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Circular Options for Jamaica's Solid Waste Sector: A Systems Perspective

Master's thesis in Industrial Ecology

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se
Report No. E2023-095

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Cover:
Cattle walking on the Riverton waste disposal site located outside of Kingston, Jamaica.

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Abstract

Policies of controlled disposal of solid waste have caused the emergence of large, unstructured disposal sites which pollute the environment through the release of leachate and greenhouse gasses. As concern for the climate and environment mounts, many low- and middle-income countries will need to transition into more circular solid waste management strategies. In Jamaica, policy makers have long been looking to reform the waste sector and introduce waste to energy technology through a public-private partnership. While considered effective in road infrastructure projects, private sector participation has met with mixed success, even social resistance, in the areas of sanitation and water provision. Through interviews with concerned stakeholders, as well as the application of frameworks for systems thinking, this study aimed to provide a systems perspective on the state of solid waste management in Jamaica, and on the possible role of a public-private partnership. The study finds that the partnership could contribute substantially towards effective waste collection and disposal, but must be combined with recycling incentives and purposeful environmental legislation in order to achieve long-term success in the areas of value recovery and environmental protection. Participatory governance policies and mechanisms are found to be essential for sustainable solid waste management. These results can inform coming debates regarding private sector participation in countries facing similar challenges.

Keywords:
Jamaica, solid waste management, system perspective, governance for sustainable development, stakeholder management

Preface

This thesis was written for a Masters Degree in Industrial Ecology at Chalmers University of Technology in Gothenburg, Sweden. The subjects of this thesis were solid waste management in low and middle-income countries, systems analysis and governance for sustainable development. These are very important topics due to the pressing need to decrease environmental pollution from solid waste and increase circularity of material resources. Jamaica is a country full of good people and rich in beautiful nature, both of which are threatened by systemic issues weighing upon the country's solid waste management system.

We extend our special thanks to supervisor Anna Nyström Claesson for her valuable guidance and endless support. Also to Drs. Michael Coley and Donna Minott Kates and the Department of Chemistry at the University of the West Indies for the warm welcome and support we received in Jamaica.

This thesis would also not have been possible without the funding received from Sida Minor Field Studies, ICCs Svenska Nationalkommités Nicolinstiftelse "CN70" and Sveriges Ingenjörers Miljöfond.

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List of abbreviations

CaPRI	Caribbean Policy Research Institute
DBJ	Development Bank of Jamaica
DSSW	Diffuse source solid waste
EC	European Commission
IFI	International financial institutions
JET	Jamaican Environment Trust
LMICs	Low- and middle-income countries
MSW	Municipal solid waste
MSWM	Municipal solid waste management
NEPA	National Environment & Planning Agency
NRCA	National Resource Conservation Authority
NSWMA	National Solid Waste Management Authority
PPP	Public-private partnership
SDG	Sustainable Development Goals
SW	Solid waste
SWM	Solid waste management
SWMS	Solid waste management system
UNEP	United Nations Environmental Program
WtE	Waste to energy

1. Introduction

Many countries operate under an economic system where most material flows through society are linear. Over time, this system has given rise to a number of issues, such as rapid depletion of natural resources and environmental pollution. Landfill sites account for an estimated 5% of global greenhouse gas emissions (Kaza et al., 2018; World Bank, n.d.b). Globally, these developments posed a major challenge to the fulfillment of the United Nations (UN) Sustainable Development Goals (SDGs) and Agenda 2030, e.g. *sustainable cities and communities* (SDG11), *responsible production and consumption* (SDG12) and *climate action* (SDG13).

A small island developing state (SIDS) in the Caribbean region, Jamaica managed an annual 1.45 million tonnes of municipal solid waste (MSW) in 2021. Of this volume, around 60 percent ended up at the Riverton disposal site located on the outskirts of Kingston (DBJ, 2022a). By far the largest of the country's eight waste disposal sites, Riverton has long been a significant source of environmental pollution through the emission of landfill gasses, leachate escaping through waterways to the Caribbean sea, as well as toxic fumes released by frequent fires (CaPRI, 2015; Office of the Public Defender, 2015). At the time of the study, industrial recycling was rare, but valuable waste items were sought after by waste pickers, persons whose livelihoods depended upon access to the waste stream. The situation was typical of SIDS and low- and middle- income countries (LMICs) generally, where population growth coupled with insufficient governance have led to waste generation outgrowing the capacity of waste management systems (Pariatamby, Shahul Amid & Sanam Bhatti , 2019).

In 2016, the government of Jamaica (GOJ) formed an enterprise team tasked with facilitating a reform of the solid waste management system (SWMS) (JIS, 2016; OPM; 2016), through a public-private partnership (PPP) designed by the Development Bank of Jamaica (DBJ, 2023). If implemented, this PPP will define Jamaica's SWMS for the foreseeable future and rely heavily on the success of policies seeking to achieve circular flows and environmental protection.

1.1 Aim and research questions

The aim of this study was to contribute to the improvement of solid waste management in Jamaica by investigating alternatives through a systems perspective. To achieve this, it posed two research questions.

> **Research question 1**: How can the existing solid waste management system change for better resource management?
>
> **Research question 2**: How can a PPP improve Jamaica's solid waste management system?

The questions were answered through the application of academic literature to the Jamaican SWMS (Grohs, 2018). As the final details of the PPP agreement were not yet determined at the time of study, its potential effects were explored based on assumptions regarding the terms of the potential agreement. These assumptions were informed by the literature as well as an interview with a DBJ manager.

2. Solid waste management in low- and middle-income countries

This chapter presents the literature used to understand the subjects, and the frameworks used to answer the research questions. Together with the background and results in the upcoming chapters, this forms the basis for the method and analysis chapters.

2.1 Solid waste management

Solid waste causes approximately 5 percent of the global greenhouse emissions due to gases released as a consequence of poor management of waste and is one of the major sources of ocean pollution(Kaza et al., 2018). Improper management of solid waste also has broad social effects, and impacts a number of other environmental systems. Examples of measures that can be used to reduce waste are introducing circular systems based on the waste hierarchy framework, and utilizing the informal waste collection sector. This subchapter presents the different topics related to the management of solid waste.

2.1.1 Waste management systems

A considerable part of all solid waste is municipal solid waste (MSW), where the definition of MSW varies between countries (EEA, 2013). The definition used by the European Environmental Agency is as follows:

> "*Municipal waste is mainly produced by households, though similar wastes from sources such as commerce, offices and public institutions are included. The amount of municipal waste generated consists of waste collected by or on behalf of municipal authorities and disposed of through the waste management system.*"

MSW typically consists of mixed waste, such as plastic, paper, food waste etc., which has to be managed by solid waste management systems. The waste management system consists of generation, collection, treatment and disposal. The generation of waste is a result of different societal activities, such as domestic, commercial, institutional and industrial activities, with different compositions of waste (Bundhoo, 2018). Waste composition also depends on factors such as population growth, economic development, geographic location, climate and cultural norms (Kaza, et al., 2018). Once the waste is generated, it needs to be collected and treated. Without waste collection in a SWM, waste would end up on the side of roads and in the environment (Bundhoo, 2018). Waste collection and transportation are often the most expensive parts of SWM (Kaza, 2018), largely due to the large investment and operational costs of vehicles. This leads to many LMICs suffering from poor collections as funds are insufficient.

Waste treatment and disposal are often closely related. Treatment and disposal options today include recycling, composting, incineration, landfilling, open-air dumping and dumping in waterways (Kaza, et al., 2018). Out of these options, recycling is the most preferred waste treatment technology as it recovers many different material fractions (EEA, 2019). Composting is the aerobic decomposition of organic materials to produce compost which can be used as soil with high nutrient content (Bundhoo, 2018). Anaerobic digestion degrades organics in the absence of oxygen, and is well suited to treat organic waste in countries with tropical climates. Through incineration, energy is recovered and the waste volume reduced (Makarichi, Jutidamrongphan & Techato, 2018). However, the incineration residue is

hazardous and requires further management to prevent negative impacts on health and the environment (Allsop, Costner & Johnston, 2001). Landfilling removes the materials from the human economy as end disposal (Hird, 2013). Dumping on land or in waterways is considered to be the worst option, as it causes issues for societies and ecosystems.

2.1.2 Circular economy and the waste hierarchy

The idea of a circular economy implies that resources coming into the economy should not leave it by becoming waste, nor diminish in value (Benton, Hazell & Hill, 2014). A circular economy therefore encourages the best environmental outcome of managing waste by recovering and keeping resources in use. By promoting a higher level of circularity of materials, natural resources are preserved (Potting et al., 2017).

The waste hierarchy is a concept used to define waste management methods, originally presented in the Waste Framework Directive developed by the European Commission (EC) (EC, 2008). The waste hierarchy is also a tool used to provide guidance for more sustainable material usage and solid waste management systems generally (Benton, Hazell & Hill, 2014). Implementation of the principles of waste hierarchy is determined by several factors, for example the extent to which the circular economy for waste is applied (EC, 2015). The fundamental principle by which the methods of waste management are ranked by the Waste Framework Directive is that waste should be managed without risk or damage to humans, animals or the environment. The waste hierarchy describes the order of circularity for managing and disposing of used products and materials from most to least circular as: prevention, reuse, recycling, recovery and disposal (Figure 2.1) (EC, 2015).

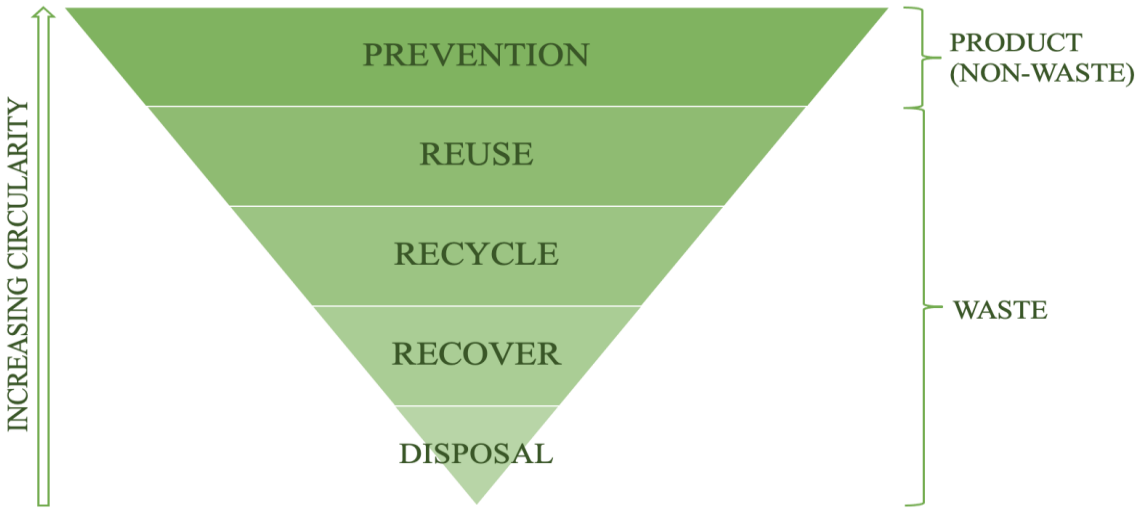

Figure 2.1 The waste hierarchy. Adapted from EC (2015)

The top four steps of the waste hierarchy are also part of a framework called the "4R framework" which often forms the basis for applied circular economy (Kirchherr, Reike & Hekkert, 2017). More efficient use of resources enabled by circular economy benefits the environment, as less resource extraction is needed to satisfy demand (Potting et al., 2017).

As the first step in the waste hierarchy, prevention refers to the need for society to prevent products from becoming waste, thus reducing the amount of waste and associated loss of value through e.g. enabling a longer use-phase through product design (Benton, Hazell & Hill, 2014; Potting et al., 2017). The second step, reuse, refers to the principle of expanding a product's life by reusing the product after

it has been initially discarded for as long as the product fulfills its function (Kirchherr, Reike & Hekkert, 2017). There are also some steps in between recycling and reuse that support keeping the product in use for as long as possible to avoid it becoming material waste. include repair and repurposing of products or parts for new products (Potting et al., 2017). Reuse is also cost efficient, motivating reuse and reselling on the market (Selvefors, et al., 2019). Recycling is in the middle of the waste hierarchy ladder. The process of recycling allows for material to be used in the manufacturing of new products (Potting et al., 2017). Materials suitable for recycling are paper, plastics, glass and metals (Bundhoo, 2018). Composting is also categorized as recycling, when it comes to organic waste (Hultman & Corvellec, 2012). The fourth step is recovery, which refers to the recovery of energy from materials (Kirchherr, Reike & Hekkert, 2017). The final step in the waste hierarchy is disposal. Disposal refers to landfilling and open-air dumping, and is the least preferred option as it means products or material will no longer be used for anything else (Hultman & Corvellec, 2012).

2.1.3 Energy recovery

Energy recovery uses different waste treatment technologies to recover energy as heat, electricity or biogas (Mutz, et al., 2017). These technologies and associated processes are often referred to as waste to energy (WtE). For treating MSW, four different technologies are commonly used: Incineration, co-processing, anaerobic digestion and landfill gas capture. Incineration entails burning combustible waste material for heat and energy recovery. Co-processing uses waste of high calorific value to replace fossil fuels in industrial processes, for example in cement ovens (Mata-Lima, et al., 2021). Anaerobic digestion converts the waste to biogas for energy use as well as soil fertilizer (Kumar & Samadder, 2017). The capture of landfill gas targets methane released by waste decomposing in landfills, which can be used to generate heat and power.

There are opportunities to use WtE as a renewable energy source, as it can replace fossil fuels for power and heat generation while also reducing the amount of waste put in landfills (Mata-Lima, et al., 2021). Compared to landfilling it would also result in an environmental benefit in terms of lower GHG emissions (Aracil, Fuentes-Cano & Gomez-Barea, 2018). Another main driver for the use of WtE is to reduce the land area usage for waste management (Diaz Barriga & Themelis, 2011). For sustainable incineration, it is vital to regulate the sector with a clear and comprehensive legal framework (Makarichi, Jutidamrongphan, & Techato, 2018).

Besides opportunities, WtE also carries with it several challenges. Even though the major fraction of MSW is organic and anaerobic digestion is estimated to work well in many LMICs, composting on a larger scale is rare (Mohee, et al., 2015). Instead, these volumes mainly go to landfills (Diaz Barriga & Themelis, 2011). This is mainly due to mainly poor public awareness and lack of adequate legislation (Mohee, et al., 2015). The main issue regarding incineration is the emissions (Allsopp, Costner & Johnston, 2001). Incineration pollutants include carbon oxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2) and hydrochloric acid gas (HCl), as well as particulate matter acid nitrogen oxides and heavy metals. Technology, monitoring and legislation are important factors that can be used to avoid emitting these substances (Makarichi, Jutidamrongphan, & Techato, 2018). The exposure to these harmful emissions increases the risk of cancer and respiratory diseases in humans (Allsopp, Costner & Johnston, 2001). Incineration of solid waste leaves behind fly ash and bottom ash, which are filled with toxic substances. Due to the toxicity, these need to be managed in a responsible way to avoid polluting the environment (Mutz, et al., 2017). Furthermore, for effective incineration, the moisture content of the waste has to be below 30 percent or the system becomes inefficient and more costly (Makarichi, Jutidamrongphan, & Techato, 2018). Generally, generation of electricity by incineration of household

waste will be of limited use due to the low efficiency of around 20% in the conversion process. If the thermal energy from the incineration can be used directly, the efficiency can be as high as 80%. (Mutz, et al., 2017). WtE is generally not a business that generates enough income exclusively through sale of energy, even with additional material recycling, to cover all its own costs. Therefore, WtE generally requires support in investment costs (Mutz, et al., 2017).

In order to integrate WtE as part of a municipal solid waste management system (MSWMS), comprehensive regulations and public awareness is needed for the waste fractions to be properly separated so that public health and the environment has adequate protection (Makarichi, Jutidamrongphan, & Techato, 2018; Mutz, et al., 2017; Margallo, et al., 2019). With these in place, WtE can be part of a holistic municipal solid waste management system, where modern technology is complemented with other waste management alternatives (Margallo, et al., 2019). Many countries with a high rate of energy recovery also have a significant recycling rate, which is important both to remove non-combustible and non-biodegradable waste as well as to move into the more circular stages of the waste hierarchy (Kumar & Samadder, 2017). Furthermore, WtE depends on efficient waste collection and transportation system to secure the needed continuous waste flow (Mutz, et al., 2017).

2.1.4 Landfills and effect on the environment and society

There are different types of landfills: sanitary, semi-controlled and open dump landfills. A landfill is considered to be sanitary if it is designed to avoid pollution of surrounding ecosystems or settlements. The design of sanitary landfill should cover waste in soil on a daily basis and should include a bottom liner, leachate collection, water monitoring, landfill gas recovery, fire control and location restrictions to prevent risks of environmental impacts of the disposal of waste (Nanda & Berruti, 2020; Kamaruddin et al., 2021). In contrast to sanitary landfills, open dump landfills and semi-controlled landfills lack such measures, which leads to increased human and environmental risks (Hird, 2013). When closing any type of landfill, it is important to maintain necessary environmental monitoring and take actions necessary to prevent environmental effects (UNEP, 2021).

Non-sanitary landfills have considerable impact on both the environment and societies. Unmanaged dumpsites are globally the third largest source of anthropogenic emitted methane (UNEP, 2021). Emissions of methane and fires are often an effect of uncontrolled anaerobic digestion of organic waste deposited in a landfill, often as part of the mixed waste in MSW. To prevent these emissions, organic waste is often treated separately to reduce the volume of waste in the landfill and to collect the methane for use as biogas (Istrate, et al. 2020). Implementing landfill gas collection during or after operations on a landfill could enable utilization of the gasses to generate electricity, and to reduce the greenhouse gas emissions. Another environmental issue caused by unmanaged dumpsites is contamination of water due to leachate (Nanda & Berruti, 2020). Leachate can result in chemical pollution of waterways close to the waste site at the surface, but the pollution can reach the groundwater as well. Heavy metals from the dumpsite can also be trapped in the soil near the site, which results in long-term contamination of the area (Vaverkova, 2019).

From a societal perspective, poorly managed waste disposal sites can have profound negative impacts on the public health of nearby communities and can cause large economic costs for those communities. Consequences for public health are commonly caused by air pollution from fires, contaminated water, and the spreading of diseases by animals living on the dump site (Njoku, Edokpayi & Odiyo, 2019).

