the amount of RSU being sent to landfill would be reduced, and more recyclable and compostable wastes would be recovered. Though not included in the KPIs, waste would also no longer be sent to uncontrolled dumpsites, less waste would be transported in vehicles, and the use of gasoline would be reduced. These changes undoubtedly make the solid waste management "less bad." However, as shown by the arrow labeled PROSEREM, the best the program can hope to accomplish through efficiency gains from LM is to move from conventional (red dot) to green (orange dot), or in this case, "lean-green." Making the PROSEREM lean and green is progress, but it is only the first step.

7.6.2. Circular economy

To continue moving up the continuum to sustainability (yellow dot), a zero-waste approach based on circular economy principles would be necessary. Currently, the UASLP is following a common trend among universities of establishing recycling programs while largely neglecting waste reduction at the source (Smyth et al., 2010). The scope of this thesis did not include purchasing, acquisition, or contracting practices, but source reduction through selective purchasing and tendering is extremely important for ISWM on the ZUP campus.

Implementing purchasing and contracting requirements based on circular economy principles would also increase the UASLP's impact on the surrounding community, promoting a circular economy on campus as well as giving a boost to businesses who support such principles. The upcoming national circular economy law will require the university to put such policies in place, so it would be advantageous to begin developing these measures. On the ZUP campus, the most promising place to start would be with the cafeterias, which are major waste generators, currently outside the scope of the PROSEREM, and operated on a contract basis. Writing requirements into the contracts to eliminate difficult to recycle materials such as Styrofoam and to separate wastes according to the four PROSEREM categories would have a significant impact.

7.6.3. Systems Thinking

A limitation of LM is that it is appropriate only for complicated systems. Its principles aim to reduce complexity because predictability is necessary for systematization, standardization, and iterative problem solving through the PDCA cycle. Arguably, any system involving multiple human beings is complex and unpredictable. Therefore, to apply LM, it was necessary to artificially reduce the scope and limit the system to a complicated system, rather than considering all its complexities. This thesis considered only the ZUP campus PROSEREM subsystem, which is a complicated subsystem within larger, complex university and urban systems.

To move beyond sustainability to regenerative systems goes beyond the scope of LM. LM is not intended to change the function of the system, but rather to change how well the system functions.

CHAPTER 8. CONCLUSION

The general objective of this thesis was to evaluate the adaptation of LM strategies to measurably improve the performance of the PROSEREM at the UASLP ZUP campus despite resource constraints. First, leading and lagging key performance indicators were identified. Then, the performance of the PROSEREM was characterized in terms of the KPIs and traditional lean VSM metrics. The VSMs were then used as the basis for workshops where improvement ideas were generated. These ideas were compiled into a proposed improvement action plan and the resulting future state VSM was drawn for each of three value streams—non-recyclables, recyclables, and compostables.

Applying this process to the PROSEREM at the ZUP campus of the UASLP permitted a greater understanding of the ways in which LM strategies, and tools can be adapted to the university ISWM context. While there is no generic formula, it is important for other universities wishing to implement LM for this purpose to consider similar adaptations. Universities work primarily with students rather than employees, and ISWM deals with waste instead of products, and disposal sites and social and environmental impacts rather than customers. Other adaptations to LM strategies depend on the specific context of each university.

To guide lean implementation and improvements to the ISWM system, this study recommends selecting key performance indicators that are legally compliant and compatible with broader system, include an even balance of leading and lagging indicators, are informed by international standards and ranking systems, and focus on data needed for management decisions. It is also recommended to plan and document the procedure for the collection of the KPI data, involve students and SMEs in the collection, and adjust the KPIs over time as the system changes and improves.

By applying LM in this way, other universities can expect to obtain useful baseline data on the performance of the ISWM, systematize the ongoing collection of KPI data, defend the need for financial investment in ISWM using data, and be well situated to achieve legal compliance, implementation of an EMS, and certification according to international standards.

8.1. LIMITATIONS

The results of this study were limited primarily by time. Due to the limited timeframe, it was not possible to implement the improvement action plan and measure the results. Instead, the results had to be calculated or estimated. The improvement ideas included in the plan were also limited by the lack of direct participation from SMEs in the workshops due to university politics. Arguably, the Shingo model was not sufficiently applied to fully evaluate the potential of LM.

8.2. FUTURE RESEARCH

Future research could track the implementation of the improvement action plan and LM in general over a longer period to measure the impacts and identify obstacles. The scope could also be expanded to assess the impacts of changes to purchasing policy on waste generation and management on the ZUP campus. Further studies could assess the transferability of the practices implemented on the ZUP campus to the other campuses of the UASLP, to the municipality of SLP, or to other universities. Finally, such studies could lay the groundwork for research into the design of management systems that push beyond sustainability into the realm of regeneration.

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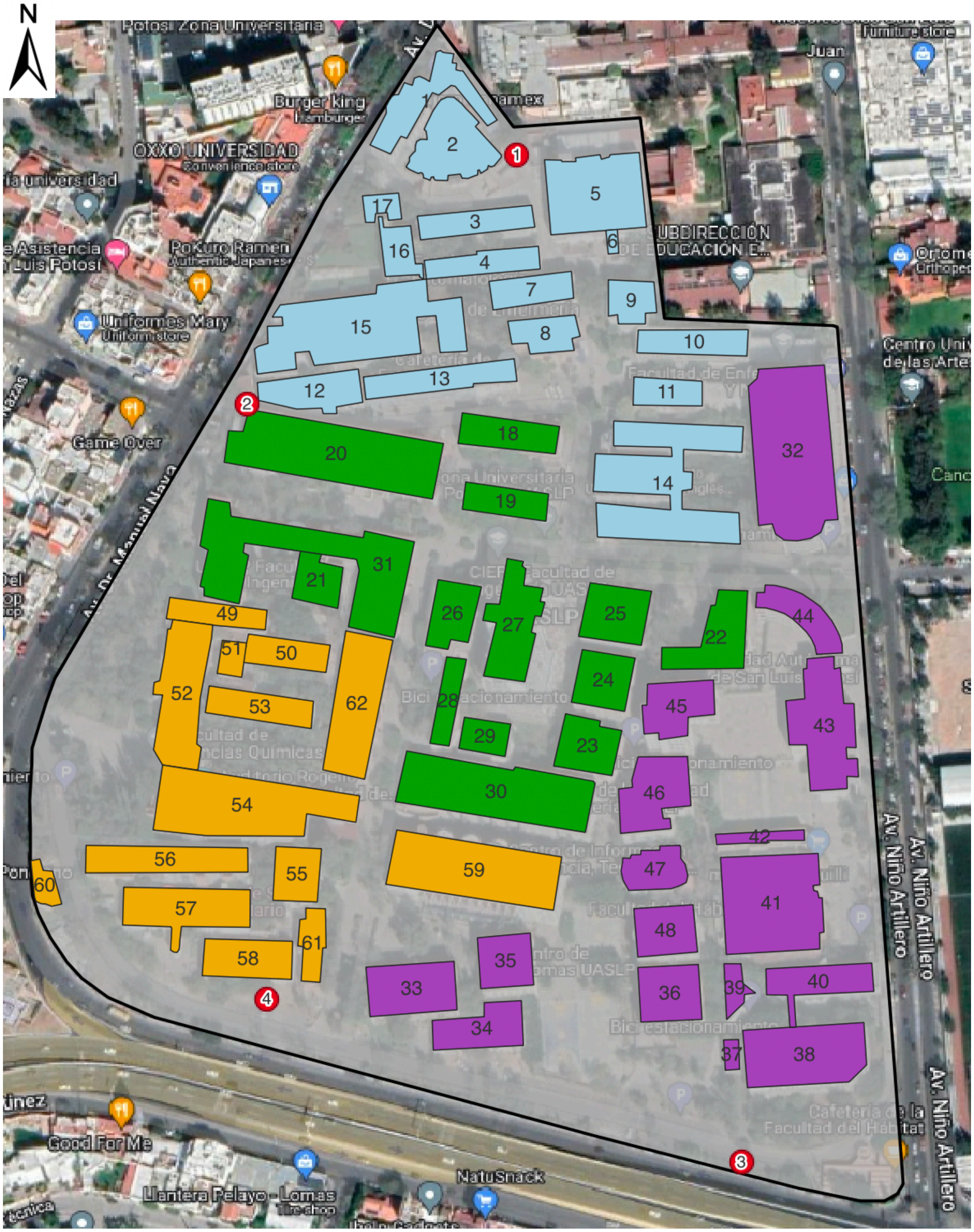
APPENDIX A

CARACTERIZACIÓN DE RESIDUOS SÓLIDOS URBANOS, CAMPUS ZUP, UASLP



Resumen

Esta caracterización de residuos permite entender la cantidad y la composición de los residuos sólidos urbanos (RSU) generados en el campus ZUP. Los datos obtenidos sirven como base para el mejor manejo de los RSU y la mejora continua del PROSEREM.