Economic costs are commonly caused by unmanaged waste degrading environment and causing health issues, in addition to the high operational costs of managing the site when working with inefficient equipment and uncoordinated operations (UNEP, 2021).

2.2 Solid waste and low- and middle-income countries

The increased waste generation that usually follows economic development of LMICs puts increasing pressure on the SWMS (Kaza, et al., 2018). In many cases, there is a need for increased structure, funding and legislation, as well as technology (Bundhoo, 2018). This chapter presents the challenges faced by LMICs in SWM, describes the potential role of the informal sector in waste management, covering three cases where authorities has attempted to integrate the informal sector of waste management into society.

2.2.1 Challenges

The technologies used for waste treatment and disposal varies greatly by income level (Kaza, et al., 2018). SWM in LMICs is typically highly inefficient, with elements of informal waste collection, dumping, and lacking environmental control (Matete and Trois, 2008). The awareness of the public concerning consequences of poor waste management is also low and the amount of MSW being recovered and recycled is limited (Bundhoo, 2018).

In low-income countries there is typically a high rate of open dumping and waste burning (Kaza, et al., 2018). This is due to the lack of legislation enforcement (Bundhoo, 2018). Recycling is usually done by informal waste workers, with challenges regarding funding and infrastructure. Some households in less urban areas that have the space and their own farmland often have a small compost for their garden (Gutberlet, et al., 2016). For middle-income countries, landfills are the usual disposal method, and will likely continue to be so for a long time (Kaza et al., 2018). However, there is a trend of development for sanitary landfills and recycling. Improvements intended to manage the large organic waste fraction common for low- and middle-income countries are being widely implemented, as well as the introduction of sorting plants with manual or some mechanical sorting.

The availability of land, as well as the increasing awareness of environmental pollution and resource scarcity, are underlying problems which discourage investments in sanitary landfills (Kaza, et al., 2018). Instead, countries are looking into developing WtE incineration plants, as that adds a source of electricity as part of the SWMS. Obstacles to development are technical knowledge on implementing improvements in the SWMS, and lack of infrastructure such as suitable roads for collection of waste (Bundhoo, 2018). Despite the challenges LMIC faces, it is important to develop the technology to manage MSW as well as to reduce the amount of waste by applying more circular systems thinking such as prevention and reuse of discarded products and materials (Matete and Trois, 2008).

MSW management relies on citizen engagement (Kaza, et al., 2018). Citizens need to understand, approve of and follow the system structure. Sustainable SWM requires on consumers to reduce their waste, separate or manage the waste at home, properly dispose of waste and pay for the SWM. To motivate such behavior, governments need citizens' trust. To raise the trust, governments should open up for citizen feedback on shortcomings in the system. To increase citizens' understanding of their part in the SWMS, education programs are important to create awareness, make SWM publicly available and provide excellent services as incentives to increase public engagement (Kaza, et al., 2018, Goodluck, et al., 2019). Examples of incentives are information on source separation and a timetable

for waste trucks, or reduced fees for waste volume reduction. A strong regulatory framework with rules and regulations is the foundation for a sustainable SWM with proper oversight from authorities, and it also relies on citizen engagement (Kaza, et al. 2018).

The quality of SWM has environmental and social effects which mostly affects society' vulnerable (Thomas-Hope, 2015). Poor SWM can impact the lower income segment's health and quality of living, as low-income communities are less likely to get their waste collected and often don't know the harms of burning and dumping waste (CWG, 2003).

2.2.2 The informal sector

Waste pickers are informal workers that rely on recovering valuable materials from waste sites (GIZ, 2011). Informal workers have been defined as people who have no contract, no stable means of income and who work with simple equipment under vulnerable circumstances. Informal workers in SWM are common in LMICs where they often recover and recycle a significant amount of waste, driven by the commodity value of materials (Thomas-Hope, 2015). There are different activities for waste picking: door to door, street, MSW truck and disposal site collection (Wilson, Velis & Cheesman, 2006). Processing the recyclables into sellable products is another WM activity often occuring in the informal sector (Gutberlet, et al., 2016). The activities by the informal sector reduces the depletion of natural resources by operating on the levels of reuse and recycling in the waste hierarchy and are essential for material recovery in low- and middle-income countries (Dias, 2016).

Waste pickers typically come from poor households (Harmann, 2017). Their initial objective is often to provide for their own or their families' basic needs. Such has been the case in Colombia, where informal recycling has been traced to the 1930's after a lot of internal political, economical and social conflicts (Dias, 2016). The conflicts led to a lot of people living without education and money in the cities, and opportunists started collecting reusables and recyclables that were discarded by others (GIZ, 2011).

Waste pickers often lack status in society as the waste picking occupation has an impact on appearance, with a dirty and smelly work environment (GIZ, 2011). The hazardous environment waste pickers work in also has health effects due to exposure to biological and chemical hazardous waste, ergonomic problems and musculoskeletal problems from hard manual work, different accidents, injuries from sharp objects and fires caused by flammable liquids inside containers, among others (Dias and Samson, 2016). These are dangers that waste pickers often underestimate as they are used to the harsh work environment (Wilson, Velis & Cheesman, 2006).

New public policies can play an important role in integrating the informal sector with formal SWM operations. It is important that policy makers consider informal waste workers when introducing new policy (Goodluck, et al., 2019). Formalizing the informal sector has many social benefits (Thomas-Hope, 2015). It can improve the living and working conditions for the informal workers, but can also enhance the services that the waste pickers are providing for society (Gutberlet, et al., 2016). To improve the working conditions in the informal sector when strategically planning the SWM system, education programs, which were useful to properly integrate the informal waste workers, prevent child labour and improve work safety (GIZ, 2011).

There are several ways to integrate the informal sector in a more structured SWM system: waste pickers could work informally but get formal support and recognition from the state, waste pickers could form co-operations, or the waste pickers could become integrated through complete integration. After getting formal recognition and support, they could work as collectors or sorters for the formal recycling sector (Dias, 2016). The waste pickers would then keep their income, but conduct their work in a safer and more socually accepted way.

Case 1: Waste pickers formalized through governmental support and recognition in Pune, India

India has over 3 000 operational dumpsites, the result of much uncontrolled open dumping in the country (CSE, 2020). It is estimated that India has over 5 million sanitary workers, employed or otherwise engaged in the SWM in India through street sweeping, collecting, sorting and transporting waste (UNDP India, 2021). Numerous initiatives to increase the sorting of recyclables have been undertaken, many of which have included the informal waste pickers. Despite the large-scale contributions to material circularity, many of the waste workers working in the informal economy still live and work under poor conditions in India (UNDP India, 2021). However, an inspiring case can be found in Pune. There, waste pickers have become official workers and have been integrated into the municipal waste management system and gained acknowledgement and improved working conditions (WIEGO, 2012). The demands of the waste pickers themselves were key in making this possible. By unionizing informal self-employed waste workers, they could prove what a big social service they were providing for the municipality for free. The Bombay Provincial Municipal Corporations (BPMC) Act of 1949 states that it is the municipalities' responsibility to manage SWM (Government of India, 1949). The discarded material recovered by the waste pickers therefore directly reduced the municipal costs by millions of US dollars every year in sanitary services (WIEGO, 2012). The waste pickers' major contribution to public and environmental health gained recognition. This led to the waste picker union's rights being institutionalized with a legal framework stating their rights to recyclable materials in the waste stream in Pune. A consequence of this integration process into formal SWM was that waste pickers received equipment and training, as well as the right to collect waste directly from residents and charge for their services (Dias, 2016).

A co-operative is an organization of at least 20 people who share income and make decisions democratically (Silva de Souza Lima & Mancini, 2017). There are many benefits to co-operatives in the informal sector (Goodluck, et al., 2019). The co-operatives were found to be crucial for the integration of the informal sector into the formal SWM system. It enabled mobilization, organization, a supporting network, official partnerships and made the sector more visible and represented (Wilson, Velis & Cheesman, 2006). An example can be found in the Philippines, where a group of waste pickers elected a leader after starting a waste pickers association. The association enabled the construction of a separation plant, and with an accepted leader, the work was organized more efficiently and the selling of recyclables yielded better prizes sold together rather than separately (GIZ, 2011).

Case 2: Catadores – Brazil's waste picker co-operatives

In Brazil, waste pickers are known in the country as catadores (GIZ, 2011). Catadores have since the 1980s been associated with co-operatives, and after the Brazilian Government identified catadores as a profession, social awareness has grown and the waste pickers have been more integrated into society (Dias, 2011, Gutberlet, 2008). Now, since 2010, catadores are included in the formal WM system in accordance with Brazil's National Solid Waste Policy and all municipalities are encouraged to integrate and hire the waste pickers (Silva de Souza Lima & Mancini, 2017). The services the catadores are promoted to do are collecting, sorting and commercializing recyclables, both to the public and private sectors (Jacobi & Besen, 2011).

Some municipalities hire co-operatives toservice public buildings, and prefer other private corporate actors (Rutkowski & Rutkowski, 2015). However, those municipalities who do not directly employ still support the catadores co-operatives with e.g. technical equipment and trainings. To further underline the important contribution to society of catadores, the government is trying to promote waste segregation at source through policies and environmental education (Silva de Souza Lima & Mancini, 2017).

The economic benefits of formal recognition for the co-operatives in Brazil have been important for tackling poverty, offering a more stable income in addition to a support network of waste pickers coming together to claim their rights in society (Gutlebert, 2008). The increased recycling also benefits the authorities as less resources go to landfills, collection has become more effective and co-operatives have begun paying taxes (Silva de Souza Lima & Mancini, 2017, Rutkowski & Rutkowski, 2015). Further benefits identified with this formalization of waste pickers is the data it has made available, which makes it possible to identify the earnings employment and socio-economic characteristics which are important to design strategies and policies for poverty reduction (GIZ, 2011).

Some challenges remain regarding the integration of the catadores into formal WM. Many catadores still work independently due to lack of knowledge of co-operatives or because they were not satisfied with the management of them (Silva de Souza Lima & Mancini, 2017). There are still children working with waste picking, and women tend to earn much less than men when re-selling the recycled materials (GIZ, 2011).

The waste pickers could also be formalized completely, as demonstrated in projects in Morocco and the Philippines where organizations employed former waste pickers successfully when privatizing the informal sector (Kaza, et al., 2018). It could improve waste collection and recycling by organizing it, and that waste pickers would be allowed social benefits such as regular income, formal identification and protective work equipment (Kaza, et al., 2018). Formalizing the waste collection industry can also be better protection for the environment, with environmental regulations to follow and monitoring (GIZ, 2011). However, there are challenges with including every informal worker when formalizing a previously informal sector completely, as seen in the case of Managua (Zapata & Zapata Campos, 2015).

Case 3: Complete formalization of waste pickers after the closing of a landfill in Managua, Nicaragua

Until 2013 La Chureca was a municipal solid waste open dumping site in Managua, Nicaragua (Zapata & Zapata Campos, 2015). After the Acahualinca development project which relocated living areas and closed the dumpsite, the waste goes to a recycling plant and a sanitary landfill. The development project has resulted in environmental, economical and social benefits (Hartmann, 2017). The open-air dump has been replaced for increased local environmental and health protection as well as material circularity. Many waste pickers' livelihood have improved through employment with salary, job training and enhanced living infrastructure. Nevertheless, the case of La Chureca also shows the challenges of implementing changes to modernize municipal SWM. As a dumpsite, 1 500- 2 000 people picked garbage in La Chureca (Hartmann, 2012), but the employment for the modern landfill only employed 580 people full time (Hartmann, 2017). So there is a reduction in employment opportunities during these SWM transitions, which led to hundreds of people losing their livelihood. Many in Managua continue to pick waste informally (Zapata & Zapata Campos, 2015). This could be due to not enough aid or information given about alternatives presented, including job training for alternative trade (Hartmann, 2017). However, it could also be due to the cultural perspective of the waste belonging to the commons and resisting the privatization of waste (Zapata & Zapata Campos, 2015). Whatever the reason, many are still living in poverty and working in hazardous environments after the Acahualinca development project (Hartmann, 2017).

2.3 Governance

Governance is a broad term used to describe the process of decision making and implementation of the decisions into human society (UNESCAP, 2009). Because governance is such a broad concept, this section focuses on governance for sustainable development and public participation. For sustainable development, a state has to have good governance which considers economical, social and environmental aspects in policy changes (Weiss, 2000). To achieve this, there are several policy tools which can be used for governments (Zaccai, 2012). Sustainable governance also relies on participation, such as stakeholder involvement or partnerships between the public and the private sectors. For sustainable SWM, it is important to build up a robust governance in order to work with challenges in the field (Rodic & Vilson, 2017).

2.3.1 What is governance?

Governance encompasses conditions to rule, the use of political authority as well as managing control of economic and social affairs, and administering a country's public and private common affairs (Weiss, 2000). The word comes from 'government', which refers to the formal institution of the state and its legitimate power (Stoker, 1998). Governance embraces the governmental institutions as well as the non-state actors operating within informal, non-governmental organizations and the private sector (Biermann, et al., 2012). It is a broad concept that varies depending on the context. It can be used in several aspects such as corporate governance, global governance, national governance and environmental governance (UNESCAP, 2009; Weiss, 2000). The use for governance in this research looks at national and environmental governance which aims for sustainable development with the goal should always be good governance that builds on stakeholder inclusion (Brett, 2003).

Good governance is built on eight characteristics (UNESCAP, 2009). The characteristics are participation, accountability, transparency, rule of law, effective and efficient, responsive, consensus oriented, and equitable and inclusive. Together they allow for a strong civil society, the development of well-functioning economic and democratic systems, and widespread public participation (Weiss, 2000). Governance is also needed to keep society's needs in focus and to regulate the private sectors which are pursuing individual gain.

Participation in governance is central for good governance and social development. It is directed through institutional arrangements to organize and inform for the sake of civil association and cooperation (Brett, 2003). To strengthen governance, participation has to go beyond governmental agencies and enhance stakeholder participation and partnership (Biermann, et al., 2012). It can be partnerships between the government and NGOs, or public-private partnerships (PPP) which are between the state and private companies (Weiss, 2000).

Accountability, for governmental institutions and the private sector, is in turn crucial for citizen participation (UNESCAP, 2009). Accountability means giving leverage with exit options, voices to the users and having a mutual dependency (Brett, 2003). For the government to hold private actors accountable, it is important that rule of law is maintained and that there is institutional capacity for monitoring and regulating (Weiss, 2000; Biermann, et al., 2012). To empower citizens it is in turn important with transparency and information disclosure from the government. Governance accountability is stronger when stakeholders have good access to information and can be part of decision making (Biermann, et al., 2012).

For transparency it is important that information is freely available and accessible to stakeholders who are affected by decisions (UNESCAP, 2009). For effective participation, transparency and openness through good information flow is important (Rodic & Wilson, 2017). Information disclosure can empower citizens and hold public and private actors accountable (Biermann, et al., 2012). If inefficient institutions limit the disclosure of information, stakeholder participation is hindered.

Rule of law is also an important pillar of good governance, and is essential for the other characteristics of good governance to work. Good governance requires a strong and enforced legal framework to protect human rights, democratic institutions and resilience against corruption (Weiss, 2000). Enforcement is key, without which rule of law degrades (Rodic and Wilson, 2017).

For good governance, the governing entity also has to commit to being effective and efficient (Stoker, 1998). It means meeting the needs of society with the resources available, and using the available resources in the way that ensures maximum benefit for society (Blühdorn & Deflorian, 2018). At the same time, responsiveness highlights the requirement of governance through institutions and processes to develop and adapt to the needs of the system within a practical timeframe (UNESCAP, 2009).

Consensus oriented governance is important in oder to mediate between all actors and the many different views of stakeholders (Blühdorn & Deflorian, 2018) and should be mediating and aims for the best interest of society (Koppenja, 2015). This requires long-term perspectives on what is needed and understanding of all social, cultural, economical and technical contexts (Grohs, et al., 2018). Lastly, equity and inclusiveness is important for society's prosperity (UNESCAP, 2009). Therefore, special attention needs to be to get participation from the most vulnerable groups affected by policies and most

likely to suffer from changes (Biermann, et al., 2012). Good governance therefore has to build processes where people, in society can impact decisions that will affect them (Weiss, 2000).

2.3.2 Policy instruments for sustainable governance

To support sustainable development and environmental inclusion for complex systems improvement, governance needs policies to be made and implemented with intention and active stakeholder participation (Grohs, et al., 2018). Effective institutional governance needs to be adaptable and often involves several actors and not just the government (Biermann, et al., 2012). Additionally, Zaccai (2012) suggests that there are five categories for policy instruments: regulations, market based instruments, voluntary instruments, collaborative actions and information instruments.

Regulations are command and control instruments that make actions mandatory or prohibited (Zaccai, 2012). It is a hierarchical tool that governments, thanks to their legitimacy, can use to regulate and standardize behavior. This is an important tool to align people for change, and has been a major contributor to the reduction of pollution in the EU. Regulation can also be norms and expectations, which can change behavior and goals based on what is considered socially desirable (Hamman, 2020). Norms are more cooperative and non-governmental actors take a bigger role, but can still be used to standardize a system (Zaccai, 2012).

Market based instruments include tariffs, subsidies and direct market competition (Koppenja, 2015). The polluter-pays principle is an example of a market based instrument applied for sustainable development (Zaccai, 2012). These instruments can be seen to encourage mechanisms, for example clean technology, and effective environmental and social development steps. Market competition is also better than direct control or voluntary instruments when it comes to leverage over the performance of private firms as financial incentives tend to dominate in the private sector (Brett, 2003).

Voluntary instruments are based on individual commitments from people or private entities (Zaccai, 2012). Voluntary agreements with the government or with other parties allow for flexibility and actions that may motivate innovative action. However, the voluntary actions have to be supported by regulations for them to align with sustainability purposes (Biermann, et al., 2012). Collaborative action is a form of governance through partnerships, which take place between NGOs and companies, NGOs and public institutions, or between the public and private sector (Zaccai, 2012). Such collaborative action, where responsibility for sustainable development is shared between actors, is imperative. Self-organized systems of control among the key participants is seen as more effective than government-imposed regulation (Stoker, 2008).

Finally, informational instruments are there to educate stakeholders and promote a sustainable development message (Zaccai, 2012). For information tools to be effective the message has to be clear and specific. Information flows can strengthen the legitimacy of governments, thus strengthening the governance (Biermann, et al., 2012).

2.3.3 Public-private partnerships and solid waste management

This chapter describes key features of public-private partnerships (PPP), potential and challenges of PPPs, as well as an overview of the application of PPPs to solid waste management. A PPP is a method of governance, under which private actors provide a public infrastructure utility (Koppenja, 2015). It can be conceptualized as a way to handle the operation of infrastructure assets by sharing ownership between the public and private sectors.

PPPs are applicable in a number of different sectors. Some of the areas where a PPP is typically viewed as suitable are energy with generation plants, transportation infrastructure construction or service, or social such as health facilities. The design of a PPP can vary greatly, but certain design characteristics are significant in all cases. Aside from the actual provision in question, PPP contracts can be characterized by the source of finance, the contract length, the burden of risk and the remuneration scheme or business model (World Bank, 2017a).

PPPs are usually allocated through a tendering process initiated by a national government through a PPP unit, an entity tasked with identifying and brokering prospective PPPs. Development banks in the particular area are often important in the establishment of a PPP (World Bank, 2007). Outside formal tendering, contracts can also be awarded based on bids from private parties (Hall, 2015). PPP can work under many different arrangements depending on the service it intends to provide. Generally it is defined by the responsibilities the public sector seeks and finds a suitable agreement with a private partner (Biermann, et al., 2012). Under one contract, the private partner is charged with designing, building and operating the asset, e.g. a power plant (Koppenja, 2015). Meanwhile, under another contract the plant would be built according to specifications and transferred at the end of the operations phase.

2.3.4. Risks of public-private partnerships

The implementation of a PPP comes with a level of inherent risk for all parties involved. Assets are typically financed through loans taken by the private partner, but guaranteed by the public (Koppenja, 2015). The operations phase is extended to enable the private partner and lender to make returns on their investments. Either the public partner pays for the service through taxes, or the private partner is permitted to charge consumers directly, or there is a combination of the two. The contract normally guarantees the private partner certain revenues (World Bank, 2017a). Together with its guarantor status, this means that the public ultimately accepts the overall risk. In return, the contract normally defines performance criteria for the private partner, which if not met may lead to withheld payment. Additionally, risk is often transferred to the private partner during especially sensitive phases, notably construction, under a so-called turnkey clause. Challenges associated with governments using PPPs for sustainable development include correctly assessing the benefits of the PPP, long-term commitments to private actors, high costs, balancing economic profitability with sustainability, and ensuring stakeholder involvement.

There is a risk of economic profitability surpassing the sustainability aspect in PPPs. Private parties may easily develop market power and may then seek economic opportunities if the market conditions and competition is underdeveloped (Koppenja, 2015). To ensure the realization and functioning of a public infrastructure in a PPP structure, regulation is essential. This regulation is based on contracts with the private company, and should include price regulation, service quality standards and coverage targets to incentify proper operations without compromising social or environmental aspects (Biermann, et al., 2012). If sustainability requirements lead to increased costs that might impact the return on investment for the private company, then the project might need to be redesigned or the government needs to compensate (Koppenja, 2015). Investments in developing the infrastructure may be costly, which may result in less sustainable solutions to be more cost efficient (Koppenja, 2015). For sustainable development, environmental and social values needs to be reflected in the performance criteria, or they are likely to be neglected in the project's implementation (Weiss, 2000).

Assessments of PPPs often take place too early or not at all, with the risk that each case is not critically evaluated and thus does not provide the intended benefits (Hodge and Greve, 2007). Therefore, for governments without sufficient resources for the assessment, generally LMICs, it might be favorable to avoid PPPs in favor of public governance (Hall, 2015). It is important that the public as a governing entity is capable of assessing the viability and performance of PPPs and of managing risks together with the private sector (Weiss, 2000). This requires significant expertise and strong institutional support. As the PPPs are often long-term commitments hard to break from, the lack of a comprehensive contract signed at the establishment of the PPP may lead to re-negotiation of contracts during the extent of the partnership which can become very expensive for both parties of the PPP (World Bank, 2017b).

PPPs can easily fail to meet expectations due to a lack of stakeholder participation and management (Koppenja, 2015). The lack of stakeholder participation can also lead to an increased risk for the private party, as lack of inclusion reduces the stakeholder understanding and project legitimacy, and leads to opposition and loss of infrastructural efficiency (Biermann, et al., 2012).

2.3.5 Cases of public-private partnerships in solid waste management in low- and middle-income countries

This section describes examples where PPPs have been used to provide SWM services in LMICs. The implementations often encounter issues not foreseen by the authorities, and tend not to work as well as hoped prior to implementation.

In Egypt, a European company won an offer for SWM services in the governorate of Alexandria, under which it would collect and dispose of MSW, as well as industrial and medical waste, and improve material recycling (Iskandar & Tjell, 2009). The cost of collection was assigned to the user. Out of 26 remaining Egyptian governorates, 15 adopted similar arrangements within a year (Milik, 2021). While collection efficiency improved substantially for many governorates in the following years, SWM suffered in other respects. The informal waste sector became regularized into the private structure, becoming subject to its rules. The outcome became tougher competition which restricted the already struggling sector to lower profits. The volume of recycled non-organic materials decreased by 30%. No organized system for organic waste management has emerged even though the conditions for organic composting and bioenergy were favourable. Despite good intentions a transition to sanitary landfills or sorting of fractions has not yet occurred in Egypt under the PPP, where 88 percent of MSW is dumped and landfill fires persist (Milik, 2021).

In Accra, Ghana, MSW collection fell behind during a period of urbanization in the 1980. The private sector became progressively engaged in order to improve performance for collection and integrate the informal waste sector with society (Volsuuri, Owusu-Sekyere & Imoro, 2022). Significant efficiency gains were realized and service coverage, as low as 51% in 1995, reached 91% in 2000 (Fobil et al., 2008). These gains could not be maintained, however; by 2005 MSW collection was fully private but coverage had decreased to 67% and operated with a state-supported cost deficit of 63% (Oteng-Ababio, 2010). Collection followed two models: communal containers covering around 70% of the user base, and house-to-house collection routes serving higher-income areas. Both models relied on user fees, making them vulnerable to free-riders and unattractive compared to the zero-cost option of illicit disposal (Oduro-Kwarteng, 2009). The system is currently ineffective and highly pollutive, with the public lacking the capacity to effectively monitor haulers or impose sanctions on polluters (Lissah, et al., 2021). Furthermore, the PPP has not led to an integration of the activities of the numerous waste pickers with the formal SWM system (Volsuuri, Owusu-Sekyere & Imoro, 2022).

2.4 Stakeholder theory and sustainability issues

Stakeholder participation occurs when the stakeholders are invited to join in on decision making and actions (Reed, et al., 2009). It is based on the recognition of a need to understand who is affected by the decisions and actions, and who has the power to influence. Any party that is affected or has the power to influence is a stakeholder (Freeman, 1984). Stakeholders are the users and governors of a system and their engagement is crucial for sustainable development (Stoker, 1998). To manage a complex system such as SWM, there is a need for stakeholders to participate (Reed, et al, 2009). Participation can be used as a tool in complex systems (Grohs, et al., 2018), and leverage points can be used to affect (Meadows, 1999) sustainable system changes.

2.4.1 Stakeholder theory and analysis

Stakeholder theory is based on the belief that the best outcome from change in a system will be possible with participation of stakeholders in the decision making process (Hemmati, 2002). A stakeholder can be an individual, a group or an organization that stands to ve affected by a change, has a claim to resources or output, or can affect the change through power, influence or responsibility (Bryson, 2004). Attention to stakeholders is important for change management success, as many issues in society contain numerous actors that are involved or affected.

Stakeholder analysis involves identifying stakeholders and categorizing them according to their involvement and stake in the decision making process (Reed, et al., 2009). Through identifying criterias that justify the involvement of different stakeholders in a certain situation, ranging from who is most affected to who can affect and the interests of the different stakeholders, the relevant perspectives can be involved for decision-making (Freeman, 1984). SWM, for example, polluters and waste management organizations are affecting stakeholders that have power over the system and therefore have an obvious place in decisions pertaining to it; meanwhile, stakeholder analysis could identify and characterize affected stakeholders, such as waste pickers or underserved households who have little power over the system but potentially valuable insights (Kaza, et al., 2018).

In stakeholder identification, the analysts identify the stakeholder individual, group or organization through knowledge and brainstorm regarding who is affected or is affecting with interest, resources or power of influence (Reed, et al., 2009). To identify more stakeholders and improve the participation, there are also stakeholder generation techniques to use, such as creating groups of stakeholders to identify additional stakeholders affected by the situation in question (Mason & Mitroff, 1981). Typically stakeholders can be divided into the following groups:

1. Stakeholders with strong opinions identified through written or spoken sources and identifies who feels strongly about a topic and thus might have a stake in the change or can affect the outcome,
2. Stakeholders with formal positions, for example the government,
3. Knowledgeable stakeholders who can provide information,
4. Stakeholders representing social participation, by being part of the system in the change,
5. Stakeholders with influence over opinions, who have leverage or influence over parts of the system or other stakeholders,
6. Stakeholders of demographics, identifying stakeholders by characteristics of e.g. occupation, age or sex that might have a stake in the decision or change, and
7. Stakeholder organizations within the system that might have important roles or relationships with other stakeholders.

The brainstorming (Reed, et al., 2009) and methodological approach (Mason & Mitroff, 1981) is well complemented with snowball techniques, where identified stakeholders from the brainstorms can add more stakeholders to a communicated list or during interviews (Luyet et al., 2012; Reed, et al., 2009).

Stakeholder characterization is done to understand power relations between stakeholders and the stakeholder perspectives on the decision or action (Luyet, et al., 2012). The power relations between stakeholders classifies stakeholders on their interest and amount of influence in a system (Reed, et al., 2009). One example of categorizing stakeholder in range of affected vs. affecting is through a rainbow diagram that categorizes stakeholders according to the degree they can affect or be affected by a decision or action (Chevalier and Buckles, 2008). Other characterizations include, for example, identifying key players with high interest and high influence or little influence with high interest, as well as different interests in the system and the degree of urgency, power and legitimacy (Mitchell, et al., 1997; Reed, et al., 2009; Luyet, et al., 2012).

2.4.2 Systems in sustainability issues

Systems aims at describing the interaction, connectivity and interdependence of entities that comprise a complex network generating an outcome (Waddock, et al., 2015). Understanding a complex problem is very important when transforming socio-ecological systems, like solid waste management where societal management of waste is poor and thus affects the environment (Waddock, 2020).

In systems theory, it is common to distinguish between different types of problems based on their structuredness and complexity (Figure 2.2). Simple and well-structured problems have clear end goals and there is agreement on how to solve them (Batie, 2008). An example of a structured problem is road maintenance (Hoppe, 2002). A more complex but still well-structured problem could be the assembly of a car, while an ill-structured but still simple problem could be choosing the car's color. In moderately structured problems, there might not be consensus on values and views on the end goal (Hoppe, 2002). An example of a moderately structured problem is the transition from fossil energy to renewable energy.

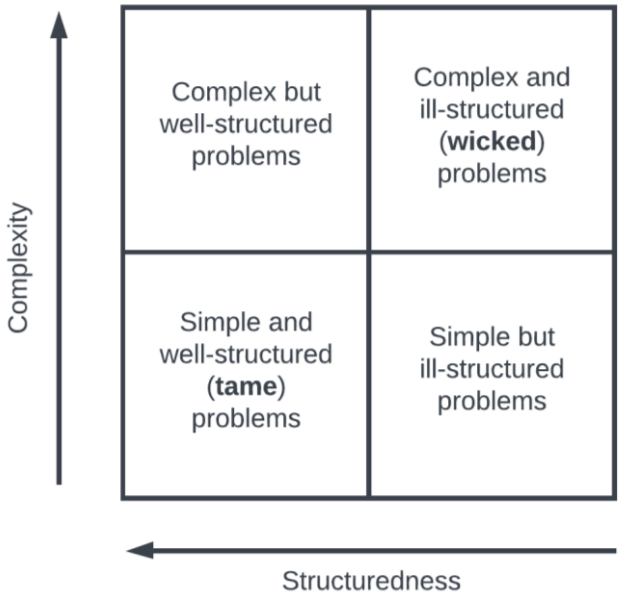

Figure 2.2. Typology of problems. Adapted from Pearce & Ejderyan (2020).

Problems that are both complex and ill-structured are called wicked(Waddock, 2020). These are characterized by the presence of a diversity of stakeholders with different perspectives of what the problem is and how change will impact them (Rittel & Webber, 1973). Because the problem perspectives are so varied and solution possibilities vary accordingly, a challenge with wicked problems is understanding the actual problem and not solving the wrong problem (Cuppen, 2012). Therefore, stakeholder dialogue becomes very important to fully understand the problem and all its complex connections in the system before taking action (Ison, Collins & Wallis, 2015).

System transformation for sustainability focuses on balancing all the different technical and contextual aspects to affect fundamental change in a complex system (Loorbach, et al., 2017). Because of the large-scale societal changes necessary to solve sustainability challenges, transitions in complex systems disrupt many aspects of existing societal systems. As problems become more complex, technical and contextual elements intertwine (Grohs, et al., 2018). Technical elements are specific knowledge or processes used to transform problems or resources, but as any technology it is also defined and conceptualized by its context. And the contextual elements refer to the environment in which all technical elements are embedded, including social, cultural, political, legal, ecological and economic aspects. Many societal systems are complex, as there are so many stakeholders affected by change and they interact with political and technical aspects (Loorbach, et al., 2017). For example, waste management is a socio-technical system, as infrastructure technologies are set in social context.

The academic field of sustainability transitions and transformation is concerned with understanding and effecting fundamental system changes for sustainability (Loorbach et al., 2017). To enbae change in complex systems, it is important to first understand the system, then make sense of what is happening and what needs to happen, and finally to connect stakeholder goals into aligned action (Waddock, 2020). To understand the issues, it is important to consider perspectives on the system, recognize patterns and explore processes in the context with system mapping. With system mapping it is possible to see a system as a whole. This holistic view is important to gain perspective and understanding the complexity of interlinked relationships between processes, e.g. which stakeholders are dependent on what parts of the system and which stakeholders can affect the different parts (Grohs, et al., 2018). Patterns can also emerge when understanding of a complex system increases, seeing feedback loops in the system mapping (Waddock, 2020). Through exploring processes, links between the patterns can be found which in turn provide insight into what will happen if one part of the system is changed, as changing one part of the system in a complex system has unpredictable effects on other aspects and new problems risk emerging (Cuppen, 2012).

By seeing the system as a whole and understanding the perspectives and links, recognition of what might be needed for sustainability transformation in a system can take place (Waddock, et al., 2020). This can be explored through scenarios to see where and how the change could happen (Grohs, et al., 2018). These transformation processes in a system that might offer great change are leverage points (Meadows, 1999). Identifying leverage points for change can be done by engaging with multiple stakeholders across the system (Waddock, et al., 2015). Leverage points, as defined by Meadows (1999) are twelve ways in which a part of a system can be changed to affect the whole, ranking from most to least powerful (figure 2.3).

1. The power to transcend paradigms is the top leverage point. Here society has realized that no paradigm is true, and the system is flexible to adapt to whatever the needed changes for sustainability requires.
2. The mindset and paradigm of the system is a very powerful leverage point. It is the shared ideas in society and constitutes the deepest sets of beliefs regarding how a system works. It is out of these that the goal, structure, rules and parameters arise. If society agrees on change, their reality is changed and the system goals and other leverage points will conform with it. Mindset change can be a very slow process faced with a lot of resistance, but with open minded people and collaborative action it can be accelerated.
3. The goal of the system is a leverage point, and with a changed system goal all the other leverage points from 4-12 can be adapted to fit that goal. For example, the value and application of a technology depends on the intention of the user.
4. Giving power to the system to add, change, evolve and self organize system structures, with technical advancement and enabling the addition of new rules and feedback loops to the system.
5. The rules of the system, for example laws and regulations, are leverage points with high power. They prevent actors in the system from doing damage, and create accountability and consequences for unlawful or unwanted behavior.
6. The structure of information flow is a leverage point, as information affects behavior. So, to change a system, the right stakeholders need to have access to the right information. This can deliver feedback and establish transparancy and accountability in institutions with increased transparency.
7. Driving positive feedback loops so that the system can self-reinforce and grow stronger.
8. Having negative feedback loops in place to correct impacts through information and control parts so that the system can self correct. An example of a negative feedback loop is monitoring systems so environmental impact and damage can be reported.
9. The length of delays relative to the rate of system changes is important for system change, as too long a delay does not provide the information required to understand whether changes are providing the wanted outcome. A system can't respond to short-term changes when it has long-term delays.
10. The structure of material stocks and flows is a leverage point, as changing the flow can change the system outcome. This is often a slow and costly process, because in socio-technical systems it involves changing infrastructure and transport networks which is hard to do if it can be done at all.
11. The size of buffers and stabilizing stocks, relative to the flows in the system, can adjust the flows in the system and bring stability over time. Larger buffers can often stabilize a system, but too big makes the system inflexible and slow to react.
12. Parameters, constants or numbers, for example subsidies, taxes or governing standards. These are short term boosters that can help a little with change but will not be enough on their own in the long run.

Figure 2.3: Meadows (1999) twelve leverage points for system change.

2.4.3 Stakeholder management for sustainable development

Stakeholder participation is key to attain good governance and sustainable development, and requires dialogue, forming relationships and collaboration (Hemmati, 2002). Stakeholder participation is the concept of involving citizens or groups that are affected or have the power to affect and represent a

perspective of a system (Bobbio, 2018). It is important to provide insight for policy-makers and stakeholders by gathering the different perspectives and choosing the best possible actions (Cuppen, 2012). Stakeholder participation can be used as an instrument for policy makers when designing new policies. For sustainable development, multi-stakeholder processes are needed (Hemmati, 2002). Because society's most demanding challenges are intertwining networks of technical and contextual elements, the perspective dimensions need to be panned out and the diverse stakeholder values and beliefs and definitions put into the process to solving the challenges in a way that is the most sustainable and inclusive (Grohs, et al., 2018).