Objetivos

Obtener datos precisos para los siguientes indicadores:

Composición	% Orgánicos compostables % Inorgánicos reciclables % Inorgánicos no reciclables

S	2	Orgánicos compostables masa kg/día
S	3	Orgánicos compostables volumen m3/día
S	4	Inorgánicos recyclables masa kg/día
S	5	Inorgánicos recyclables volumen m3/día
S	6	Residuos no aprovechables masa kg/día
S	7	Residuos no aprovechables volumen m3/día
S	8	RSU a Peñasco masa kg/día
S	9	RSU a relleno sanitario San Juanico masa kg/día
S	10	RSU a Peñasco volume m3/día
S	11	RSU a relleno sanitario San Juanico volumen m3/día
S	12	RSU a Peñasco mass kg/capita/día
S	13	RSU a relleno sanitario San Juanico masa kg/capita/día

Materiales

- Lentes de seguridad (1 por persona)
- Guantes de cuero (1 par por persona)
- Guantes de latex (1 par por persona)
- Cubrebocas (1 por persona)
- Protección solar (bloqueador, mangas largas, gorra/sombrero)
- Cinta adhesiva (1 rollo)
- Marcador permanente (2)
- Cajas de plástico (6)
  - Sterilite 14699002 40 gal/151L o similar
- Lona (1)
  - De al menos 12 m^2 (3m x 4m)
- Báscula digital con capacidad de 200 kg (1)
- Bolsas de basura de polietileno transparente
- Escoba y recogedor (1)
- Kit de primeros auxilios (1)
- Alcohol en gel (1)
- Cámara o celular con cámara (1)

- Portapapeles (1)
- Lápiz (1)
- Copia de la hoja de datos adjunta (1)
- Copia de la tabla de números aleatorios adjunta (1)

Procedimiento

1. Tomar foto de punto de recolección
2. Llenar parte 1 de hoja de campo
   a. En caso de lluvia, no realizar muestreo.
3. Utilizar cinta y marcador permanente para numerar cada bolsa.
   a. Si hay residuos sueltos, utilizar escoba y recogedor para ponerlos en una bolsa. Numerar esa bolsa también.
4. En parte 2 de hoja de campo, anotar el peso (kg) de cada bolsa.
5. Utilizar tabla de números aleatorios para escoger una muestra de al menos 10% de las bolsas y al menos 50kg.
6. Vaciar las bolsas seleccionadas sobre la lona.
7. Designar una caja de plástico para cada una de las 3 categorías (orgánicos compostables, inorgánicos reciclables e inorgánicos no reciclables).
8. Separar los residuos en las 3 categorías según la tabla abajo, colocando los residuos en la caja correspondiente.
9. Cada vez que se llene una caja, pesar la caja y anotar el peso en la hoja de datos.
10. Vaciar la caja en una bolsa, cerrar la bolsa y seguir con la separación.
11. Seguir hasta que todos los residuos de la muestra estén separados y los pesos de las cajas estén anotados en la hoja de datos.
12. Si la última caja para cada tipo de residuos no está llena, estimar el porcentaje y anotar en la hoja de datos.
13. Anotar observaciones, problemas, sugerencias etc.
14. Dejar limpio el punto de recolección.
    a. Todos residuos en bolsas cerradas
    b. Sin residuos sueltos

Caracterización de Residuos Sólidos Urbanos, Campus ZUP, UASLP

Parte 1

Fecha		Hora	
Punto de recolección		Condiciones climáticas:	
Foto			

Parte 2 - peso (kg) de bolsas

	Peso (kg)
Bolsa 1	
Bolsa 2	
Bolsa 3	
Bolsa 4	
Bolsa 5	
Bolsa 6	
Bolsa 7	
Bolsa 8	
Bolsa 9	
Bolsa 10	
Bolsa 11	
Bolsa 12	
Bolsa 13	
Bolsa 14	
Bolsa 15	
Bolsa 16	
Bolsa 17	
Bolsa 18	
Bolsa 19	
Bolsa 20	
Bolsa 21	
Bolsa 22	
Bolsa 23	
Bolsa 24	
Bolsa 25	
Bolsa 26	
Bolsa 27	
Bolsa 28	
Bolsa 29	
Bolsa 30	
Bolsa 31	
Bolsa 32	
Bolsa 33	
Bolsa 34	
Bolsa 35	
Bolsa 36	
Bolsa 37	
Bolsa 38	
Bolsa 39	
Bolsa 40	
Bolsa 41	
Bolsa 42	
Bolsa 43	
Bolsa 44	
Bolsa 45	

Parte 3 - peso (kg) de cajas

Volumen de caja						
	Org. comp. (kg)	% llena	**Inorg. rec. (kg)**	% llena	**Inorg. no rec. (kg)**	% llena
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Subproducto	Categoría
Cartón	**Inorgánico reciclable**
Envase de cartón encerado	
Lata	
Material ferroso	
Material no ferroso	
Papel	
Plástico rígido y de película	
Vidrio de color	
Vidrio transparente	
Unicel - LIMPIO	
TetraPak	
Algodón	**Inorgánico no reciclable**
Cuero	
Residuos finos	
Fibras sintéticas	
Hueso	
Hule	
Loza y cerámica	
Madera	
Pañal desechable y residuos sanitarios	
Trapo	
Unicel - SUCIO	
Otro	
Fibra dura vegetal	**Orgánico compostable**
Residuos alimenticios	
Residuos de jardinería	

APPENDIX B

CARACTERIZACIÓN DE INFRAESTRUCTURA, CAMPUS ZUP, UASLP

Resumen

Esta caracterización de la infraestructura permite entender la disponibilidad y la condición de micro estaciones de separación en el campus ZUP. Los datos obtenidos sirven como base para mejorar el manejo de los RSU y la mejora continua del PROSEREM.

Objetivos

Obtener datos para los siguientes indicadores:

Razones principales de incumplimiento	cualitativo
Estado actual de limpieza de las micro estaciones	% calificadas de 1 a 5

E	8	% de microestaciones con juego de botes correcto
E	9	% de microestaciones con separación incorrecta

Materiales

- Cubrebocas (1 por persona)
- Protección solar (bloqueador, mangas largas, gorra/sombrero)
- Celular con cámara e internet (1)
- Portapapeles (1 por persona)
- Lápiz (1 por persona)
- Copia de la hoja de datos adjunta (1 por persona)

Procedimiento

1. Utilizar tabla de números aleatorios para escoger una muestra de 3 edificios de cada zona de recolección.
2. Tomar foto de micro estación.
3. Llenar hoja de datos.

Caracterización de infraestructura

* Indicates required question

1. Foto de micro estación

   Files submitted:

2. Punto de recolección al cual pertenece *

   Mark only one oval.

   - ⬭ 1
   - ⬭ 2
   - ⬭ 3
   - ⬭ 4
   - ⬭ desconocido

3. Número de edificio (si afuera, escribe 0) *

   ____

4. Ubicación *

   Mark only one oval.

   - ⬭ Afuera
   - ⬭ Lobby, vestíbulo, entrada principal, área común o área de espera
   - ⬭ Pasillo
   - ⬭ Otra

5. ¿La micro estación está configurada de acuerdo con PROSEREM, con tres contenedores, etiquetados con los nombres y colores correctos como se muestra en la foto? *

   Mark only one oval.

   - ⬭ Sí
   - ⬭ No

6. De lo contrario, ¿cuál de los siguientes aplica? (marque todos los que correspondan) *

Check all that apply.

- [ ] a. Hay demasiados contenedores
- [ ] b. No hay suficientes contenedores
- [ ] c. Falta el contenedor para productos orgánicos o no está etiquetado correctamente
- [ ] d. Falta el contenedor para reciclables inorgánicos o no está etiquetado correctamente
- [ ] e. Falta el contenedor para inorgánicos no reciclables o no está etiquetado correctamente
- [ ] f. Existen categorías de contenedores distintas a las señaladas por el PROSEREM.

7. Si hay más de un contenedor, ¿cuál de los siguientes describe mejor el nivel de separación de los residuos?

Mark only one oval.

- ( ) 1- residuos separados completamente de acuerdo con las etiquetas de los contenedores
- ( ) 2- la mayoría de los residuos coinciden con la etiqueta con algunos artículos mal separados
- ( ) 3- la mayoría de los residuos aún coinciden con la etiqueta, pero hay errores notables de separación.
- ( ) 4- en general los residuos no coinciden con la etiqueta del contenedor.
- ( ) 5- los residuos no reflejan ninguna separación.
- ( ) n/a

8. ¿Cuál de los siguientes describe mejor el estado general de la micro estación? *

Mark only one oval.