There are different techniques that can be used to increase stakeholder participation (Luyet, et al., 2012). Participation can be encouraged through transparency in processes through information sharing, interviewing stakeholders to gather stakeholder perspectives, or holding workshops (Hemmati, 2002). Information sharing is important as it involves citizens in the change and the stakeholder participation is a step towards inclusion and democracy (Meadows, 1999, Bobbio, 2018). Stakeholder interviews allow for a first step of stakeholder involvement in the decisions making process (Reed, et al., 2009). Using workshops, stakeholder participation can be taken one step further. It opens up for more dialogue and mutual learning between stakeholders (Hemmati, 2002). The dialogue can increase the understanding of perspectives, issues and wanted outcomes for a change that can support decision making. Mutual learning is also important to fully utilize stakeholder participation as a tool. Stakeholder dialogue enhances learning through consultation and helps establish relationships and ownership between the stakeholders (Bobbio, 2018). It does not necessarily result in consensus, but should instead manage the gaps between stakeholder groups to utilize the diversity and lift the voices of the less powerful stakeholders (Cuppen, 2012).

3. Solid Waste Management in Jamaica

Jamaica is an island nation in the Caribbean. While blessed with an abundance of natural beauty, the country has long faced challenges connected to high poverty rates, crime and natural disasters (World Bank, 2020). Jamaica's waste management system was based around waste disposal sites spread around the island, managed by the NSWMA. The SWMS in Jamaica faced many challenges, ranging from inadequate collection to adverse environmental impact. However, there were ongoing projects to develop the SWM.

3.1 Jamaica's socio-economic status, waste management and environmental challenges

Jamaica's socio-economic status was a factor influencing the general state of SWMS, where there had been many issues associated with solid waste. Previous efforts undertaken to improve it had not made large changes towards effective waste management. The NSWMA's role as the managing authority in the SWMS had been limited, which led to challenges with illicit disposal and for the operations at the Riverton waste disposal site.

This section presents the socio-economic status of Jamaica, the general state of waste management in Jamaica, issues associated with waste and previous efforts undertaken to improve it. Additionally, the NSWMA's role as the managing authority in the SWMS is presented and the challenges regarding the Riverton waste disposal site are introduced.

3.1.1 Jamaica's socio-economic status

Jamaica is the third largest Caribbean island with a population of 2.9 million inhabitants (World Bank, 2020). Jamaica is also defined as a Small Island Developing State (SIDS) (UN, n.d.a). SIDS are island states which have been specifically identified in three geographical regions: the Caribbean, the Pacific and the Atlantic, Indian Ocean and South China Sea (AIS) (UNEP, n.d.a). They have been defined based on their unique social, economic and environmental vulnerabilities and development (UN, n.d.b). This specific group of island nations are very dependent on the sea, with the majority of their natural resources coming from the ocean (UNEP, 2014). tThe dependency on the sea and fragile ecosystems on and around the islands makes SIDS the most vulnerable nations to biodiversity loss and climate change through e.g. invasive species and the decline of coral reefs and mangrove forests (Birchenough, 2017). Other characteristics that make SIDS highly vulnerable based on social and environmental parameters are their geographical location in regions with heavy weather and tsunamis, limited physical size, and a concentration of their population along coastal zones, even if all SIDS are not identical (Lewis, 2022). The economic vulnerability of SIDS is caused by high economic dependency and costs connected to import as they must rely on international trade for many goods as a result of the narrow resource base (UN, n.d.b). Increasing waste generation is one among all these challenges faced by SIDS. Waste generation is becoming one of the major problems for many SIDS, which has resulted in a need for sustainable waste management methods (Mohee, et al., 2015).

Jamaica is a developing country and an upper middle-income economy, but is still struggling with high crime rates, high public debt and exposure to natural disasters (World Bank, 2020). There was also a high rate of informal workers in Jamaica (Torero et al., 2006). The poverty rate, as defined by the UN, has historically been high, with the lowest ever estimated to 12.6 percent in 2018 (Smith, 2020).

3.1.2 Solid waste management in Jamaica

At the time of the field study, the legal basis for SWM and recycling in Jamaica was the 2001 National Solid Waste Management Act. Through this act the NSWMA was founded and given the task of monitoring and sustainably managing Jamaica's solid waste (NSWM Act, 2001). An extended legal framework for SWM and recycling in Jamaica was formed by the National Solid Waste Management Policy, the Public Cleansing Regulations, the Public Health Act of the Ministry of Health and the Trade Act (Riquelme, Méndez & Smith, 2016).

In 2022, Jamaica produced over 1.09 million tonnes of MSW per year (DBJ, 2022a). At the time of the study, the MSWM consisted of garbage collection from residential and businesses by truck, which was then taken to the end destination of landfilling (NSWMA, n.d.c). Waste was collected directly from houses by emptying the smaller waste bins, or large communal containers or open containers called skips where neighborhoods or companies could throw away their waste. The frequency of appearance of bins and containers, and the waste collection was irregular (JET, 2016).

The NSWMA collected both residential and commercial waste and was at the time of the study in management of the country's landfills (NSWMA, n.d.a). There were also private contractors who collect waste (Pan American Health Organization, 2003). The containerization of waste was not regulated by the NSWMA, which had led to a wide variation in households' preferred waste containers and less purposely designed vessels. These varied from cardboard boxes in the kitchen to welded metal cages on the street, leading to health and environmental issues connected to vermin and odors (Post, 2007). Other ways for residents to get rid of waste include burning waste close to living areas, as well as discarding waste in nature, gullies and rivers (JET, 2016). It was estimated that more than 300,000 tonnes of garbage was illegally dumped every year (Smith, 2010). Furthermore, open burning of waste was illegal under section 4 of Jamaica's Country Fires Act (1942) unless permission was given. The law had not been well enforced and few penalties administered. It was estimated that 30% of Jamaicans burn their garbage (figure 3.1) (JET, 2016).

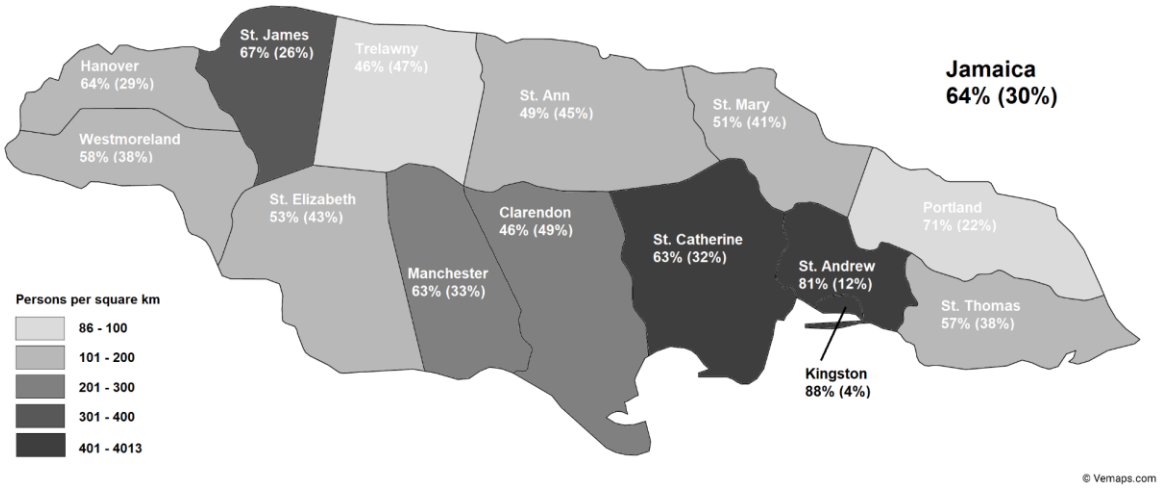

Figure 3.1. Municipal collection vs. (burning) as preferred method of garbage disposal, by parish. Undisplayed methods (6%) include, in order of national magnitude: independent municipal dumping; dumping in own yard; dumping into bodies of water; burying; private collection (Statistical Institute of Jamaica, 2011).

Waste that was recycled in Jamaica consisted of plastics, cardboard, paper, newspapers, toner cartridges, car batteries and electronic devices. Recycling was typically carried out by different private companies on the market (JET, 2020). In 2011 there was a temporary ban on all metal scrap export due to uncontrolled levels of metal theft, which had reduced the amount of metal scrap dealers in Jamaica (Recycling Today, 2011). Through a public private partnership with the Government of Jamaica, Recycling Partners of Jamaica (RPJ) had been recycling plastics (Stewart, n.d.). With the directive to remove plastic from the environment they had six collection depots where people could drop their plastic off, but they were planning to increase the amount to one in each parish (Spence, 2022). The recycling rate of new plastic bottles was estimated to 20 percent, with plastic bottles representing approximately 13 percent of the total waste in Jamaica (Salmon, 2022). Similar statistics on other recycling waste streams were not available. Naturally, recycling possibilities were fewer outside of urban areas (JET, 2016).

A waste characterization study was conducted as part of the preparations for the PPP, wherein the composition of the waste stream and the recovery potential of waste fractions was also assessed. Table 3.1 shows the results of the study.

Table 3.1. Jamaican MSW fractions by percentage. Adapted from DBJ (2022a). The 'Other' fraction is composed of sanitary, electric/electronic, hazardous and inert waste, as well as wood.

Fraction	**Size**
Paper	6.5 %
Cardboard	9.0 %
Glass	3.5 %
Metals	2.6 %
Plastics	16.8 %
Textiles	6.7 %
Organic waste	39.7 %
Other waste	15.3 %

The population of Jamaica ranked waste management as an important issue. A study of public environmental concerns by Post (2007) showed the Jamaican's concern about garbage disposal, as SWM was ranked above air pollution or deforestation (Espeut, 1999). A more recent study by NEPA (2016) on the same subject, showed that the concern for garbage disposal had increased. The most notable differences were in the answers on "major issues affecting the environment", where the answers of garbage disposal was ranked highest in 1998 with the majority of 17.7 percent (Espeut, 1999), and in the later survey of 2016 the concern had increased to 27.3 percent (NEPA, 2016). This showed the increase of public awareness and concern for the perceived substandard SWM.

A considerable amount of waste produced in Jamaica is not collected, and is instead dumped into the environment. It is estimated that 30 percent of the domestic waste in Jamaica is not collected (Riquelme, Mendez & Smith, 2016). Many challenges for the SWM in Jamaica are connected to the large source of uncollected residential waste. If a resident isn't at home in many areas the waste isn't collected, and,

even if it is collected, many feel like it isn't often enough (JET, 2016). Another problem is informal settlements not having waste collection, resulting in small unofficial dumpsites and throwing garbage into gullies or rivers (JET, 2016). With poor SWM in Jamaica, risks of attracting mosquitoes and flies increase, which would spread diseases like dengue fever, yellow fever and bubonic plague.

3.1.3 The National Solid Waste Management Authority

At the time of the study, The National Solid Waste Management Authority (NSWMA) was the government agency responsible both for all SWM in Jamaica and, by law, to manage solid waste in a safe way (NSWMA, 2019). The authority took over responsibility for Jamaica's solid waste in 2001 under the National Solid Waste Management Act (2001). This duty was previously assigned to the parish-run Parks & Markets companies, which constituted the authority's operational arm and provided practical services. The services of these were divided between the parishes of Jamaica into four "waste sheds," wherein the solid waste produced was collected by the relevant P&M company and taken to one of Jamaica's eight official waste disposal sites (NSWMA, n.d.b, NSWMA, n.d.c).

The solid waste management system in Jamaica was funded by the property tax, but a number of coinciding factors make the solid waste management system underfunded. The governmental funding model for the SWM was based on the property tax, which was intended to be paid by all persons in possession of land. The tax was meant to supply SWM collection and disposal, as well as all other waste management, building and rehabilitating roads and communities (Ministry of Local Government & Community Development, n.d). The fact that the tax was intended to fund so many different areas has resulted in low levels of funding for each individual area. Further shortcomings in the funding model had been the weak tax administration and low tax compliance within the large informal sector in Jamaica which resulted in missed collected taxes in many communities (International Monetary Fund. Western Hemisphere Dept., 2022).

The state of the SWM in Jamaica had been perceived as ineffective, and not providing the service sought by the citizens of Jamaica. Critics pointed to the failure of the NSWMA to observe environmental protocols (Office of the Public Defender, 2015), their erratic and unenthusiastic garbage collection (JET, 2016) and the ineffective regulatory framework (McCaulay, 2018). The NSWMA had reported a pickup accuracy of 70 percent (NSWMA, n.d.c), however especially rural areas had experienced the lack of resources of the NSWMA (Radio Jamaica, 2016). There, complaints from citizens were mostly related to the poor quality of service with inefficient waste collection and improper disposal (Auditors General Department, 2022). The NSWMA had not been performing to peoples expectations, resulting in pileups of garbage in communities and along roadsides threatening the environment. This was made worse as the NSWMA did not enforce litter laws (JET, 2016). There had also been an issue with lack of responsible actors for the cleaning of waste and maintaining the gullies. The National Works Agency (NWA) claimed responsibility for the management of gullies, but did not require removal of the solid waste (JET, 2016).

The solid waste management in Jamaica was generally not in compliance with legislation. The disposal sites in Jamaica had been lacking the required permits for waste management (JET, 2016). In 2012, NEPA initiated legal proceedings against NSWMA over legal breaches of environmental legislation at the Riverton waste disposal site in Kingston, as the disposal site had been operating without an environmental permit (Radio Jamaica News, 2012). In 2014, the NSWMA was granted two environmental permits by the National Resource Conservation Authority (NRCA), one for treating waste and one for transportation, storage and disposal of hazardous waste (Wright, D.A., 2014).

Meanwhile, the NSWMA had been operating the landfill without permits. Shortly after the permits were granted, NEPA issued a notice of intended suspension on the NSWMA for breaches of the NRCA permits (NEPA, 2014). None of the eight operational official disposal sites in Jamaica fulfilled the environmental legislation (JET, 2016).

NEPA was an executive agency under the executive agency act and was in charge of the environmental protection in Jamaica. The NEPA assisted the NRCA with administrative and technical assistance. Despite this, NEPA did not have any legal force behind its convictions (Office of the Public Defender, 2015). This hindered the agency from implementing many ramifications to handle the mismanagement of SW (CaPRI, 2015).

3.1.4 Previous improvement efforts

Historically, considerable effort has been put into trying to improve the waste management in Jamaica. Millions of Jamaican dollars were spent by the Government of Jamaica (GOJ) to clean oceans and rivers from misplaced solid waste (JET, 2016). There were also yearly coastal clean-up days organized by the NGO Jamaican Environmental Trust (JET) for the International Coastal Clean-Up day and funded by the Tourism Enhancement Fund (Harrison, 2015). As the majority of waste found in oceans and on beaches was single use plastic, a Plastic Waste Minimization Project was launched in 2019 by the GOJ, NEPA, UNEP's Caribbean Sub-Regional Office and its International Environmental Technology Centre, and co-financed by the Japanese Government, to reduce and manage plastic waste and strengthen legislation (UNEP, 2021b). In 2022, a new project by the Grace Kelly foundation, The Ocean Cleanup and the Clean Harbour Jamaica initiatives was launched to prevent waste that had been thrown in gullies from being washed out into the harbor (Jamaica Observer, 2022).

Projects with the aim of improving solid waste management in Jamaica had been conducted, but had faced challenges. In 2014, the GOJ together with the World Bank initiated a financing program to improve SWM in 18 low-income communities (Burrowes, 2017). The project's aim was to enhance SWM collection and street sweeping to communities which had not received any of those services. A challenge was the behavior change needed, which was managed through stakeholder meetings and communication on how the new sorting and collection would happen.

Composting had limited use as a waste management method in Jamaica, but was considered to have potential. To minimize waste, a composting project was launched in 2009 by the NSWMA (CaPRI, 2015). There was a potential overseas market in the Bahamas for compost, as well as good potential locally, but there was no large-scale commercial industry for composting in Jamaica (NSWMA, n.d.d). Instead, people were encouraged to do it in their own homes through their own investments. One study showed how composting would be a very appropriate addition to the SWM in Jamaica, and a result of the outcome could be the dirt being used as landfill cover material (Pendley 2005).

NGOs have been active in projects to improve the SMW in Jamaica. The Environmental Action (ENACT) programme was a collaboration between the GOJ and the Canadian International Development Agency (CIDA). The program worked together with NGOs to solve national environmental problems around the island (Morgan, 2005). It was implemented in the early 2000s and has since allowed Jamaican Environmental Trust (JET) to implement an environmental program in schools as well as work towards institutionalizing education for sustainable development (JET, 2018). JET described their mission as "to protect Jamaica's natural resources using education, advocacy and the law to influence individual and organizational behavior and public policy and practice" (JET, n.d.a).

Besides beach clean-ups and the school educational program, other projects that JET have undertaken since being founded in 1991 include: environmental films and advocacy campaigns, a World Bank funded demand side management energy conservation project with the Jamaica Public Service Company, different recycling projects and SWM field research papers (JET, n.d.b). Recent educational campaigns to the public include "Nuh Dutty Up Jamaica", which educated citizens on the importance of reducing waste and disposing of it correctly (UNESCO, 2015). The campaign was deemed a success in terms of message understood by receivers, many waste clean-ups and the campaign lasting for 5 years (The Gleaner, 2019).

3.1.5 Environmental challenges

In the Caribbean region SWM was not a prioritized public policy issue, although it was connected to both economic and environmental prosperity (Riquelme, Méndez & Smith, 2016). Often SWM did not receive the required priority in the political agenda because there were other economic and social issues which typically got more attention. Furthermore, defined by the Planning Institute of Jamaica (2007), there were no sanitary landfills in Jamaica. This absence of modern waste management had considerable socio-economic and environmental consequences.

Improper SWM has significantly impaired ecosystem functions, and has thus affected dependable social and economic welfare (Planning Institute of Jamaica, 2007). Mangroves and coral reefs were essential for Jamaica's coast as they protected communities from storms and flooding (World Bank, 2019). They were also important for fishing practices and thus connected to the livelihood of many Jamaican residents. However, the Jamaican mangroves were threatened with more than 770 hectares of mangrove forests destroyed over the past two decades. One of the threats to the coast and wetlands were contamination by substances from runoffs from urban areas, such as solid waste and hazardous pollution that came with it (NEPA, 2020). The non-biodegradable plastic waste suffocated the freshwater and marine species. Other negative environmental impacts from improper solid waste management in Jamaica included: pollution of soil, ground and surface water, spread of cancerogenous substances in wildlife and microplastics increasing in nature (Planning Institute of Jamaica, 2007). Heavy metals, which are very toxic, were also found in high levels in soil at some of Jamaica's agricultural areas and were believed to be in the fish in Kingston Harbour from where fishermen haul in seafood on a daily basis (JET, 2015, & Planning Institute of Jamaica, 2007).