- ( ) 1-Muy limpia y ordenada
- ( ) 2-Mayormente limpia y ordenada
- ( ) 3- Aceptable pero ligeramente sucia o desordenada
- ( ) 4-Sucia y/o desordenada
- ( ) 5- Extremadamente sucia y/o desordenada

APPENDIX C

PROSEREM REPORTE DE INCIDENCIA

Punto de recolección *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ Punto de Poda
- ◯ UniHuerto

Seleccione sí o no para cada uno de los siguientes problemas según si se observa el problema en el punto de recolección. *

	Sí	No	No sé
Bolsas no cerradas	◯	◯	◯
Bolsas no transparentes	◯	◯	◯
Residuos sueltos	◯	◯	◯
Cajas de cartón no aplastadas	◯	◯	◯
Poda presente en punto que no sea punto de poda	◯	◯	◯
Escombra presente	◯	◯	◯
RPBI presente (residuos peligrosos biológicos infecciosos)	◯	◯	◯
RP presente (residuos peligrosos)	◯	◯	◯
RME presente (residuos de manejo especial)	◯	◯	◯
Acumulación excesiva de residuos o residuos no colectados con frecuencia adecuada	◯	◯	◯
Fauna nociva presente	◯	◯	◯
Otra observación (explicar en siguiente pregunta)	◯	◯	◯

Descripción de problema(s) observado(s) u otro comentario

APPENDIX D

ENTREVISTA SEMIESTRUCTURADA EN SITIO DE DISPOSICIÓN FINAL

Hola, mi nombre es Emily Miner. Soy estudiante de segundo año de maestría en ciencias ambientales en la UASLP. Mi trabajo de tesis se enfoca en mejorar la gestión de RSU en el campus ZUP de la UASLP. La UASLP está trabajando para mejorar la separación de RSU en el campus para que puedan ser enviados a los sitios apropiados de disposición final, reciclaje o compostaje. Para asegurarnos de que los residuos se manejen correctamente, queremos comprender mejor las necesidades de los sitios de disposición final. Por eso le entrevisto hoy. La información será utilizada para mi tesis, la cual propondrá mejoras al programa de gestión de residuos en el campus ZUP de la UASLP. Tengo una serie de preguntas que hacerle, pero cualquier otra información que desee compartir también es bienvenida. Además, dado que el español no es mi idioma nativo, le agradecería mucho si me diera su consentimiento para que el audio de esta entrevista se grabe para que pueda volver a escucharla más tarde y tomar notas.
¿Está de acuerdo en hacer la entrevista y dejarme usar la información para los fines que describí?
¿Tengo su consentimiento para grabar?
¿Tengo su consentimiento para tomar fotos del sitio?
empezar a grabar

Nombre
Título profesional
Nombre de la organización
¿Cuánto tiempo ha trabajado en la organización? ¿En qué rol(es)?
¿Qué tipo de residuos recibe su organización?
¿De quién, de dónde y cómo recibe la organización estos residuos?
¿Cuánto de estos residuos recibe la organización?
¿Cuántos residuos recibe la organización de la UASLP?
¿La organización cobra una tarifa por recibir residuos de la UASLP? Si es así, ¿cuánto?
¿Qué sucede con los residuos una vez recibidos?
¿Cuáles son algunos de los desafíos que enfrenta la organización en el procesamiento de esos residuos?
¿Cuáles son algunas cosas que UASLP podría hacer para facilitar el proceso?
¿Cómo se comunica usted (o su organización) con la UASLP?
¿Podemos ir a ver dónde se reciben y procesan los residuos?
¿Algo más que le gustaría compartir?
¿Le interesa participar en un taller en el mes de mayo o junio sobre el futuro del programa de residuos de la UASLP?
¿Le interesa ver los resultados finales de la tesis?

APPENDIX E

SEGUIMIENTO SEMIESTRUCTURADO DE RECOLECTORES

Hola, mi nombre es Emily Miner. Soy estudiante de segundo año de maestría en ciencias ambientales en la UASLP. Mi trabajo de tesis se enfoca en mejorar la gestión de los residuos en el campus ZUP de la UASLP. La UASLP está trabajando para mejorar la separación de RSU en el campus para que los residuos puedan ser enviados a los sitios apropiados de disposición final, reciclaje o compostaje. Para asegurarnos de que los residuos se manejen correctamente, queremos comprender mejor los pasos y los desafíos que implica recolectar los residuos de los puntos de recolección y transferirlos a los sitios de disposición final. Es por eso que le estoy siguiendo y entrevistando hoy. La información será utilizada únicamente para mi tesis, la cual propondrá mejoras al programa de manejo de residuos en el campus ZUP de la UASLP. Tengo una serie de preguntas que hacerle, pero cualquier otra información que desee compartir también es más que bienvenida. Además, dado que el español no es mi idioma nativo, le agradecería mucho si me diera su consentimiento para que esta entrevista se grabe en voz para que pueda volver a escucharla más tarde para tomar notas.
¿Está de acuerdo en hacer el seguimiento y dejarme usar la información para los fines que describí?
¿Tengo su consentimiento para grabar?
¿Tengo su consentimiento para tomar fotos del proceso de trabajo durante el seguimiento?
empezar a grabar

Preguntas:

1. Nombre (opcional)
2. Título del trabajo
3. ¿Cuánto tiempo ha trabajado en este rol?
4. ¿Cuál es su horario de trabajo (horas, días)?
5. ¿Cuándo y con qué frecuencia recoge los RSU de los puntos de recolección?
6. ¿Me podría mostrar su rutina normal para hacer eso?
7. ¿Ha recibido alguna capacitación para hacer este trabajo? ¿Cuándo? ¿De qué se trataba?
8. ¿Cuál diría que es el mayor desafío al que se enfrenta al hacer este trabajo?
9. ¿Qué cree que se podría cambiar para hacer este trabajo más fácil?
10. ¿Algo más que le gustaría compartir? Cualquier información o sugerencia que tenga es apreciada y será tenida en cuenta mientras trabajamos para mejorar la gestión de residuos en el campus.

Gracias por tomarse el tiempo. ¿Le interesa participar en la mesa de trabajo (taller participativo) en junio? ¿Le interesa ver los resultados finales de la tesis?

APPENDIX F

SEGUIMIENTO SEMIESTRUCTURADO DEL PERSONAL DE INTENDENCIA

Hola, mi nombre es Emily Miner. Soy estudiante de segundo año de maestría en ciencias ambientales en la UASLP. Mi trabajo de tesis se enfoca en mejorar la gestión de los residuos en el campus ZUP de la UASLP. La UASLP está trabajando para mejorar la separación de RSU en el campus para que los residuos puedan ser enviados a los sitios apropiados de disposición final, reciclaje o compostaje. Para asegurarnos de que los residuos se manejen correctamente, queremos comprender mejor los pasos y los desafíos que implica recolectar los residuos de las microestaciones y transferirlos a los puntos de recolección. Es por eso que le estoy siguiendo y entrevistando hoy. La información será utilizada únicamente para mi tesis, la cual propondrá mejoras al programa de manejo de residuos en el campus ZUP de la UASLP. Tengo una serie de preguntas que hacerle, pero cualquier otra información que desee compartir también es más que bienvenida. Además, dado que el español no es mi idioma nativo, le agradecería mucho si me diera su consentimiento para que esta entrevista se grabe en voz para que pueda volver a escucharla más tarde para tomar notas.
¿Está de acuerdo en hacer el seguimiento y dejarme usar la información para los fines que describí?
¿Tengo su consentimiento para grabar?
¿Tengo su consentimiento para tomar fotos del proceso de trabajo durante el seguimiento?
empezar a grabar

Preguntas:

1. Nombre (opcional)
2. Título del trabajo
3. ¿Sindicalizado o contratado?
4. ¿Nombre de la empresa contratante si es contratada?
5. ¿Departamento?
6. ¿Cuánto tiempo ha trabajado en este rol?
7. ¿Cuál es su horario de trabajo (horas, días)?
8. ¿Cuándo y con qué frecuencia recoge los RSU y los lleva a los puntos de recolección?
9. ¿Me podría mostrar su rutina normal para hacer eso?

*** seguimiento, otras preguntas a medida que surjan y tomar fotos ***

10. ¿Cuál diría que es el mayor desafío al que se enfrenta al hacer este trabajo?
11. ¿Qué cree que se podría cambiar para hacer este trabajo más fácil?
12. ¿Sabe qué sucede con los residuos después de que se llevan a los puntos de recolección?
13. ¿Algo más que le gustaría compartir? Cualquier información o sugerencia que tenga es apreciada y será tenida en cuenta mientras trabajamos para mejorar la gestión de residuos en el campus.

Gracias por tomarse el tiempo. ¿Le interesa ver los resultados finales de la tesis?

APPENDIX G

ENCUESTA DE GENERADORES DE RESIDUOS SÓLIDOS URBANOS

El objetivo de esta encuesta es comprender mejor los hábitos y actitudes relacionados con la disposición de residuos sólidos urbanos de los miembros de la comunidad universitaria perteneciente al campus ZUP (zona universitaria poniente) de la UASLP. La información recolectada formará parte de una tesis de maestría que tiene como objetivo simplificar y mejorar la gestión de los residuos sólidos urbanos en el campus y reducir el impacto ambiental de la universidad. Por favor, responda las preguntas de la manera más honesta y completa posible sin usar ninguna otra referencia. Sus respuestas no se asociarán con su nombre u otra información personal y se utilizarán únicamente para los fines de esta investigación de tesis. Muchas gracias por su participación.

1) ¿Cuál es su edad?
    a. Menor a 18 años
    b. 18-24 años
    c. 25-34 años
    d. 35-44 años
    e. 45-54 años
    f. 55-64 años
    g. Mayor a 64 años
2) ¿Cuál es su identificación de género?
    a. Mujer
    b. Hombre
    c. Otro
    d. Prefiero no contestar
3) ¿Cuál describe mejor su rol en la UASLP?
    a. Estudiante de licenciatura
    b. Estudiante de maestría
    c. Estudiante de doctorado
    d. Personal académico
    e. Personal administrativo
4) ¿Cuánto tiempo tiene conociendo el campus ZUP de la UASLP?
    a. Menos de 1 año
    b. 1-2 años
    c. 3-4 años
    d. 5-6 años
    e. más de 6 años
5) ¿Cuántos días a la semana asiste al campus ZUP de la UASLP?
    a. Nunca
    b. 1 día
    c. 2 - 3 días
    d. 4 - 5 días
    e. Más de 5 días

6) ¿En cuál zona del campus pasa más tiempo? de acuerdo con el siguiente mapa
    a. Zona 1 (azul)
    b. Zona 2 (verde)
    c. Zona 3 (morada)
    d. Zona 4 (amarilla)

7) ¿Qué importancia tiene para usted la protección del medio ambiente?
    a. Sin importancia
    b. Poco importante
    c. Soy neutral
    d. Importante
    e. Muy importante
8) ¿Qué tan importante considera que es el reciclaje?
    a. Sin importancia, poco importante, soy neutral, importante, muy importante
9) ¿Separa sus residuos reciclables en su hogar?
    a. Nunca
    b. Casi nunca
    c. A veces
    d. Casi siempre
    e. Siempre

10) ¿Separa sus residuos reciclables en el campus?
    a. Nunca
    b. Casi nunca
    c. A veces
    d. Casi siempre
    e. Siempre
11) ¿Cuál de los siguientes factores influye en su decisión de separar sus residuos reciclables en el campus o no?
    a. Mi preocupación por el impacto ambiental
    b. Si sé si el artículo es reciclable o no
    c. Si sé dónde está el contenedor de reciclaje
    d. La proximidad del contenedor de reciclaje
    e. La condición del contenedor de reciclaje (lleno, sucio, maloliente)
    f. Si confío en que el reciclaje se gestiona correctamente después de ponerlo en el contenedor.
    g. Si veo a otras personas separando sus residuos reciclables
    h. Otro (especificar)
12) ¿Qué importancia considera que tiene el compostaje de los residuos orgánicos?
    a. Sin importancia
    b. poco importante
    c. soy neutral
    d. importante
    e. muy importante
13) ¿Usted separa sus residuos orgánicos compostables en su hogar?
    a. Nunca
    b. Casi nunca
    c. A veces
    d. Casi siempre
    e. Siempre
14) ¿Usted separa sus residuos orgánicos compostables en el campus?
    a. Nunca
    b. Casi nunca
    c. A veces
    d. Casi siempre
    e. Siempre
15) ¿Cuál de los siguientes factores influye en su decisión de separar sus residuos orgánicos compostables en el campus o no?
    a. Mi preocupación por el impacto ambiental
    b. Si sé si el artículo es compostable o no
    c. Si sé dónde está el contenedor de composta
    d. La proximidad del contenedor de composta
    e. La condición del contenedor de composta (lleno, sucio, maloliente)
    f. Si confío en que la composta se gestiona correctamente después de ponerla en el contenedor.
    g. Si veo a otras personas separando sus residuos compostables
    h. Otro (especificar)

16) El programa de manejo de residuos sólidos de la UASLP se llama PROSEREM (Programa de separación y reciclaje de materiales). ¿Qué tan familiarizado está con este programa?
  a. Nunca he oído hablar de él
  b. He oído hablar de él, pero no sé qué es
  c. Sé qué es, pero no sé cómo funciona
  d. Sé la idea general
  e. Lo conozco en detalle

17) ¿Ha visto contenedores con estos colores o etiquetas en el campus antes?
  a. Sí
  b. Sí, y he visto diferentes etiquetas o colores
  c. No
  d. No, he visto diferentes etiquetas o colores
  e. No estoy seguro

18) ¿Puede relacionar el color con el tipo de residuo que va en el contenedor?

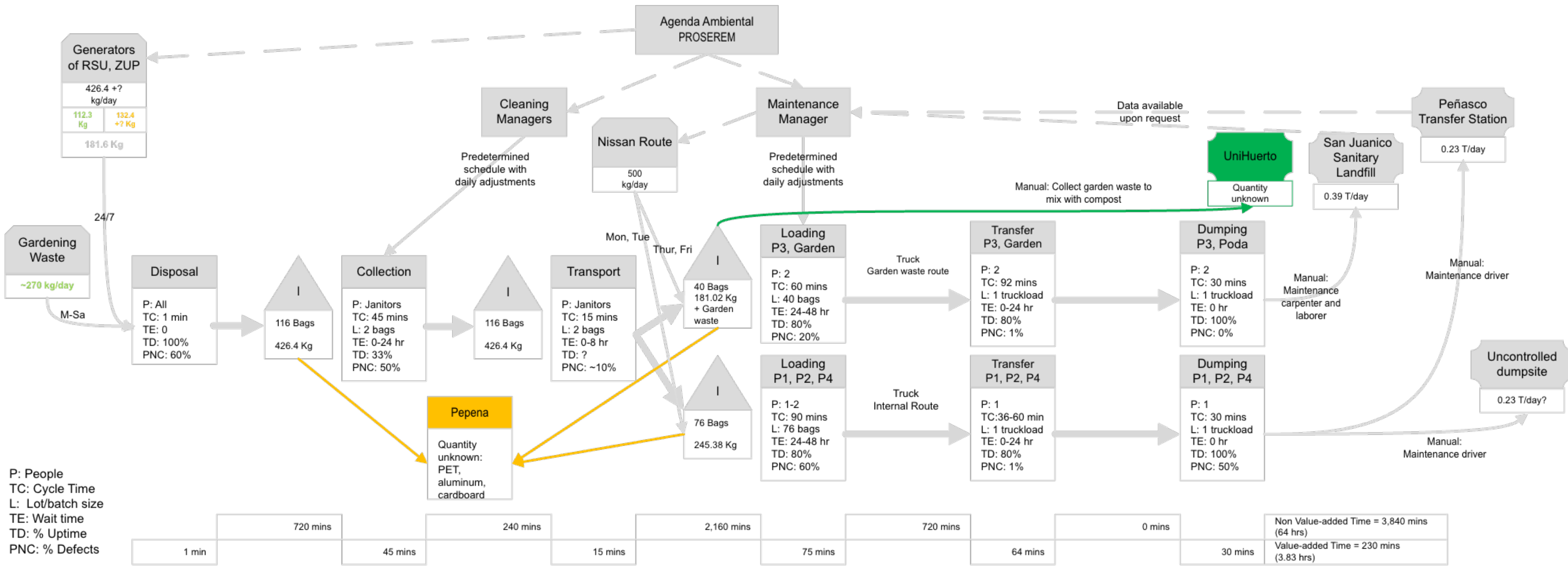
	Inorgánicos reciclables	Residuos no reciclables	Orgánicos compostables
Verde			
Gris			
Naranja			

19) Para cada elemento a continuación, indique qué contenedor cree que es correcto. – verde, naranja, gris, otro
  a. Restos de bistec
  b. Cáscara de plátano
  c. Bolsa de supermercado de plástico
  d. Botella de plástico
  e. Botella de vidrio
  f. Lata de aluminio
  g. Caja de cartón
  h. Batería AA
  i. Plato de comida de unicel
  j. Tenedor de plástico
  k. Servilleta
  l. Papel de oficina
  m. Taza de café de papel

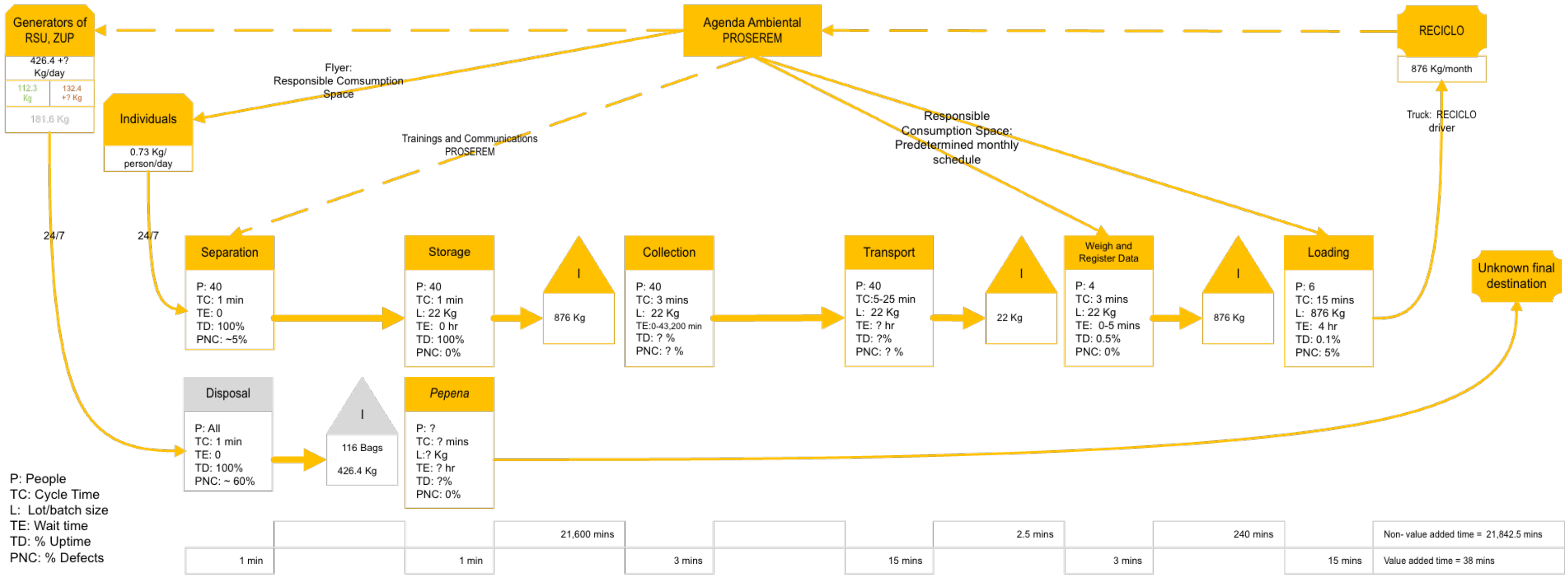
20) ¿Algún comentario o sugerencia que le gustaría compartir sobre la separación de residuos sólidos urbanos en el campus ZUP? Todas sus respuestas serán leídas y aportarán ideas para mejorar la logística de los residuos sólidos urbanos