3.1.6 Investigations into the privatization of Jamaica's solid waste management

Due to all the difficulties faced in SWM in Jamaica, the Jamaican government announced a new project to privatize the solid waste management system in 2016 (JIS, 2016). The withdrawal of the NSWMA from operations into a regulator entity has long been a pursuit by the government in the hopes to improve the SWM in Jamaica. The new arrangement would see private actors handling solid waste collection as well as new engineered landfills and WtE plants (DBJ, 2022b). Caribbean PPPs have historically targeted the transportation and energy sectors (World Bank, 2017b), but also SWM in some cases, both regarding collection and disposal (Riquelme, Méndez & Smith, 2016).

In a previous study by CaPRI (2015) on improvements needed for the Jamaican waste management, it was estimated that a PPP could bring about a foreign investment of US$143 million for an incineration plant able to consume 647 000 tons of municipal waste per year. The project was expected to be economically profitable, and would bring benefits such as reduced air emissions, waste volume reduction and job opportunities (CaPRI, 2015). Challenges faced by WtE in the caribbean included investment cost, establishment of a continuous supply of materials for furnace feeding, too much wet

organic content leading to corrosion of the equipment and the legal and regulatory framework that needed to be adapted to administrate WtE activities (Riquelme, Mendez & Smith, 2016). However, WtE could help with other challenges faced by Caribbean countries, such as contributing to energy security and reducing the landfill area needed with SIDS's limited land availability (De Cuba, et al., 2008).

The study conducted by the Development Bank of Jamaica (DBJ) investigated how to engage private investors to manage the SWMS in Jamaica, which would hopefully improve management and make the SWMS more sustainable (Guyana Chronicle, 2022). In the PPP project, a new waste characterization analysis was made to determine the waste flow content and possibilities for treatment (DBJ, 2022b).

3.2 The Riverton waste disposal site

The Riverton waste disposal site, covering a large area of land just outside of Kingston, was situated right next to a residential area and surrounded by water and wetlands (figure 3.2). There were many challenges on the site due to lack of proper landfill management. The same challenges can be assumed to have existed on the other seven official disposal sites, but as they were not receiving the same large volumes the issues did not have the same magnitude (NSWMA, n.d.). None of the NSWMA's waste disposal sites in Jamaica were designed to be sanitary landfills (Riquelme, Mendez & Smith, 2016). The Riverton Municipal Solid Waste Disposal Site was established in 1983 and has been the primary disposal site for the island's residential and commercial solid waste, receiving 57 percent in 2015 (NSWMA, 2015). The solid waste has been disposed of at the designated sites in accordance with policy, but with no formal recovery processes.

Figure 3.2. Location of the Riverton Municipal Solid Waste Disposal Site. Google Earth.

3.2.1 Environmental issues connected to the Riverton disposal site

The Riverton disposal site presented several environmental difficulties. Its foundation was not lined to prevent the release of leachate into the surrounding wetland ecosystems, nor was the rate of release tracked (CaPRI, 2015). The significant organic fraction dumped at the Riverton disposal site decomposed to methane. The rate of methane release was unknown, as it was not measured. Due to the presence of the gas, the site also became a notorious fire risk. Hazardous substances such as sulfur dioxide, nitrogen dioxide and particulate matter (PM5 and PM10) were being released into the air due

to these fires (NEPA, 2018). The dispersing of toxic ashes was a threat to the environment as well as human health.

While plastics were not a large fraction relative to organics, a recent study by Rose & Webber (2019) found measurable quantities of microplastics in the surface waters of Kingston Harbor, of which a percentage could come from Riverton. Hazardous waste was at high risk of being mixed in with the rest of the waste and leaching into the nearby ecosystems, as there was no waste water cleaning (Planning Institute of Jamaica, 2007). As the Riverton disposal site was located close to mangroves, the Hunts Bay area and the Duhaney River, the operations at the landfill also led to water pollution here (CaPRI, 2015). The heavy metal contaminations from lead and cadmium had significant negative impacts on surrounding wildlife. A major problem was the pesticide containers with harmful residue still remaining, thrown in with the regular waste (Planning Institute of Jamaica, 2007).

Furthermore, as mentioned above, the management of the waste site was going on illegally and not operating in alignment with the environmental permits (The Gleaner, 2014). With all used goods and discarded material being disposed of at the landfill, with only few diverging waste streams, there has been a large loss of material resources from society which in turn was part of the issue with depleting the earth's natural resources (Saunders, 2016).

3.2.2 Challenges at the Riverton waste disposal site

In 2015, the annual cost of the NSWMA's SWM was estimated to be JA$10,3 billion (CaPRI, 2015). Of this budget, the annual operations at the Riverton waste disposal site stood for more than 50 percent of the costs: JA$6,8 billion which is close to a cost of JA$16,8 million daily (CaPRI, 2015). All the waste collected was driven and dumped in waste cells at the disposal site. There was little to no sorting before the waste was disposed of at the disposal site, which means there was no volume reduction (CaPRI, 2015). Waste volumes were also increasing, and as the most common method of disposal was landfilling, the increasing volumes on a limited area was an increasing issue (Planning Institute of Jamaica, 2007). Especially with lack of equipment, the compaction was low, which resulted in an even bigger demand for land.

The landfill was a place where several residents made a living as waste pickers (The Gleaner, 2022). But historically it was not a safe environment, as the lack of safety measures, heavy machinery and easy access to the landfill site led to a high risk of injuries (CaPRI, 2015). There had been deaths at Riverton, where a young man fell and hit his head on a truck tailgate as recently as 2019 (Jamaica Observer, 2019).

There have been frequent fires at the Riverton waste disposal site, with over 400 reported fires between 1996 and 2015 (Office of the Public Defender, 2015). Two of the most recent massive fires at Riverton were in 2012 and 2015. Both fires lasted for over a week, with 120 acres of burning land. The fire in 2012 cost JA$25 million to extinguish (CaPRI, 2015). One thousand residents, of which most were children, needed medical assistance due to smoke inhalation (Office of the Public Defender, 2015). Furthermore, it caused the ports, schools and businesses to close down and forced people to leave their homes to escape the black smoke that covered 80 percent of Kingston (Morris, 2015). The fires burdened the taxpayers and caused respiratory problems and cardiac illnesses (CaPRI, 2015).

4. Method

This report was based on a case study of solid waste management in Jamaica. The aim of the study was to gain more understanding of Jamaica's solid waste management system from the stakeholders point of view, outline scenarios for improved resource management and analyze how a PPP could work within the system for sustainable solid waste management.

The method is structured to describe the methodology based on which the study was conducted. This includes data collection, method of analysis and method discussion. The methodology explains the key methodological choices, and research beliefs that the study is based on. The data collection gives full detail of the research method used to collect data. Method of analysis describes how the data is processed and analyzed, covering data categorization and the structuring of scenarios.

The study took a bottom-up approach aiming at drawing conclusions from observations made in the field study. The research observed the system to later investigate the characteristics of issues within the solid waste management in Jamaica. In order to understand all the aspects of this complex system in accordance with Grohs, et al. (2018), the study employed a method of qualitative data collection through a field study, consisting of interviews and field observation, and a literature review on the subject of waste management, waste management in low-and middle-income countries and governance of change as well as public information on Jamaica's solid waste management system.

The study was conducted in alignment with several intellectual perspectives, or research beliefs, partly normative in nature. For the sake of transparency, these are listed below:

- The study was motivated by UN doctrines of good governance (UNESCAP, 2009) and sustainable development, specifically SDG 12 on ensuring sustainable consumption and production (UN Conference on Sustainable Development, 2012).
- Jamaica's SWMS was characterized as a complex system (Grohs et al., 2018) in need of transformation (Loorbach et al., 2017), which necessitates collaboration and joint problem framing between concerned stakeholders. This motivated the choice of performing qualitative interviews. Solutions were described in terms of leverage points (Meadows, 1999).
- The function of Jamaica's SWMS was conceptualized as complex in itself, composed of the three sub-functions of waste disposal, value recovery and pollution prevention. This was in basic accord with the European waste hierarchy (EC, 2008) and the principles of industrial ecology (Lifset & Graedel, 2002)..

4.1 Data collection

The data collection for the study consisted of a field study based in Kingston, Jamaica, and a literature review. The data collection consisted of field observations and interviews, as well as data gathered from secondary sources from January 2022 to February 2023.

4.1.1 Literature and secondary sources

The data collection consisting of secondary sources were covered by literature of previous research, websites and news articles. Access to knowledge on how municipal solid waste could be managed in various approaches were reached with online search engines Web of Science, Google Scholar and Google. Manual resources though printed literature from previous university courses and through Chalmers University Library were also used in the literature data collection.

The literature review on previous research regarded the different subject areas: solid waste management practices, solid waste management in low- and middle-income countries, governance, stakeholder management for sustainability issues, and solid waste management in Jamaica.

Solid waste management practices were reviewed to support operational knowledge in different ways to handle solid waste. This topic covered different disposal methods and waste prevention practices with a circular economy. Keywords used in search engines were: “integrated waste management”, “landfills", “landfill issues”, “circular economy”, “the waste hierarchy”, “incineration”, incinerations challenges” and “sustainable + waste.”

Solid waste management in low- and middle-income countries studied activities and challenges around unstructured waste sites and informal recycling systems. This topic was widely researched to understand the environmental, social and economic issues of unstructured SWM and disposal sites through reports and other case studies. It was also necessary to understand the implication of an informal SWM system around waste recovery and how that can be affected through changes in the SWM system. This search used the keywords “waste + informal”, “waste pickers”, “unmanaged landfills”, and “closing dumpsites.”

Subject area of governance was included to understand the cause of many issues identified during the field study; the topic of governance was added in the second part of the literature review. This search used the keywords “govern + stakeholder”, “govern + sustainability”, “good governance” and “public governance”, in addition to literature from the industrial ecology courses at Chalmers University of Technology.

Literature regarding stakeholder management in contemporary sustainability-related applications was studied to support the method of research for the field study, which was stakeholder analysis. Stakeholder management in sustainability issues subject area supported the method of research for the field study, which was stakeholder analysis. It regarded stakeholder identification techniques, interview techniques as well as background and support for the research area. It also supported data management with stakeholder categorization methods and the analysis with techniques for looking at complex systems to investigate solutions for sustainable development. This topic was researched though literature from courses at Chalmers University of Technology, as well as through online searches with the keywords “stakeholder + sustainability”, “stakeholder + management”, “wicked problems”, “complex systems”, “public participation” and “leverage points”.

Jamaican solid waste management was covered to understand the case of study, to deepen background understanding of Jamaica and the country’s SWM. The search on Jamaica was done using the keywords “Jamaica solid waste management”, “waste in Jamaica”, “Jamaica Riverton disposal site”, “Jamaica NSWMA” and “waste littering Jamaica”. After more understanding, to dig deeper into the environmental issues with the waste in Jamaica and the planned PPP, keywords like “Development Bank of Jamaica and public private partnership”, “Jamaican environmental trust and waste”, and “environmental challenges in Jamaica”. For this topic, news articles were also very useful. To find the news articles, the internet search engine Google was used with the same keywords previously mentioned, as well as the NSWMA’s website and looking into online archives of news agencies Radio Jamaica, Jamaican Observer and The Gleaner.

4.1.2 Stakeholder identification & characterization

This study treated stakeholders as any person, group or organization in a position to affect or be affected by change (Bryson, 2004) affected or affecting changes (Reed, et al., 2009) in the SWMS as a stakeholder that fulfilled one or more of the following criteria: strong opinions, formal position for effect, knowledgeable stakeholders, representation of social participation, influence over opinions, organizations within the SWMS and stakeholders from seven specific demographics: strong opinions, formal position, knowledgeable, representing social participation, influence over opinions, demographics or organizations (Mitchell & Mason, 1981).

Stakeholders were identified using brainstorming (Reed, et al., 2009), identifying through demographics (Mason and Mitroff, 1981) and through the snowballing technique (Luyet, et al., 2012). The purpose behind utilizing all these techniques was to establish a diverse group, capable of providing as much substantive input as possible, and ensuring some representation for the interests of passive stakeholders (Hemmatti, 2002).

A preliminary list of stakeholders was composed through brainstorming, and was made by looking specifically for stakeholders likely to be affected by changes or who had political or operational power to affect changes in the SWMS (Reed, et al., 2009). For additional identification, stakeholder groups were composed using the seven stakeholder identification approaches (Mason and Mitroff, 1981) supported by literature review covering the subject of Jamaican solid waste management. For example, some stakeholders were identified by the imperative method as they expressed certain views in articles or reports. Additionally, positional stakeholders were detected by looking at who other stakeholders were holding responsible, and reputational and organizational stakeholders were identified through literature that they had composed. Lastly, more stakeholders emerged during the interview process through "snowball sampling" when stakeholders spoke about their views on the solid waste management system in Jamaica or directly asked about if there were any others they thought should be included in the study (Luyet et al, 2012).

4.1.3 Stakeholder interviews

The interviews were conducted from the 14th of February to the 12th of April 2022 in Kingston, Jamaica. The interviews had a semi-structured layout, based on open questions to inspire stakeholders to describe the SWM system in their own words and explore barriers to change and opportunities for new insight and activities (Waddock, 2020).

Stakeholders were first contacted per e-mail and telephone and asked for an interview. Interviews followed a semi-structured format based on discussion topics, chosen to investigate the perspectives of stakeholders upon the SWM system. The topics were the following:

1. Current material flows in the solid waste management system.
2. Other actors and their effect on the solid waste management system.
3. Issues within the solid waste management system.
4. Suggested improvements for the solid waste management system and obstacles to these.
5. A desired future for resource management.

The interviewed stakeholders were asked to elaborate on these topics, describing in their own words their understanding of the SWM in Jamaica, the challenges and their own visions for the future. The

aim was for them to be held and recorded in person, but it was sometimes necessary to hold them online due to logistics restrictions and with respect to the Covid-19 pandemic recommendations. Where consent could be obtained, interviews held in person were recorded using an Olympus WS-853 digital voice recorder. Most of the interviews were conducted in person. However, due to logistic reasons and Covid-19 restrictions a few interviews were held over Zoom. These were recorded using the program's record function. All interviews lasted for approximately one hour. Not all identified stakeholders were interviewed, as a consequence of some being hard to contact and time limitations. Below in table 4.1 is a list of the stakeholders that were interviewed in this study.

Table 4.1. List of interviewed stakeholders.

Number of stakeholders	Occupation
1	Manager at DBJ
1	Manager at NEPA
1	Director of a private collection company
1	Technical consultant on air emissions
2	Representatives of environmental NGOs
4	NSWMA senior staff members
1	NSWMA junior staff members
4	Researchers at University of the West Indies
3	Directors of recycling companies
2	Environmental managers in the private sector
4	Waste pickers
1	NSWMA street sweeper
6	Residents of Kingston
2	Artists working with recycled material

In some cases, specific questions had also been prepared in advance, relating specifically to the stakeholder's expertise. These questions were then investigating more intro parts of the solid waste system. For example, the representative of NEPA was asked to describe their role as a governing agency and relations to other stakeholders in the system more thoroughly to understand the challenges they were facing. Similarly the DBJ manager was asked to describe more in detail the plan for the PPP as they were the ones in charge of that, and waste pickers were asked to describe their experiences and operations on the waste disposal site.

4.1.4 Design of a stakeholder workshop

A workshop was conducted to enable a stakeholder dialogue. This was important for problem definition and an addition to the research to fully understand the problem before working towards solving the complex problem that was Jamaica's waste management (Cuppen, 2012).

The stakeholders were invited to discuss sustainable solid waste management in a workshop at UWI Mona Campus. The purpose of the workshop was to complement the interview data through a co-creative stakeholder process with the following goals:

- Understanding previously generated problems with different perspectives present.
- Challenging and refining previously generated ideas.
- Discussing systemic possibilities and obstacles for recycling non-combustible waste in the case of a PPP introducing WtE facilities

The topic of discussion was how to best manage non-combustible waste. This topic was selected in order to investigate alternative strategies to incineration with energy recovery, which had emerged as a popular policy alternative during interviews. This would center the discussion on strategies higher in the waste hierarchy. However, due to untimely arrivals of stakeholders where several arrived up to an hour late, the discussion ended up being mostly about the NSWMAs need to work with illicit waste prevention and the want for increased aid in the recycling sector.

Invitations were sent per e-mail to 18 stakeholders considered relevant to this topic, i.e. representing formal entities, recycling value chains and academics. Two tables of seven seats were prepared. The group was divided to facilitate two parallel discussions in hopes of gathering more data and to allow for more engagement from each participant. The goal was to have the two discussions around different types of recyclable waste: one around plastic and glass and the other around metals and e-waste. This would allow for participants to leverage their own expertise to discuss the waste streams in greater detail. The workshop was divided into two parts, corresponding to obstacles and possible solutions, as discussed during interviews. Table 4.2 shows the schedule for the workshop.

Table 4.2. Schedule for workshop session on April 1, 2022.

Time	**Activity**	**Description**
13:30	Introduction	Introductions of participants, this study and the workshop.
13:45	Discussion 1	Discussion on the obstacles of the SWM system.
14:00	Summary 1	Summary of previous discussion.
14:10	Break	
14:15	Discussion 2	Discussion on potential solutions to the obstacles previously identified.
14:45	Summary 2	Summary of the previous discussion.
15:00	Closing remarks	Final words and thanks.

4.2 Data management

The data management consisted of stakeholder characterization, identifying system patterns, creating scenarios and analyzing the data. The stakeholder characterization (Chevalier and Buckles, 2008) and mapping of the system patterns (Grohs, et al., 2018) structured the data collected and was presented in the study's results. Creating the scenarios (Grohs, et al., 2018; EC, 2008) constituted the base for the analysis and its outcome explored the answers to the research questions.

4.2.1 Stakeholder characterization

Stakeholders previously interviewed in the study were characterized in a range of affected vs. affecting through a rainbow diagram (Figure 4.1) (Chevalier and Buckles, 2008).