APPENDIX H

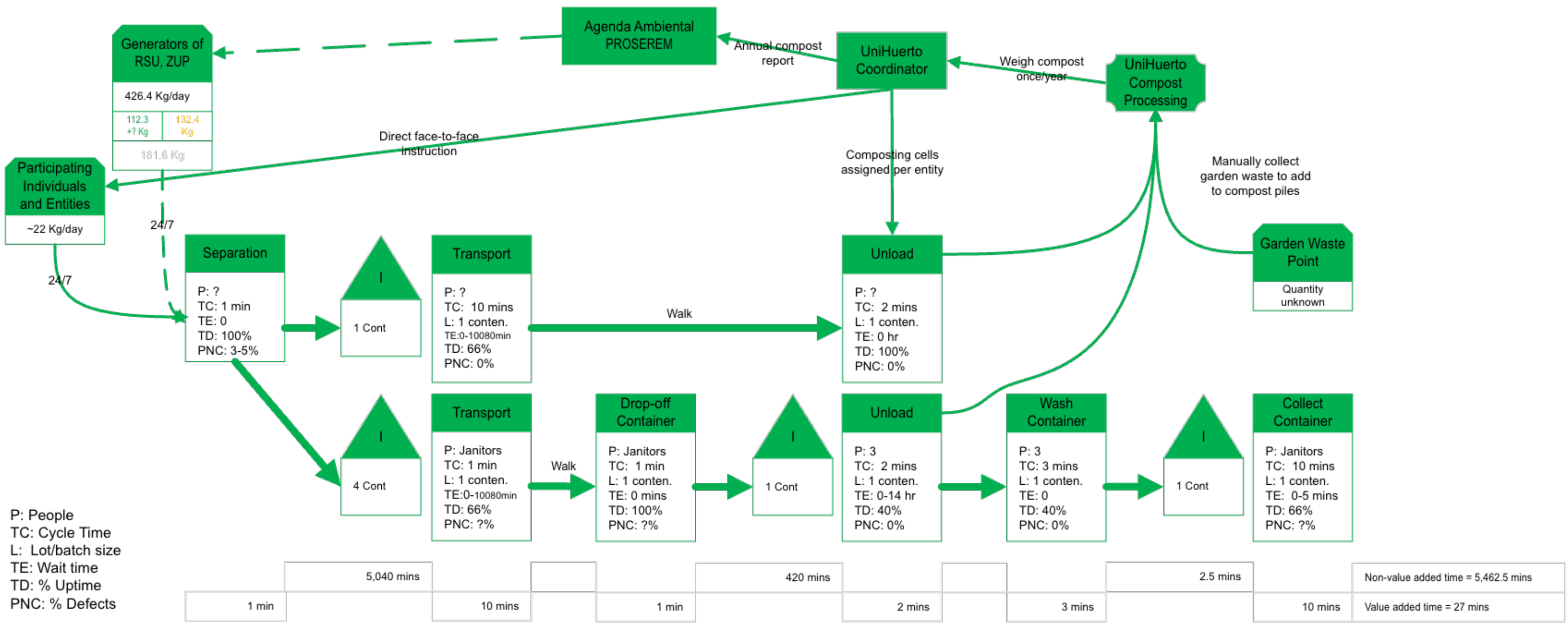
PROSEREM: Inorganic Non-recyclabes Current State VSM
June 1st, 2023



PROSEREM: Inorganic Recyclabes Current State VSM
June 1st, 2023

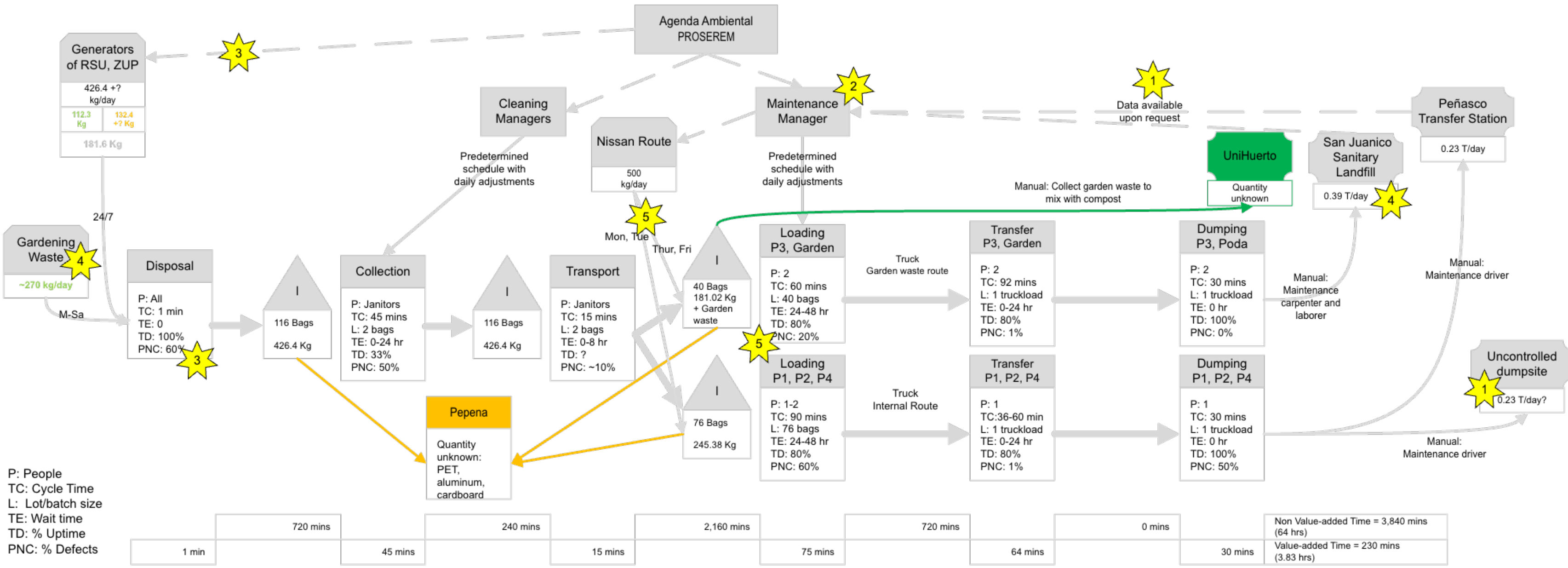


PROSEREM: Organic Compostables Current State VSM
June 1st, 2023

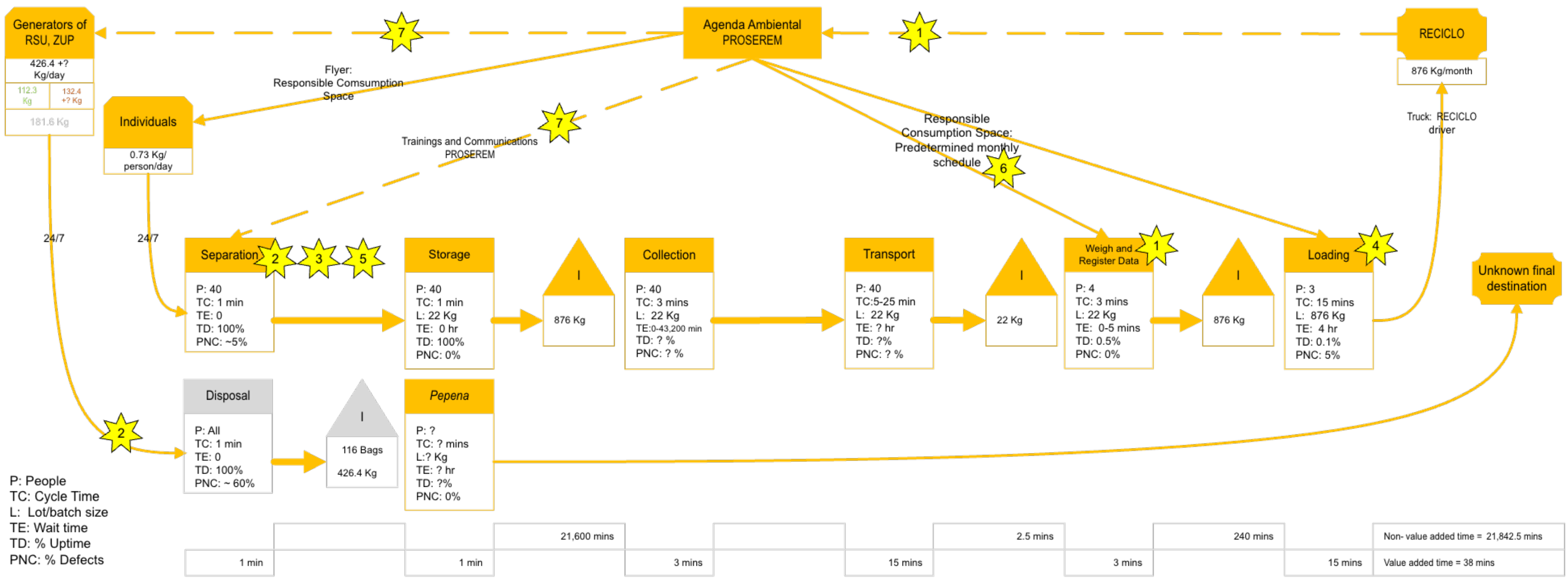


APPENDIX I

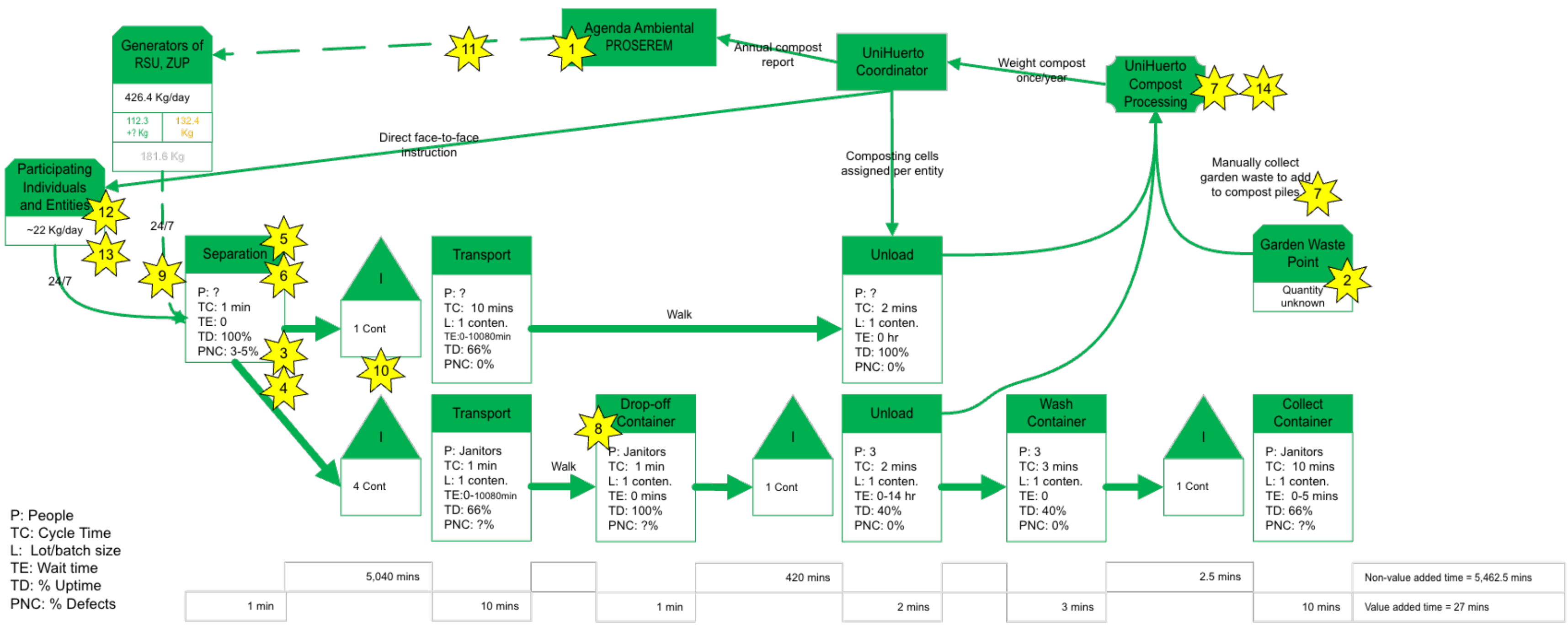
PROSEREM: Inorganic Non-recyclabes VSM Improvement Bursts
June 1st, 2023



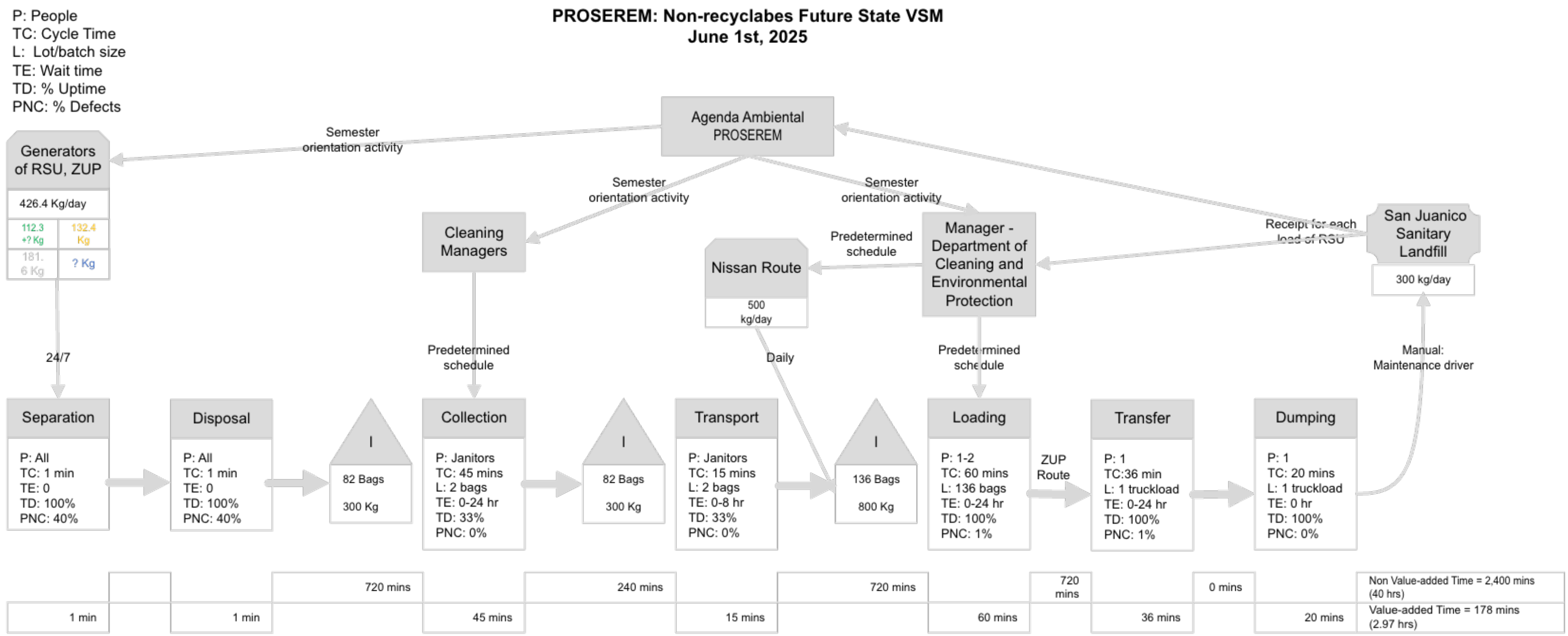
PROSEREM: Inorganic Recyclabes VSM Improvement Bursts
June 1st, 2023