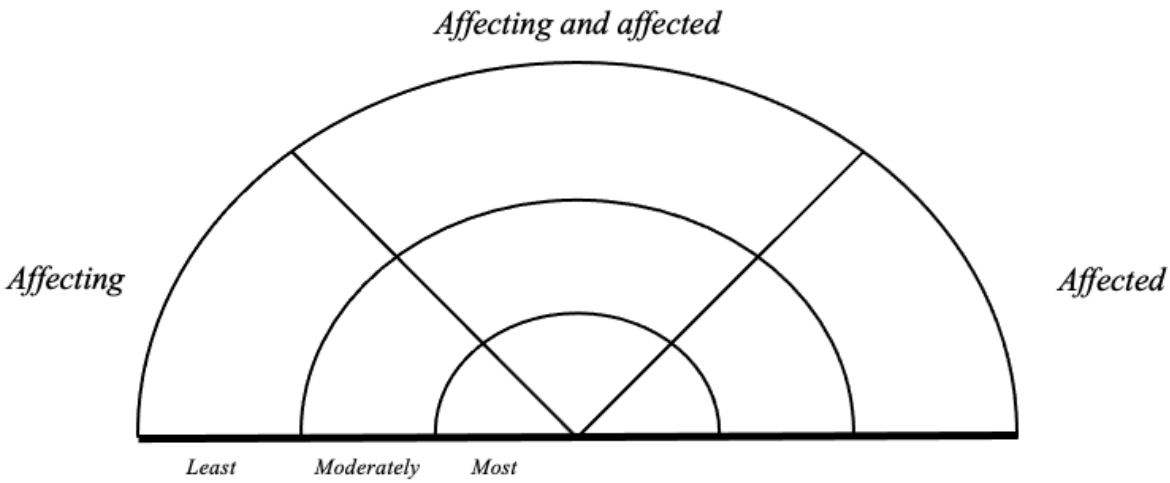

Figure 4.1: Rainbow diagram (Adapted from Chevalier and Buckles, 2008)

The stakeholders were placed in the respective categories according to the degree they either had the power to affect the SWMS or would be affected by changes in the SWMS. The power to affect considered possible influence to affect decisions or actions, and were stakeholders such as governmental institutions or larger operating companies. The affected category regarded stakeholders without influence in decision making but whose daily activities or lives would be affected by a large reconstruction of the SWMS.

4.2.2 Identification of systems patterns

Before analysis, the gathered data was prepared to describe and understand the SWM system in Jamaica based on observations, stakeholder interviews and the workshop. The data were managed using the conceptual framework to assess system thinking by Grohs, et al. (2018). The definition was based on conceptualizing the problem and understanding the wanted future end, which was done by involving varying reasonings to get different perspectives on the system. The problems were defined as technical and contextual elements, with the findings structured accordingly. Technical elements were both technologies and engineering devices, as well as theoretical concepts of technology in the SWMS. Technology was furthermore described as tools, knowledge and processes employed in the SWM system, conceptualizing the problem and resources as well as the solution and consequences of those. Additionally, contextual elements referred to the environment around the technical elements, and was

divided into social, cultural, political, legal, ecological and economic features as suggested by Grohs et al. (2018). This framework focused on processing the data to enable solving complex problems with long-term solutions for sustainable development for the SWMS.

The processes and material flows of Jamaica's SWMS were reconstructed from the system patterns identified and the data collected from interviews and the workshop. System maps were drawn up of identified processes in the SWMS, the links between them and the materials, information or emissions that the processes were passing on to other parts of the system. It was assembled to get an overview of what is happening to be able to see where change could happen and be able to explore how change would influence the rest of the system (Waddock, 2020).

4.2.3 Creating scenarios

The scenario based analysis was structured after the scenario theory by Grohs, et al. (2018), as a method to understand the changes needed and the leverage on how to change them (Meadows, 1999) to improve resource management in accordance with the waste hierarchy (EC, 2008). To answer the first research questions, the analysis was discussing Jamaica's SWMS, and to answer the second research question, the project analyzed if the technological addition of a PPP and incineration could improve the SWM for increased resource management and what kind of governance that would require (UNESCAP, 2009).

4.2.4 Analysis strategy

In the analysis, the study's two research questions were addressed. This SWMS was studied through scenarios to explore links between the different processes and stakeholders (Figure 4.2) (Grohs, et al., 2018).

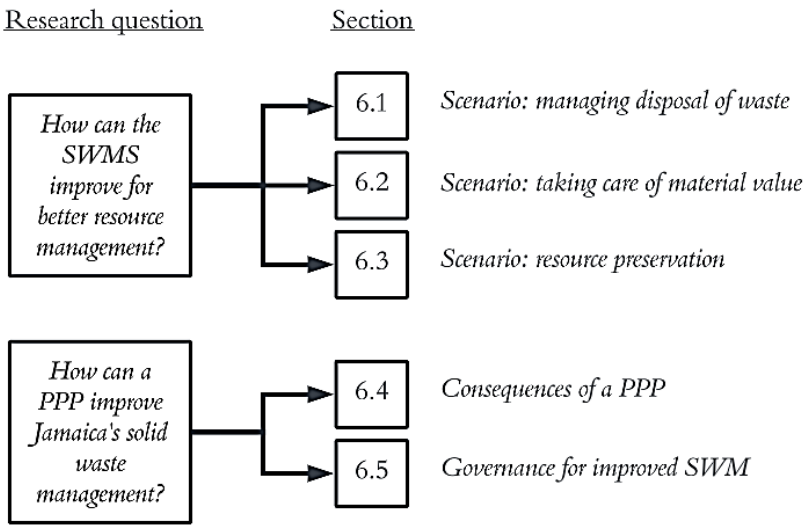

Figure 4.2: The research question answered in the different chapters.

The first research question, *How can the solid waste management system improve for better resource management?* was addressed in chapters 6.1, 6.2 and 6.3. With scenarios the analysis investigated possible operations and outcomes for how Jamaica's waste management structure could be improved to move towards better taking care of material value and natural resources. The scenarios for research question one were made from addressing the different levels in the waste hierarchy. So the first scenario, *6.1 Managing disposal of waste*, regarded disposal of waste energy recovery through incineration. The

second scenario, *6.2 Taking care of material value*, addressed managing waste for improved material resource recovery. Lastly, the third scenario, *6.3 Resource preservation*, addressed the prevention of waste connected to the top two levels in the waste hierarchy, reuse and prevention.

To understand the different issues and the needed changes in the SWM to manage the problems identified through stakeholders. The processes in Jamaica's SWM system chart presented in result (Waddock, 2020) were each handled to see what kind of change could be made after Meadows' (1999) theory of leverage points, previous cases in other low- and middle-income countries, and the solid waste management literature on challenges and possibilities with solid waste management technologies.

The second research question, *How can a public-private-partnership (PPP) improve Jamaica's solid waste management?* was analyzed in chapters 6.4 and 6.5. The first part of 6.4 explores the possible consequences of a PPP based on SWM literature including previous PPP cases in other low- and middle-income countries. The consequences of different processes were investigated, for collection, disposal and incineration, and for material recovery. Resource preservation, which was discussed in the first research question, was not discussed here as the PPP does not affect that scenario. Instead, 6.5 discusses governance requirements for environmental protection and increased circylarity, using the literature on policy instruments for sustainable governance (Zaccai, 2012).

5. Results

This chapter presents the results of the study, sorted into three sections. The first part presents the stakeholder analysis, presents the stakeholders stake and contextual aspects of the SWMS (Grohs, et al., 2018), and the stakeholders power to affect the waste management system is shown through a rainbow diagram (Reed, et al., 2009). The second part presents the contextual and the technological elements of the solid waste management system in Jamaica represented by stakeholder quotes (Grohs, et al., 2018). Lastly, Jamaica's waste flows are presented as flows and as a system in a cause-effect diagram (Waddock, 2020).

5.1 Stakeholders part in Jamaica's solid waste management system

The SWMS in Jamaica had many stakeholders intertwined and dependent on the system. The stakeholder roles vary from operational to legal, and their stakes were different depending on their work within Jamaica's SWMS.

5.1.1 Stakeholder characterization

Ten major stakeholders or stakeholder groups were identified and characterized according to their stake and valued aspects in Jamaica's SWMS (Grohs, et al., 2018) and the resources they could use to affect it or each other. Table 5.1 summarizes the results, which are explained in greater detail below.

Table 5.1. Stakes and resources of stakeholders.

Stakeholder	**Stake**	**Aspect**
DBJ	Business case responsible for PPP	Political
NEPA	Responsible for environmental permitting	Political
NSWMA	Responsible for all solid waste management in Jamaica	Political and technical
Private haulers	Business, handles waste collection	Economical & technical
Recycling companies	Access to recyclable materials	Economical & technical
Waste pickers	Access to recyclable materials & vulnerability	Economical, technical & social
Commercial sector	Need of garbage collection	Social
Households	Need of garbage collection	Social
Env. NGOs	Environment	Ecological
Academics/experts	Opinions	Ecological & technical

The DBJ, NEPA and NSWMA were extensions of the government and thus had political stakes in the system, in that they had been given missions to achieve certain objectives. The mission of the NSWMA was the effective and environmentally sound management of solid waste, for which purpose the authority was permitted to *"do anything or enter into any arrangement which, in the opinion of the authority, is necessary…"*(4§ NSWM Act, 2001). The authority also possessed significant resources in the form of equipment and personnel, as well as the best available technical knowledge and information regarding the SWMS. Meanwhile, the potentially conflicting mission of the NEPA, as the agency relates to SWM, was to fulfill the mandate of the NRCA to ensure the conservation, protection and proper use of natural resources (NRCA Act, 2001). The NEPA had the mandate to issue permits and impose sanctions based on expert scientific counsel. The mission of the DBJ was likewise potentially conflicting, being the divestment of the NSWMA. This was a powerful position in itself, but the DBJ could also use the technical knowledge of domestic and international consultants.

Private haulers and recycling companies had economical stakes and technical knowledge to contribute to the SWM. The economic stake for the haulers was their waste collecting business and commercial waste collection. Recycling companies typically dealt in plastics, cardboard, scrap metal and electronic waste. These companies bought items and materials from waste pickers and some formal businesses, then processed and sold material to largely foreign buyers. The economic stake of the recycling companies was in their access to recycling material. Both haulers and recyclers also possessed technical knowledge and equipment to support operations in the SWMS. Waste pickers had the same economic stake as the recyclers, with the need for access to recyclable material, and the knowledge about recyclable fractions. Waste pickers had an additional social stake in the SWMS, as they were a vulnerable group in society living in informal settlements and without the social security of employment.

The residential and commercial waste generators had a strong stake in that they needed their waste reliably collected for the sake of sanitation and public health. Since private haulers were more strongly oriented towards the commercial sector, businesses had greater power to choose their service providers than did households; these were left with their important but so far unimpactful right to democratic representation. Finally, environmental NGOs, such as Jamaica Environment Trust (JET), were characterized by acting on behalf of the natural environment and the environmental aspect was thus their main stake in the SWMS. These organizations could interface with various institutional actors and educate the public.

5.1.2 Stakeholders power of affecting vs. being affected

Stakeholders in the SWMS had different power levels to affect the system. Stakeholders were classified in a rainbow diagram (figure 5.1) (Reed, et al., 2009). There were affecting stakeholders, affected stakeholders or those who were both. Those who had power to affect the system could make changes in the SWMS, whereas some stakeholders did not have any power and were only subjects to the system. Lastly, there were scales of involvement ranging from least to most.

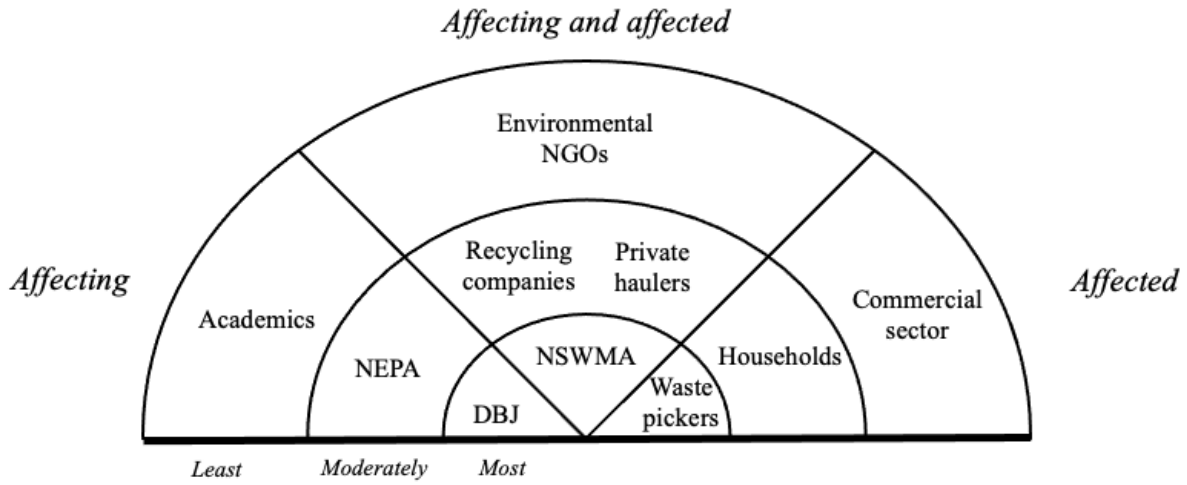

Figure 5.1. Stakeholders in the Jamaican solid waste management system. (Adapted from Reed, et al. 2009).

In the category of affecting stakeholders, concerning decision making and implementing change for sustainable development, the DBJ was the most influential, NEPA was moderately affecting and academics were least affecting in Jamaica's SWMS. The DBJ was the stakeholder with the most power to affect as they had all the power to decide on the partner for the PPP during the pre-study for the PPP. The DBJ also had the mandate to decide on the layout for the partnership and put together the recommendation regarding PPP partner and layout to the government. NEPA was an affecting stakeholder due to their influence over national legal governance regarding the management of waste, which included the environmental permits for all the landfills, NSWMA, recyclers and would also oversee the private partner in a PPP. These stakeholders had knowledge and opinions that could support and influence decisions with a legitimate voice, but had no official power to make any decisions in the SWMS.

Stakeholders that were both affecting and affected were the NSWMA, recycling companies, private haulers and environmental NGOs. The NSWMA was the most influential in the SWMS in terms of operational activities, as they were legislated as the agency to manage municipal solid waste. They would also be the most affected if the system were to change as that would imply a change in their operations and processes. Recycling companies and private haulers did not have any political decision making power, but had operational influence as their processes took care of the physical waste in the SWMS. Also, if the system were to change for increased recycling, incineration or added competition on the market for waste and collection though a PPP, these stakeholders would be very affected. Least influential in the affecting and affected category were environmental NGOs. As their main stake was the environment, they were affecting as they had a strong opinion and a voice in many communities through their work. However, they as representatives of the environment were affected by poor waste management and lacking regulations as that was cause for environmental degradation.

The affected category included the waste pickers, households and the commercial sector in Jamaica's SWM. The waste pickers were the most affected as they depended on the access to solid waste for their livelihood. If their access to recyclable and reusable material would be eliminated, then they would be even more vulnerable in society. As they were a marginalized group in society they also had the least power to influence the whole system, even as their stakes were the highest. Households were moderately affected stakeholders because they were affected by the poor municipal collection by the NSWMA and would be affected by changes in the collection or regulations on waste management.

Lastly, the commercial sector was also affected by the operations of the SWMS, as their business also depended on the waste collection.

5.2 Contextual and technical aspects of the waste management system

Dividing up the problem according to Grohs et al. (2018), this chapter will continue to present the results including the social, cultural, political, legal, ecological, economic and technical aspects of the problems surrounding SWM in Jamaica.

Many agreed that there were many aspects of the poor waste management in Jamaica, and that it needed a great deal of work on many fronts to tackle the problem. And so, the study considered many aspects and identified various problems in the system that stakeholders wanted to change.

> *"We need a strategy, a plan that includes everybody."*

5.2.1 Social and cultural aspects

A social concern was the health of the waste pickers who were scavenging at the Riverton waste disposal site. This was expressed by the affected waste pickers but also by other stakeholders aware of the poor working condition. The waste pickers themselves perceived that the biggest issues for them was the sun and the dust, and so small sheds had been raised close to the tipping area to allow for shaded breaks. However, the other stakeholders believed that hazardous waste and lack of protective equipment was the biggest threat. Generally, the waste pickers did not take any vaccines and were therefore prone to hepatitis and tetanus amongst other dangerous diseases in the unclean environment. A worker at the NSWMA explained that they have offered health care to cover vaccine costs for the waste pickers, whereas another one said that health care is almost free in Jamaica and that they tried to educate the waste pickers on safety measures but that it was their own responsibility to go get vaccinated. Overall, the vaccination rate in Jamaica was low.

A lack of education was a clear concern for academics and environmental NGOs. The high poverty rate impacted the education rate, and many citizens in Jamaica did not have any higher education. There had been no curriculum added from the government for schools to teach children about environmental impacts of waste and emissions. The social consequences of the lack of education were unsustainable disposal patterns. These disposal patterns led to low recycling rates and high rates of illicit disposal of household waste. It also led to a cultural perception of waste lacking any value in society, which in turn led to a wish to immediately remove the waste from their sight by any means. This was also a consequence connected to the lack of solid waste infrastructure and the poor waste collection. To remedy these disposal patterns, NGOs started educational campaigns themselves. Instead of the government, they worked with schools to set up educational classes about recycling, waste fraction separation in homes and consequences of waste pollution. The educational campaign was also extended to the general public, where clean up initiatives expanded to a national waste pollution awareness campaign.

> *"You have to teach the people how to dispose of their things properly, and they will. Just cleanups, it wasn't solving anything. It moved from cleanups to piloting some projects and putting bins in communities; and then public awareness and education became very critical."*

It was the high poverty rate in Jamaica that led to many waste pickers making a living from collecting recyclables at the disposal sites. In interviews, they explained how some never went to schools, and so could not get a job. Others did not want to work for anyone else and valued the freedom in working for themselves. Either way, closing the Riverton waste disposal site would have affected the waste pickers there immensely, leaving them without any income and few other options. Therefore, other stakeholders with more power such as the DBJ and academics felt that there would have to be a plan made by them to integrate the waste pickers into other operations.