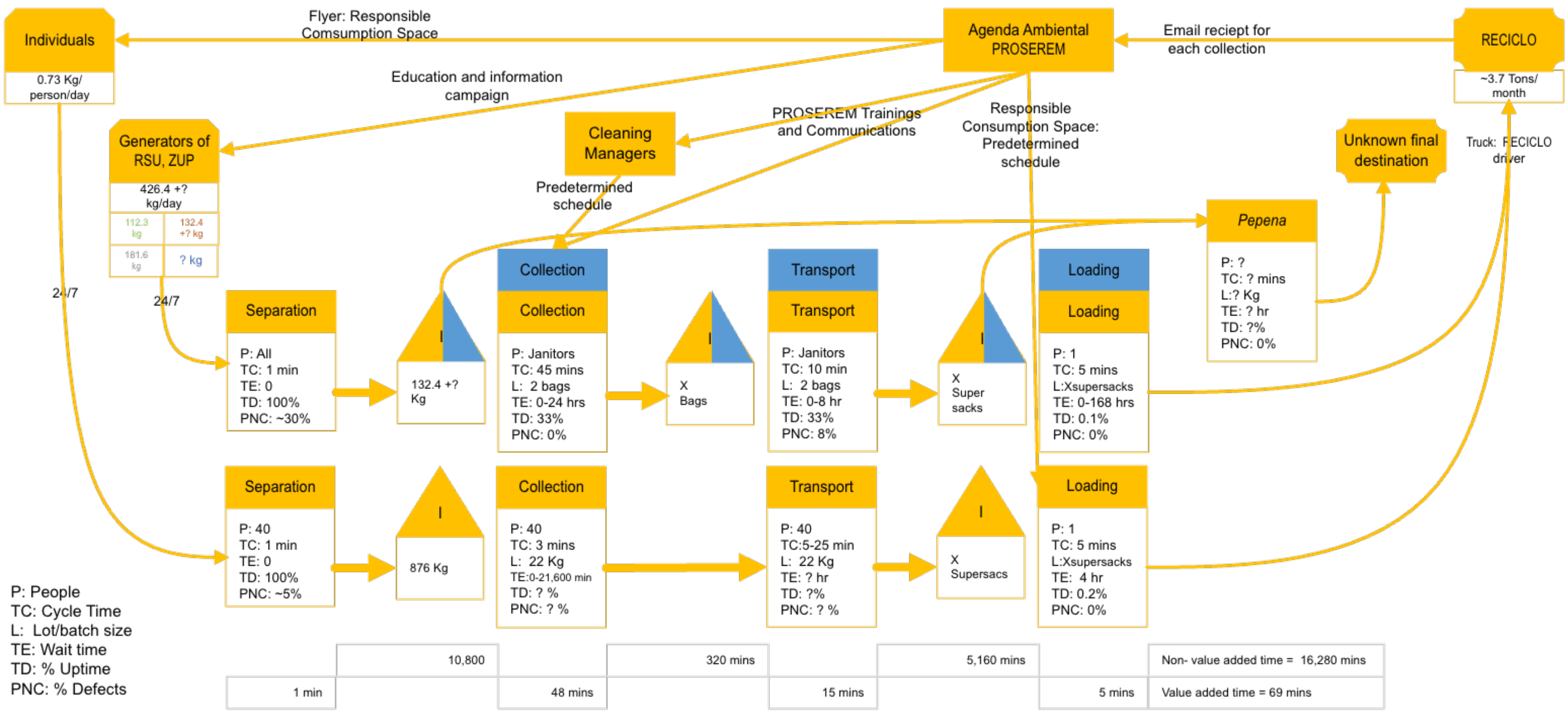
PROSEREM: Organic Compostables VSM Improvement Bursts
June 1st, 2023



APPENDIX J

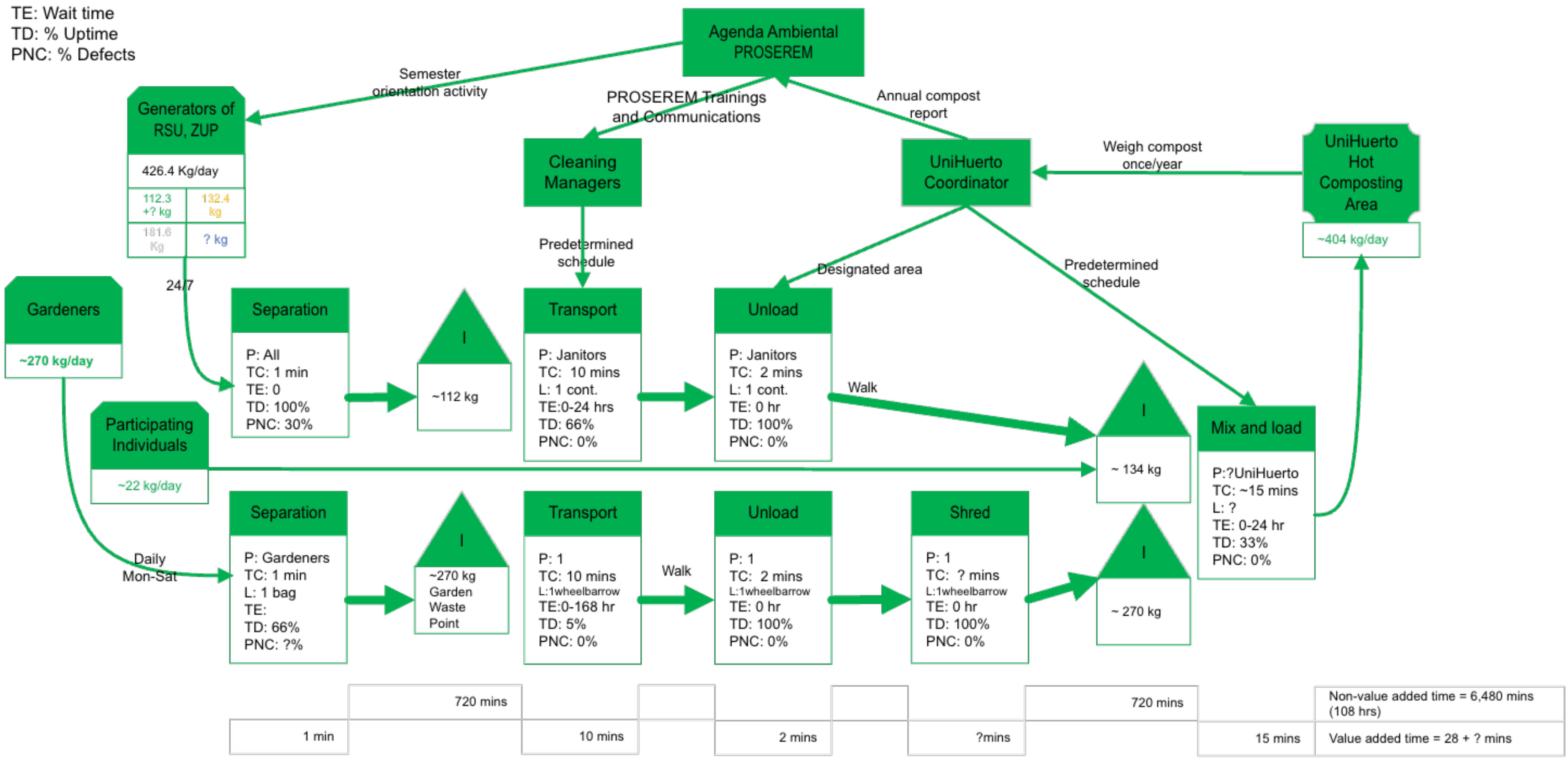

P: People
TC: Cycle Time
L: Lot/batch size
TE: Wait time
TD: % Uptime
PNC: % Defects
PROSEREM: Non-recyclabes Future State VSM
June 1st, 2025
Agenda Ambiental PROSEREM
Semester orientation activity
Generators of RSU, ZUP
426.4 Kg/day
112.3 +? Kg
132.4 Kg
181.6 Kg
? Kg
Semester orientation activity
Semester orientation activity
Cleaning Managers
Predetermined schedule
Nissan Route
500 kg/day
Manager - Department of Cleaning and Environmental Protection
Receipt for each load of RSU
San Juanico Sanitary Landfill
300 kg/day
24/7
Predetermined schedule
Daily
Predetermined schedule
Manual: Maintenance driver
Separation
P: All
TC: 1 min
TE: 0
TD: 100%
PNC: 40%
Disposal
P: All
TC: 1 min
TE: 0
TD: 100%
PNC: 40%
I
82 Bags
300 Kg
Collection
P: Janitors
TC: 45 mins
L: 2 bags
TE: 0-24 hr
TD: 33%
PNC: 0%
I
82 Bags
300 Kg
Transport
P: Janitors
TC: 15 mins
L: 2 bags
TE: 0-8 hr
TD: 33%
PNC: 0%
I
136 Bags
800 Kg
Loading
P: 1-2
TC: 60 mins
L: 136 bags
TE: 0-24 hr
TD: 100%
PNC: 1%
ZUP Route
Transfer
P: 1
TC:36 min
L: 1 truckload
TE: 0-24 hr
TD: 100%
PNC: 1%
Dumping
P: 1
TC: 20 mins
L: 1 truckload
TE: 0 hr
TD: 100%
PNC: 0%
720 mins
240 mins
720 mins
720 mins
0 mins
Non Value-added Time = 2,400 mins (40 hrs)
1 min
1 min
45 mins
15 mins
60 mins
36 mins
20 mins
Value-added Time = 178 mins (2.97 hrs)

PROSEREM: Recyclabes Future State VSM
June 1st, 2025



P: People
TC: Cycle Time
L: Lot/batch size
TE: Wait time
TD: % Uptime
PNC: % Defects

PROSEREM: Compostables Future State VSM
June 1st, 2025



APPENDIX K

IMPROVEMENT ACTION PLAN

Objective

Support the 2030 PROSEREM goals by improving the performance of the PROSEREM by June 1st, 2025, as measured by the following key performance indicators.