The Riverton waste disposal site also had a social cost in terms of health issues on the population around Kingston. Children that were living in neighboring districts to the Riverton disposal site often got respiratory diseases at a young age, which got better when they moved further away from the waste disposal site, as was the case for a stakeholder who grew up close to the Riverton waste disposal site. Additionally many waste pickers worked without any protection or insurance, breathing in toxic fumes every day at Riverton. On occasions with large fires, academics observed how medical facilities were crowded with people suffering from respiratory issues.

> *"There is a problem for many people growing up in the west of Riverton with asthma and other respiratory diseases in St. Catherine due to fires on the disposal site. No studies being done on the effects. I grew up in St. Catherine. I still have asthma, but I used to have a lot more breathing issues growing up. As did many in my class."*

5.2.2 Political and legal aspects

Many believe there were a lot of gaps in legislation and legal enforcement within the SWMS. There were several aspects related to this. Firstly, there was the lack of regulation for specific waste fractions. A chemist who had worked with hazardous waste management for companies explained that there were no policies towards hazardous waste. So there were no facilities to take care of hazardous waste and it was thus treated in an unsafe and unregulated way. According to the NSWMA, there was separate collection and burying of toxic waste at the Riverton waste disposal site. However, the NSWMA had received no directives or instructions on how to handle different types of hazardous waste.

> *"We [in Jamaica] don't have a policy towards hazardous waste. So we don't have a facility to collect hazardous waste. So it is not treated any differently than other waste."*

Secondly, the lack of regulation and monitoring of waste haulers led to illicit dumping which was also a political issue. A large company that worked with waste hauling complained about the lack of the legal framework for waste disposal. As there were barely any regulatory guidelines for collection contractors, anyone with a truck could buy a certificate and pick up waste. This was a problem from the perspective of the waste haulers as smaller waste haulers could pick up waste from customers and then dump it anywhere, creating a faulty system. The perspective was shared by environmental NGOs who saw this as a fault in the monitoring, leading to unwanted dumping areas which polluted the environment.

> *"The regulation of the entire industry is basically nonexistent. Anyone can pick up waste and then dump it somewhere else."*

In some cases the legislation was considered too tough for the recycling sector, and was perceived as counterproductive for recyclers. For several recycling businesses, certificates and regulations were

perceived by the recycler to not enable waste collection and recycling, but were a political and economic obstacle. The demands of the permits made recycling a costly and technically tricky sector to enter. Demands include storage space size requirements and strict monitoring demands of storage spaces. With the lack of monitoring of the sector, the legislation made it hard to become a responsible recycler. This also impeded the ability of businesses to compete with illegal exporters who did not have the same operational requirements.

> *"They [the government] say they have a framework of some legislation. To me it is only to collect more money from us. It's not necessarily geared to make Jamaica better. And I'm just being frank."*

The lack of political support for recyclers was also mentioned by a recycling start-up non-profit organization that produced different construction materials from recycled plastic, cardboard and paper. As it expanded, the lack of government support meant that they could not get any funding. Instead, many stakeholders wanted the national parliament to push for more environmental legislation to support products made from recycled material.

> *"The type of policies that I would love to see is to give the products made from recycled materials an advantage in the market space, so there would be a win-win situation for recyclers, the environment and society."*

As explained by an environmental NGO, the lack of environmental protection legal framework in Jamaica was a major reason that the waste disposal sites were not managed better. The legal framework that did exist was often not followed, for example the requirements of monitoring of waste disposal sites. The Riverton site did not measure its production of methane or dust, and so without monitoring it was not feasible to determine the amount of air pollutants. Additionally, the poor quality of the operations at the site led the NEPA to withdraw the permit that allowed the NSWMA to operate the landfill. However, because of the lack of waste disposal alternatives and the shortcomings of the legal framework, the NSWMA never stopped collecting waste and the Riverton disposal site kept receiving waste.

The political management of the NSWMA was another political aspect of the SWMA. Over the recent decades, the NSWMA management had suffered high turnover of staff as new politicians came into power. Workers at the NSWMA emphasized this as an obstacle in the development of the SWMS, as there was no continuity and few employees with WM knowledge or experience. This had led to inefficient operations for waste collection and disposal site operations. Both companies that worked in the recycling sector, NGOs and academics believed that if the NSWMA outsourced the operations and put more effort into regulatory processes, the SWM would be better managed and more environmental laws could be enforced.

> *"The NSWMA are supposed to be the regulative authority on the island, and they are pretty much failing in that regard. While at the same time trying to compete with private companies for collection of commercial waste, when they can't even manage the residential waste over which they are responsible."*

All the points above, the lack of proper landfill management, poor collection and a weak legal framework, had caused distrust in the ability of the government to handle waste management. It had created a societal problem, with a "not in my back yard" mentality (NIMBYism). This attitude created

by poor SWM governance had made it hard for the government to find new locations for sanitary landfills as no one believed additional disposal sites could be managed without becoming a health hazard. Therefore, many stakeholders believed that privatizing the operational management of the MSW could increase the citizen engagement for improved SWM as the citizens may feel more positively about it.

> *"There is the issue of public confidence. We believe that the public might have more confidence in the private sector being the face of waste management than any public sector entity. So we're hoping that the perception that people have and the attitude that people have towards waste disposal and so forth will be different in the long term"*

5.2.3 Ecological

Ecological issues of the SWMS were mostly connected to the illicit disposal of waste which led to vast pollution of the gullies and bays around the islands, and the ecological impact of the disposal sites.

> *"It is impossible for it [the Riverton waste disposal site] now to get to the point where it is not a major pollutant"*

A major issue pointed to by stakeholders was the plastic which polluted the environment when not properly disposed of. Some citizens did not comprehend fully how serious the consequences were, while for academics the pollution was the worst part of the SWMS.

> *"People throwing waste into the environment and on the side of the roads, it's not good."*

The representative from an environmental NGO referred to the report "garbage and the gully" in an interview, explaining that there was a big issue with many people throwing their SW in gullies and rivers. Poorer people tended to get most of the blame, but there were also citizens in the higher economic classes who threw their household waste in the conveniently located gullies. All gullies and rivers around Kingston flowed towards Kingston harbor, and so all the waste which was dumped in the waterways will be flooded out to sea through the harbor after heavy rain. In the Kingston harbor there was a large mangrove forest. The mangrove forest provided shelter not only to the city but also to seabirds and nursing fish, as could easily be understood by a boat trip out into the harbor. Without this nursery, the fish around the coasts near Kingston would severely diminish. Now the forest is threatened by the MSW as the large amount of waste which was washed out into Kingston harbor ends up around the mangrove forests. The waste covering the seafloor blocked the waterflow into the middle of the forest. Layers of PET water bottles, tens of fridges and filled plastic backs could be seen when visiting the forest by boat. Without fresh oxygenated water flowing around the roots the forest would start to die from the middle. Waste on the seafloor also inhibited the seeds from sinking all the way down and setting root, slowing the recovery process of the forest.

> *"The plastic, it ends up on our reefs, it ends up on our beaches, it's just a big issue. It is a combination of poor collection, no facilities and no regulations."*

The quote above describes what happened to some of the waste dumped in the ocean and that it was perceived as a problem. It also represented an issue of ownership of the waste. There was no one appointed responsible for diffuse source solid waste (DSSW), e.g. beaches and forests. In the big cities, there were street sweepers employed by the NSWMA to keep the streets clean. But as it washed up on

beaches, it was either private people or NGOs who took it upon themselves to clean the area. This was not seen as a sustainable solution, as there was no long-term commitment made by the government to work towards reducing waste in the environment and many places did not get cleaned. The new initiative that was being undertaken through Ocean Cleanup and the Grace Kennedy Foundation, in which garbage was trapped at the mouth of some gullies. However, this initiative did not originate in the NSWMA, showing stakeholders once again that the government did not take enough responsibility for environmental pollution. Many stakeholders did not see it as a solution to the actual problem of waste not being collected and there being a need to dispose of waste elsewhere, as it only reduced the waste that ended up in the ocean but did not reduce waste being thrown into the gullies.

> *"There is no formal arrangement for NSWMA or other to collect the garbage that comes up on the beach. So it actually becomes a cost for the community to clean the beach. Not sure many people are aware, but I'm sure we're not the only community that's affected. A lot of people actually have to pile it and containerize it themselves, at their own cost"*

Besides the harm solid waste was causing to the marine environment, the SWMS causes a lot of air pollution. Frequent large fires occurred on the waste disposal site, either controlled or accidental. The field study also encountered countless backyard fires, emitting dark smoke on fields as well in cramped communities polluting the air.

A pressing environmental concern was the linear mode of consumption represented by disposal sites, which held a vast array of discarded products and materials that could offset the use of virgin materials as could be seen on site visits. Many expressed that they wanted to see more recycling and care for the island's natural resources.

> *"I think it [waste] should be sorted at source to avoid the cross contamination. With sorting at source, we could get more recycling and more reuse. I want as much [recycling] as possible from the environmental point of view."*

5.2.4 Economic

During the site visits, economic activities on the Riverton waste disposal site were observed. These activities included picking anything with a value on the market, as well as saving money on animal fodder with cattle grazing on the dumpsite. The waste pickers worked during the day to collect the different materials which included plastic bottles, any type of metal, clothes and e-waste. The materials were either reused and resold on local markets in Kingston or sold to recycling collection companies.

> *"I pick loom [aluminum], iron, batteries, copper, plastic, anything. We don't make a lot, but we do it. It's on a minimum wage level."*

The economic interest in waste extended to the recycling companies. As there was no other formal recycling scheme, a large volume of recyclables comes from the waste pickers activities on the waste disposal sites. If the Riverton disposal site were to close and no formal recycling infrastructure set up in society, these companies would lose a part of their income as the material flow could become more diluted. At the same time, closing of the site would also mean excluding the waste pickers from collecting waste on the site and depriving a group in society of their income.

A concern was that the volumes of waste generated on the island made the economic viability of the recycling business questionable. With the energy demand for recycling and reshaping used material, it was an increasingly costly endeavor in Jamaica due to the high prices of energy. Many stakeholders remembered there being recycling companies on the island. These closed down partly due to high energy costs.

To a large degree, the NSWMA was funded by the Jamaican property tax as discussed in section 3.1.3. The property tax was not effectively designed, and generally results in lower income than what would be required to sufficiently fund the NSWMA and other recipients of funding. In extraneous cases, a little funding can be applied for from the environmental levy. This leads to the NSWMA always tracing the poor waste management back to lack of funding. The funding would need to increase to address the many problems regarding MSW management.

> *"I know that in general, there's an issue as well, with people not paying their property taxes. I wonder if people knew that these things were tied with some of these basic life necessities that they complain about, if they would urge that payment."*

The economic interests of waste haulers were also affected by the NSWMA's insufficient funding. It has led the NSWMA to take more commercial contracts, in addition to their residential collection obligation, to make more money. This causes competitiveness for private haulers to collect the same waste, while being at a disadvantage as the NSWMA has more resources. At the same time, these resources used by the NSWMA to collect commercial waste to increase the revenues of the agency were taking away resources that should be used to provide residential homes with waste collection.

The opinions on the divestment of the SWM were widespread. Many had the impression that the divestment would be a profitable affair. The private company would be incentivised to make a profit which would make operations more efficient and thus automatically improve the whole SWMS. Others were concerned that the taxpayers would be the ones to pay for the investment, and that that would be hard to implement as many were not able to pay their taxes as it was due to poverty. There were also a couple of stakeholders in the SW sector who thought investments should go to supporting the local recyclers instead of only investing in divestment projects. This would mean supporting Jamaican businesses as well as improving the material circularity instead of only focusing on WtE.

5.2.5 Technical aspects of the waste management system

Technical elements in this section refers to the specific objects and tools that Jamaica has at its disposal for the management of MSW, such as trucks or lack of modern technology. It also includes the knowledge and the processes, such as the processes developed by Grohs et al. (2018), which in this case are different parts of the recycling process and knowledge gaps in the management.

The lack of structure of the NSWMA combined with limited monitoring processes and enforcement tools caused poorly managed operations of waste collection and a lack in technological equipment. Field officers would travel to communities to check if waste had been collected, to monitor whether the collection of municipal waste was working properly. The NSWMA administration had recently decided to reduce the budget for traveling. The reduction in funding eliminated all monitoring of the waste collection by the authority. An employee at the NSWMA expressed the want to use more technology in the overall management of solid waste, from collection to disposal and by extension the treatment of waste. Long term modern technology, with tracking of trucks through GPS and monitoring the trucks

loading weight per hour could however be a solution to this problem with investment in monitoring technology in the future. Another technical aspect of the NSWMA governance was the large degree of centralization in the operations, meaning many regional matters had to go through the central management department, where there was a lack of technical knowledge. Therefore, some operations which regions or companies could do on their own were hindered by the organizational structure.

The infrastructure was a technical aspect of the SWMS that was brought up by both operating stakeholders as well as NGOs. Firstly, many communities were not designed to give garbage trucks access. Informal communities in particular had narrow roads and paths, and lacked skips or garbage bins to pick up from. Less urban areas were also a challenge to reach. Many roads outside of Kingston were in very poor condition, which made collection in rural areas even more difficult. There used to be trains running across the island which could be used for long transportations, but not as many were in use at the time of the study. All stakeholders wanted to see more reliable collection everywhere, and city development in poorer communities and communal skips were mentioned missing in the system.

The operations of the Riverton waste disposal site was considered a problem by many stakeholders, operating, socially and environmentally concerned alike. The waste disposal sites in Jamaica lacked many technical instruments. The landfill used to have much more equipment, with different bulldozers and compactors, but the government did not maintain the equipment properly. Therefore, much of the equipment broke down and was not replaced. Hazardous waste was containerized and buried on the waste site. There had been some improvements made in the years prior to the study connected to firefighting, with increased coverage of dirt over the waste, night patrols on the disposal site to watch for fires, as well as more soil ready to use if a fire needed to be stifled. Cattle and dogs were seen roaming the waste disposal site.

A common complaint was that the landfill was located next to residential communities. It was convenient to have a landfill close to large cities as it reduced logistical costs, fuel being considered especially costly. There were some waste transfer stations as well, used to increase sorting and reloading waste to be transported longer distances. However, they were described to be more akin to small dumps with no sorting and frequent fires occurring.

> *"You have some transfer stations as well, because Jamaica is quite large compared to other Caribbean countries. So, they will carry waste from communities to those smaller facilities and it is then transported to Riverton. However, I am not sure it really works that way. I think in theory it is supposed to work that way. Because I have been past the facility in St Thomas, and it is just a mountain of waste which is occasionally on fire."*

Any waste sorting for recycling was done by informal waste pickers. There was a specific part of the waste site where trucks carrying commercial waste with a high quantity of PET bottles and cardboard dumped their load. Here, the same group of waste pickers sorted through the waste every day. They were unofficially employed by a woman who has worked on the waste site picking plastic and cardboard for over 15 years. She had contacts with the larger PET and cardboard recycling companies in Jamaica who paid for her recyclable material by the kilogram. Other materials which were picked at the disposal site were scrap metals, e-waste and clothes to resell.

> *"These people make a living from waste in some way or the other. They are in the scrap metal trade, they are in, you know, waste picking activities, reselling materials… some of them you could even say recycle to some extent, because some people collect plastic bottles and so forth."*

It may have been viable to extract landfill gas from the Riverton waste disposal site, with the purpose of using the methane released for energy. However, landfill gas extraction was not viable with the continuous human activity that was taking place on the site. If the Riverton waste disposal site were to be closed, there would have been a need for a system to replace the site. Such a system did not exist at the time of the study. So, even if there was a need to close the dumpsite, there was also a need for the improved infrastructure for SW.

"You cannot close Riverton. People would just start burning in their backyard every day."

At the time of the study recycling operations included re-use of unbroken glass bottles, and recycling companies sorted and exported recyclable material. E-waste, PET, metals and cardboard made up the majority of materials that were exported for recycling. Another small-scale recycling solution was the recycling of discarded material into construction material. The non-profit organization based itself in communities, and turned their waste into construction material for walls, chairs, and playgrounds for schools. It was a technical solution based on solving social issues in communities while also tackling the environmental issue of waste. However, the project never gained the needed support from the government and thus didn't manage to cover the costs needed for its production processes and had to shut down after six years.

Besides landfills and recycling, WtE was seen as an option for SWM in Jamaica with a study made by the DBJ to support the decision for a PPP. The arguments presented by stakeholders in preference of WtE plants were that it would address several problems nationally, with allocating the waste streams there to reduce the volume and at the same time get technical knowledge so the system could operate on its own with imported technical knowledge. The opposite side saw WtE, and especially incineration, as a non-renewable alternative hindering further development for circularity by competing for recyclables such as plastic and cardboard, in addition to continued air pollution.

There was also a fascination with creating completely new things from discarded material. As there was so much of it, artists were using the free material to create tools or jewelry, and expressing themselves through sculptures and cultural art pieces.

5.3 Mapping of Jamaica's solid waste management system

Jamaica's solid waste flows were mapped through the total flow in society, and as a cause-effect diagram. The flowchart of solid waste in society showed the journey and different places solid waste could end up. Meanwhile, the cause-effect relationships interpreted the processes increasing or lessening environmental and health issues from the SWMS.

5.3.1 Jamaica's solid waste flows in society

Figure 5.2 shows a model of Jamaican solid waste flows, represented as a stock and flow diagram.