Key Performance Indicator			Current 2023	Goal 2030	Projected 2025
Leading					
E	1	% ZUP Campus community who believe separating organic waste is important	89.4	98	92
E	2	% ZUP Campus community who believe separating recylable waste is important	96.9	98	98
E	3	% ZUP Campus community aware of PROSEREM	20.7	50	44
E	4	% ZUP Campus community who correctly identify organic waste container	84.4	90	87
E	5	% ZUP Campus community who correctly identify recyclable waste containers	74.4	90	80
E	6	% ZUP Campus community who correctly identify non-recyclable waste containers	80.0	90	83
E	7	PROSEREM participation score for ZUP campus community	24.8	50	30
E	8	% of micro-stations with correct set of containers	2.7	25	5
E	9	% of containers with cross-contamination of wastes	75	50	70
E	10	% of cleaning staff trained on PROSEREM	0	50	0
Lagging					
S	1	Incident reports at collection points per month	3.6	2.0	3.6
S	2	Organic compostables mass kg/day	92.94	92.94	92.94
S	3	Organic compostables volume m3/day	0.39	0.39	0.39
S	4	Inorganic recyclables mass kg/day	193.82	193.82	193.82
S	5	Inorganic recyclables volume m3/day	6.05	6.05	6.05
S	6	Inorganic non recyclables mass kg/day	321.82	96.55	321.82
S	7	Inorganic non recyclables volume m3/day	9.78	2.93	9.78
S	8	Total RSU to Peñasco mass kg/day	*0.23	0.00	0.00
S	9	Total RSU to San Juanico landfill mass kg/day	*0.40	0.32	0.30
S	10	Total RSU to Peñasco volume m3/day	6.16	0.00	0.00
S	11	Total RSU to San Juanico landfill volume m3/day	10.63	9.78	8.00
S	12	RSU to Peñasco mass kg/capita/day	0.018	0.00	0.00
S	13	RSU to San Juanico landfill mass kg/capita/day	0.032	0.001	0.001

Action Plan

Non-Recyclables Value Stream

#	Action	Responsible Party/ies	Start date	Target date
N1	Require receipts or other confirmation that wastes are delivered to their assigned disposal site.	Institutional Manager, Maintenance Manager, Manager of new department (N1)	September 1st, 2023	Ongoing
N2	Create a more specialized department or unit to be responsible for solid waste management, other than the maintenance department.	UASLP Administrative Secretary, Maintenance Manager, Institutional Manager	September 1st, 2023	December 1st, 2024
N3	Host an activity at the beginning of each semester to introduce the PROSEREM.	Agenda Ambiental, Institutional Manager	August 15th, 2023	Ongoing, each semester
N4	Shred garden waste on campus rather than sending it to San Juanico.	UniHuerto Coordinator	September 1st, 2023	Ongoing as of November, 2023
N5	Remove points 1, 2, and 3. Consolidate non-recyclable waste collection at current point 4 with legally compliant container(s).	Agenda Ambiental, Manager of new department (N1)	December 1st, 2023	June 1st, 2024

Recyclables Value Stream

#	Action	Responsible Party/ies	Start date	Target date
R1	Obtain receipts from RECICLO for each collection showing volume and date.	SGA Coordinator, RECICLO	September 1st, 20203	Ongoing
R2	Rework PROSEREM categories to include 4 categories, adding one for paper and cardboard.	Agenda Ambiental, Institutional Manager	September 1st, 2023	November 1st, 2023
R3	Collaborate with RECICLO to design and build the appropriate containers for the collection point.	Institutional Manager, RECICLO	August 1st, 2023	January 1st, 2024
R4	Purchase custom super sacks to be used only for the UASLP that can be interchanged inside the containers at the collection point and at the collection events.	Institutional Manager	January 1st, 2024	March 1st, 2024
R5	Place adequate containers at the collection point to keep the point orderly.	Agenda Ambiental,	March 1st, 2024	Ongoing
R6	Expand or adjust hours of Responsible Consumption Space to accommodate those who work during the day.	Agenda Ambiental	March 1st, 2024	Ongoing
R7	Increase and improve communication to the university community with murals, videos, better signage, and QR codes on containers.	Agenda Ambiental, Institutional Manager, Education and Research Manager	March 1st, 2024	Ongoing

Compostables Value Stream

#	Action	Responsible Party/ies	Start date	Target date
C1	Rework the PROSEREM categories.	Agenda Ambiental, Institutional Manager	September 1st, 2023	November 1st, 2023
C2	Get rid of container drop-off system.	UniHuerto Coordinator	September 1st, 2023	November 1st, 2023
C3	Collect garden waste generation data.	Agenda Ambiental, Gardeners	September 1st, 2023	November 31st, 2023
C4	Place sign or plaque at the compost processing point indicating not to smoke.	Agenda Ambiental	September 1st, 2023	November 1st, 2023
C5	Place containers for recyclables and non-recyclables at the compost processing point so people can dispose of their waste properly.	Administrator of Engineering Dept.	September 1st, 2023	December 1st, 2023
C6	Purchase shredder.	Agenda Ambiental, UniHuerto Coordinator	In progress	November 1st, 2023
C7	Update list of compostable wastes accepted.	UniHuerto Coordinator	August 1st, 2023	September 1st, 2023
C8	Designate a space for hot composting in the processing point.	UniHuerto Coordinator	September 1st, 2023	September 30th, 2023
C9	Place appropriate infrastructure for separation of organic wastes on campus.	UniHuerto Coordinator, Administrator of each generating entity	October 1st, 2023	October 1st, 2024
C10	Locate containers in ideal place to facilitate collection by the janitors.	Responsible technician of each generating entity	October 1st, 2023	November 1st, 2024
C11	Educate directors about the importance of separating organic wastes.	Agenda Ambiental Institutional Manager	September 1st, 2023	Ongoing
C12	Increase the participation of the university faculties, offices, and other entities.	Agenda Ambiental, Institutional Manager	September 1st, 2023	Ongoing
C13	Receive larger quantities of organic waste.	UniHuerto Coordinator	September 1st, 2023	Ongoing
C14	Purchase biodigesters. *	Agenda Ambiental, UniHuerto Coordinator	TBD	TBD

Estimated Costs of Implementation

#	Improvement Action	Initial Cost	Cost per unit	Quantity	Ongoing Cost
N1	**Require receipts or other confirmation that wastes are delivered to their assigned disposal site.**	MXN 0.00			MXN 0.00
N2	**Create a more specialized department or unit to be responsible for solid waste management, other than the maintenance department.**	Staff time			Staff time
N3	**Host an activity at the beginning of each semester to introduce the PROSEREM.**	Staff time			Staff time
N4	**Shred garden waste on campus rather than sending it to San Juanico.**	See C5			Staff time
N5	**Remove points 1, 2, and 3. Consolidate non-recyclable waste collection at current point 4 with legally compliant container(s).**	MXN 24,550.00			
	Consolidate waste colleciton at point 4	MXN 0.00			MXN 0.00
	Cement floor for point 4	MXN 4,950.00	MXN 550.00	9	MXN 0.00
	New signage for point 4	MXN 100.00	MXN 100.00	1	MXN 0.00
	Containers for recyclables	See R3, R4			MXN 0.00
	Container for non-recyclables	MXN 19,500.00			MXN 0.00
	Non-recyclables subtotal	**MXN 24,550.00**			
R1	**Obtain receipts from RECICLO for each collection showing volume and date.**	MXN 0.00			MXN 0.00
R2	**Rework PROSEREM categories to include 4 categories, adding one for paper and cardboard.**	Staff time			MXN 0.00
R3	**Collaborate with RECICLO to design and build the appropriate containers for the collection point.**	MXN 2,800.00	MXN 35.00	80	MXN 0.00
R4	**Purchase custom super sacks to be used only for the UASLP that can be interchanged inside the containers at the collection point and at the collection events.**	MXN 560.00	MXN 70.00	8	MXN 0.00
R5	**Place adequate containers at the collection point to keep the point orderly.**	See R3, R4			MXN 0.00
R6	**Expand or adjust hours of Responsible Consumption Space to accommodate those who work during the day.**	MXN 0.00			MXN 0.00
R7	**Increase and improve communication to the university community with murals, videos, better signage, and QR codes on containers.**	variable			variable
	Recyclables subtotal	**MXN 3,360.00**			
C1	**Rework the PROSEREM categories.**	**Staff time**			MXN 0.00
C2	**Get rid of container drop-off system.**	**MXN 0.00**			MXN 0.00
C3	**Collect garden waste generation data.**	**Staff time**			MXN 0.00
C4	**Place sign or plaque at the compost processing point indicating not to smoke.**	**MXN 260.00**	MXN 130.00	2	MXN 0.00
C5	**Place containers for recyclables and non-recyclables at the compost processing point so people can dispose of their waste properly.**	**MXN 4,800.00**	MXN 4,800.00	1	MXN 0.00
C6	**Purchase shredder.**	**MXN 15,765.00**			MXN 0.00
C7	**Update list of compostable wastes accepted.**	**MXN 0.00**			MXN 0.00
C8	**Designate a space for hot composting in the processing point.**	**MXN 0.00**			MXN 0.00
C9	**Place appropriate infrastructure for separation of organic wastes on campus.**	**MXN 41,230.00**	MXN 665.00	62	MXN 0.00
C10	**Locate containers in ideal place to facilitate collection by the janitors.**	**MXN 0.00**			MXN 0.00
C11	**Educate directors about the importance of separating organic wastes.**	**Staff time**			Staff time
C12	**Increase the participation of the university faculties, offices, and other entities.**	**Staff time**			Staff time
C13	**Receive larger quantities of organic waste.**	**Staff time**			Staff time
	Compostables Subtotal	**MXN 62,055.00**			
C14	Purchase biodigesters. *	**TBD**			
	Total	**MXN 89,965.00**			