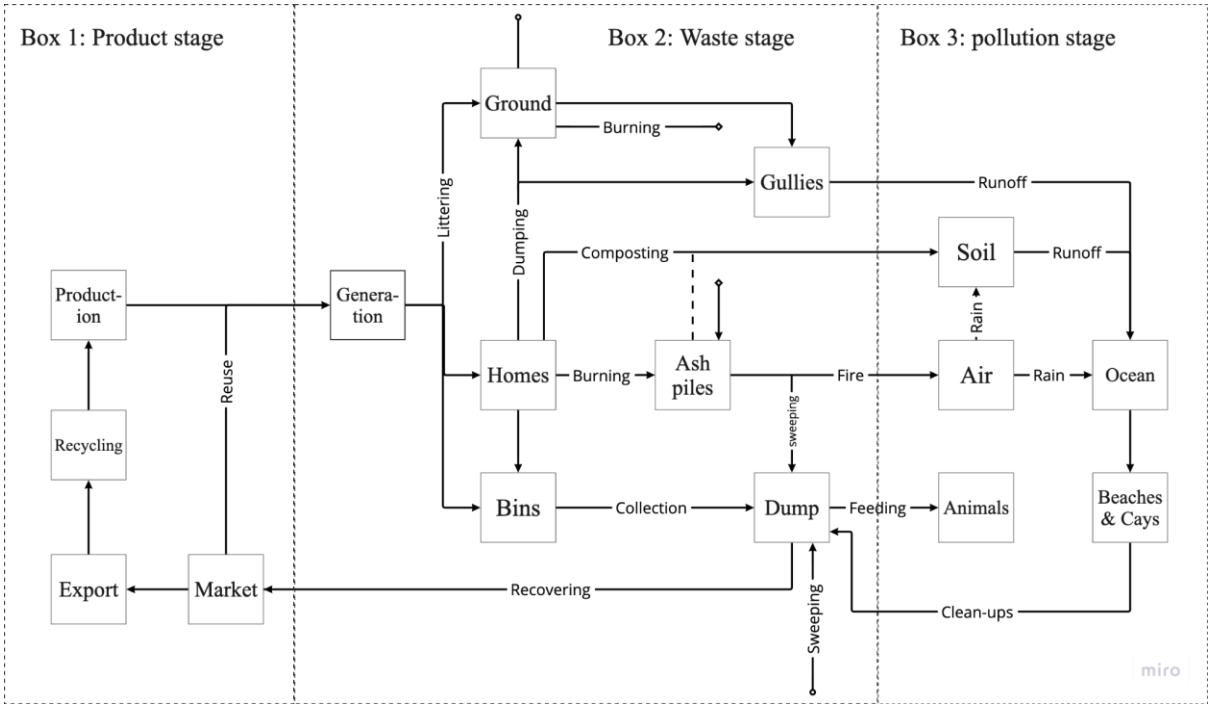

Figure 5.2. Jamaican waste flows.

The flowchart (figure 5.2) divides the waste flows between three stages, these being a product stage, a waste stage and a pollution stage. As material moves from product to pollution, it tends to become less accessible and its value tends to decrease. Within and between these stages, waste is moved or transformed through various processes.

In the first box, waste generation was fed by the production of material goods, which may to some degree have been composed of recycled materials, and by reused goods. In the second box, the generated waste originated from both the residential and commercial sectors, with much being imported. Waste typically had three paths that it would take through this stage. In some cases, the waste was littered directly onto the ground (streets, forest floors, unofficial dumping areas), and from there swept up by collection crews and taken to the dump, swept into gullies by wind or runoff, or lit on fire. Waste was also stored in homes or commercial facilities, and from there dumped into gullies, dumped elsewhere, composted in households, burned or placed into bins for collection. Finally, some waste was thrown directly into bins. From there, waste was taken to the dump by collection crews or spread into the street by animals or wind if not collected frequently enough.

In the third box, the pollution stage, the waste has largely escaped into the environment. The air was polluted by emissions from fires at the disposal sites or in the city. The rain brought down airborne emissions over the soil and ocean. The soil therefore received waste from illicit disposal and small-scale composting, and from the air with rainfall. The ocean received waste from the air and soil, as well as from the gullies that empty into harbors. Birds and cattle fed on the organic waste deposited at disposal sites. Lastly, beaches and bays received waste from the ocean. The only relief these received was from infrequent and voluntary cleanup initiatives.

5.3.2 Cause-effect relationships in the solid waste management system in Jamaica

Figure 5.3 below shows the cause-effect diagram, connecting all the discussed aspects and issues in the system. It is a simplified system derived from figure 5.2, used to show the cause and effect relationships between the different processes and affect loops in Jamaica's solid waste management system.

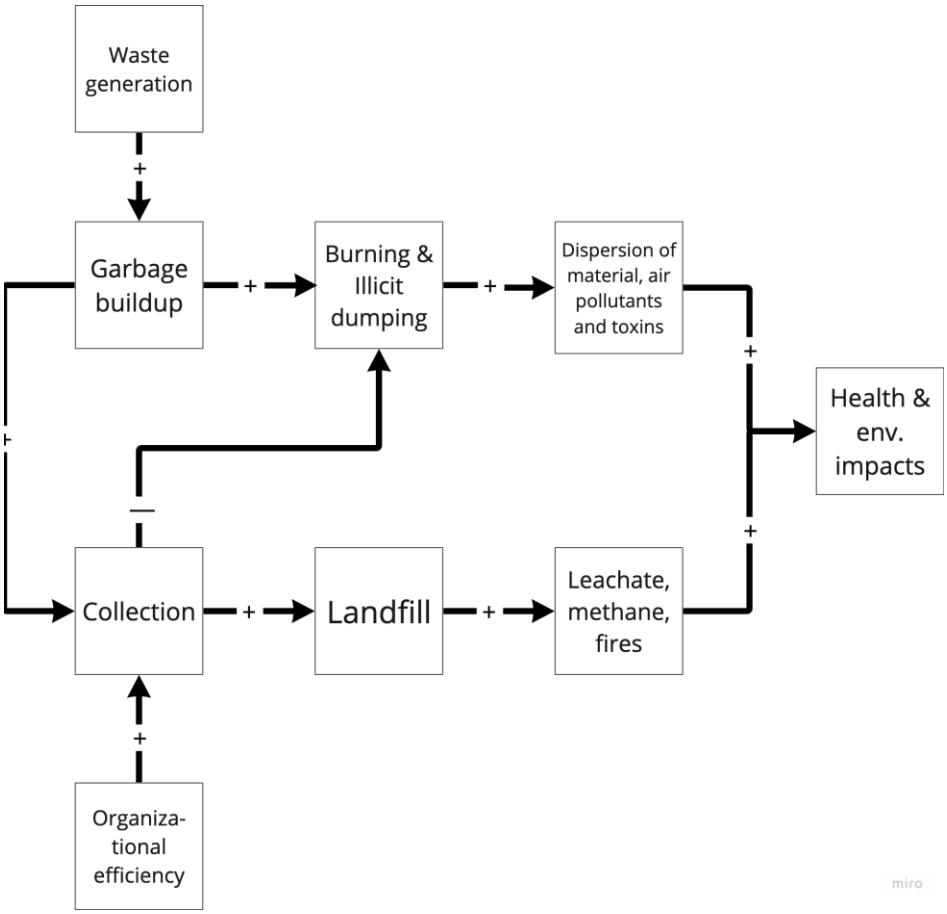

Figure 5.3. Cause-effect chain in Jamaica's solid waste management.

The system was composed of processes that caused effects in the SMWS. First, garbage was generated due to consumption. Garbage buildup was driven by waste generation and increased disposal urgency. Absent regular collection, this urgency forced households to burn or illicitly dump their garbage unassisted, which led to the dispersion of toxic substances and microplastics. Collection acted to reduce this dispersion by alleviating disposal urgency. The main driver of collection was the NSWMA's organizational efficiency, while the real driver of pollution was waste generation itself. However, the landfill was a polluter in itself due to inadequate management. The diagram illustrates the fact that in order to stop environmental and health impacts from pollution, it would be necessary to both increase collection and improve disposal practices.

6. Analysis

At the time of the study, the SWMS in Jamaica was not working according to stakeholder expectations, due to the lack of collection, lack of circularity and existing environmental pollution caused by poor SWM. This analysis explores different parts of the system in scenarios, investigating leverage points and governmental tools which could improve the waste management in Jamaica (Grohs et al., 2018). Chapters 6.1-6.3 aims to explore the answer to research question 1: *How can the solid waste management system change for better resource management?* Here, the scenarios are based on the waste hierarchy and how it can be adapted to this case for enhanced resource recovery. Chapters 6.4-6.5 are dedicated to answer research question 2: *How can the PPP improve the SWMS?,* and to explore the consequences of the planned PPP and the needed governance to establish the PPP sustainably.

6.1 Managing disposal of waste

The basic function of solid waste management is to remove household waste from homes and dispose of it in a safe way (Bundhoo, 2018). Crucial parts of this baseline are waste collection and disposal technology, both of which Jamaica was having difficulties with. When the waste was not collected, it was instead disposed of in illicit ways, through dumping in the environment or backyard burning, causing harm to human health and ecosystems (figure 65.3).

As a first step intended to improve the waste management to a point where the system can dispose of waste properly, the scenarios that follow examine the first two steps in the waste hierarchy: landfilling and energy recovery (EC, 2008), as those were prioritized by the Jamaican government (DBJ, 2022a).

6.1.1 Collection of all waste to reduce the environmental dispersion of waste

One way of classifying the waste collection process as of sufficient quality is when the illicit burning and dumping has stopped and the users find the collection service sufficient for their waste disposal needs. To improve the system at the collection process, the need was either to reduce the garbage build up at the waste generation point, or increase the frequency of collection (figure 6.1). To manage this, there were short and long term improvements.

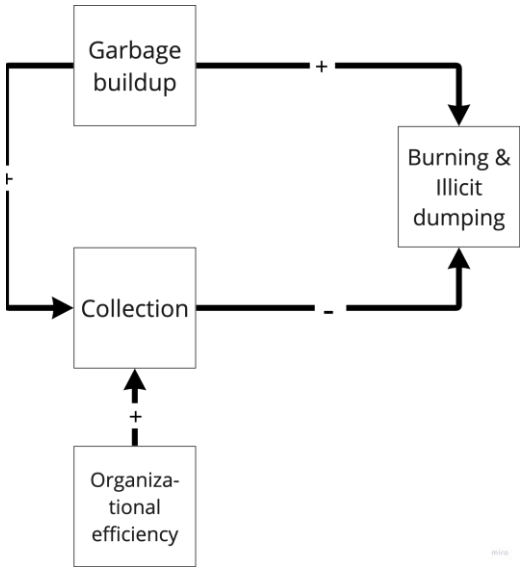

Figure 6.1. Processes in Jamaica's SWMS connected to waste collection.

The short term improvements were adding waste containers to manage the garbage build up, and improving the collection routes to improve the collection frequency. To reduce the garbage build up at the source, adding a buffer would be an appropriate leverage point (Meadows, 1999). The buffer would be to add waste containers and skips outside for houses and communities. A lack of bins has also led to citizens throwing their waste elsewhere to prevent the waste contaminating their homes, with the consequence of increased contamination of gullies and rivers (JET, 2016). The identified lack of waste bins for households has also resulted in poor design of waste bins outside of homes. This poor design has led to health risks as vermin scavenge for food (Post, 2007). As the responsible governmental agency with much influence over the system (figure 5.1), the NSWMA has the power to provide standardized and purposely designed skips for households and communities to throw away waste. This technical addition to the system would enable citizens to throw away their waste in a controlled way and reduce health and environmental impacts.

More frequent collection involves planning, conducting and monitoring of the collection, and has been regarded as a short term improvement. At the time of the study, the NSWMA was in charge of the collection in accordance with the National Solid Waste Management Act (2001). However, both citizens and the NSWMA stated that the operational efficiency of collection was insufficient. Pick-up routes and schedules were not planned and followed, affecting the whole country based on all stakeholders' perceptions. NSWMA also saw a need to monitor the routes to see when the waste was not collected by the agency's haulers. This could be done by modern tracking technology, as suggested by the agency. It could also be complemented by enabling feedback loops into the system supported by information flow from the NSWMA to the citizens (Meadows, 1999). If the planned schedule were to be communicated to households, citizens would know when to expect collection and would also know when the waste has not been picked up. With a system where citizens could report on back to the NSWMA when the schedule was not follow, faults in the collection organization - e.g. if a hauler was not doing the correct route, or areas were left out in the collection planning, or if the schedule for the day was too tight - could be identified and remediated. This would require public participation and ownership on a low level (Brett, 2003), giving more power to the citizens as stakeholders (Reed et al, 2009).

The long term improvements to the system regards technical infrastructural challenges and economic incentives. Communities in Jamaica that especially lacked waste collection were informal settlements. An appropriate leverage point to use here would be to restructure the flows (Meadows, 1999) by rebuilding communities where roads were too poor or houses too narrow to enable efficient waste collection. This leverage point would be most useful for improving the situation in the long term perspective, as well as important to increase equality in the SWMS. The reversed order would be to go from illicit disposal to controlled disposal. Allowing the existence of these informal communities has hurt the society which they are part of in the long run. Instead they need to be replaced by new formal communities to allow for urban planning customized after the needs of society, for both low-income takers as well as societal services such as waste collection.

All the previously mentioned improvements were in turn affected a lot by the economic aspect, especially as collection was presumed to be the most expensive part of municipal solid waste management (Bundhoo, 2018). The leverage point of increasing the economic parameter so that the NSWMA receives increased funding, could boost the technical improvements needed for monitoring and purchasing the needed vehicles. Long term investments to improve the infrastructure and rebuild communities would also be needed, but would not fall directly under the SWM. Instead, it would have

to be the responsibility of the central government. The changes would impact the social aspects as they would increase collection equality, enabling disposal behavior for controlled collection instead of the habit of illicit disposal.

6.1.2 Improve the disposal system - landfill

The second part of the disposal scenario included the improved controlled disposal, which started with the waste being disposed of in a landfill. This led to health and environmental impacts as the landfill leached, emitted methane and caused frequent fires (figure 6.2).

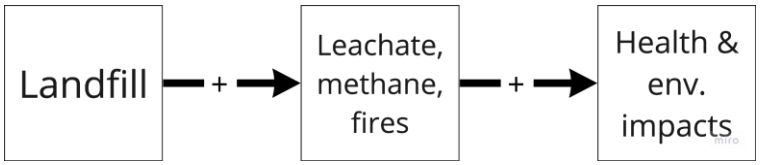

Figure 6.2. Processes in Jamaica's SWMS connected to landfilling

Even if waste was collected, the state of the disposal sites was such that it still was a hazard to health and the environment due to leachate, methane emissions and fires on Jamaicas' municipal disposal sites. To decrease the impact of the disposal on the environment and public health there was a possibility to look at the waste hierarchy and how the landfilling could be improved short term and long term, as well as how incineration could work, and other WtE technologies that could fit Jamaica's SWMS.

To improve the landfilling in the short term would entail improving the operations at Riverton through managing the waste at the site. The effect of investing in machines to spread out and compact the waste, and to cover the dumped waste frequently would reduce the volume of waste and the leachate of waste (Kamaruddin, et al., 2021). In turn, this would lead to less methane production and fires, which would decrease the impact on public health and environment. One way to start this process would be to use economical incentives to boost the investment of the needed technical equipment (Meadows, 1999). The government would be the stakeholder with the power to start the process and to prioritize investments in the budget, to give the NSWMA the possibility to implement the improved operational directives.

In the long term the focus for disposal would be to move from municipal disposal sites, especially Riverton as the largest one, to sanitary landfills. By changing the structure of the flows, where everything goes to the disposal sites, the system needs to be rebuilt and waste stopped from continuously going to Riverton (Meadows, 1999). This means closing the disposal sites and focusing on technical construction of sanitary landfills with bottom lining, soil covering and leachate collection (Nanda & Berruti, 2020). Other results would be reduction of methane emissions, limitation of toxins and improved health of people and ecosystems close to the landfill. For improved sanitary landfill functions, incineration or recycling (which will be discussed in further detail below) should be considered. Closing of the old landfill would still require monitoring of leachate and fires to avoid hazardous incidents, as pollution and fires would be still a risk (UNEP, 2021). Landfill gas collection could also be established on both the old disposal sites and the new sanitary landfill (Istrate, et al. 2020).

6.1.3 Improve the disposal system - incineration

Incineration could be a good addition to reduce the volume of waste going to landfill (Diaz Berriga & Themelis, 2011). As one third of Jamaicans burn their own household waste (JET, 2016), the burning of waste could be done in a more controlled way. It would be one step up the waste hierarchy ladder

(E.C., n.d.) as energy could be recovered and be a welcome addition to Jamaica's infrastructure (Mutz, et al, 2017). For the technical aspect of incineration to work in Jamaica, it would require improved collection efficiency, economic means of investment, new regulatory framework, as well as a way to manage the public health issues that incineration could bring along.

The collection efficiency would become increasingly important for Jamaica's SWMS if incineration were introduced to the system (Mutz, et al., 2017). As the incineration effect depends on the continuous flow of fuels, which in this case would be the solid waste, the goal of the SWMS should become to collect all the generated waste (Meadows, 1999), as explored in 6.1.1.

The economic aspect of incineration was challenging as it would require large investments to establish the needed infrastructure. It is important because incineration will never be profitable on its own for municipal solid waste, but will always need economic support for either the start-up investment or the continuous running of the plant (Mutz, et al, 2017). The goal for the running of the system will have to motivate the economic loss by getting a new energy source and the needed volume reduction (Meadows, 1999). However, in the case for incineration considered by the Jamaican government, the goal was that the incineration plant should finance its own operational costs after the investment cost has been covered, as expressed by the DBJ leading the investigation. This could become a problem, as the self financing outcome might not be feasible. The feasibility of the self financing will depend on the incineration efficiency (Makarichi, Jutidamrongphan, & Techato, 2018).

For incineration efficiency, waste pretreatment would be preferred. To improve the effect of incineration, organic waste fractions could be redirected for anaerobic digestion (Mohee et al, 2015). The separation of the organic waste fraction from the rest would result in more efficient incineration as the moisture content goes down (Kumar & Samadder, 2017). Additionally, with the anaerobic digestion, Jamaica could utilize the high organic content in the municipal waste (DBJ, 2022) by collecting biogas which could generate power and heat.

Incineration is ineffective without sorting, and is only suitable for a holistic waste management approach (Kumar & Samadder, 2017). Incineration has been most effective in countries with high recycling rate as the non-combustible waste is removed from the waste going to incineration. For these factors to be improved to such a point where incineration is sufficiently effective, focus must be to work on public awareness and separate more fractions. This is therefore connected to the 2nd scenario: taking care of the material value, with the next level in the waste hierarchy: recycling.

6.1.4 Improve the disposal system – regulatory framework

A new regulatory framework will have to be formed to regulate incineration. One of the main issues with incineration is the toxic emissions from the process (Allsopp, Costner & Johnston, 2001). Compared to landfilling all waste, incineration could reduce the country’s greenhouse gas emissions, as methane would not be produced on the landfill. However, without the proper measures, incineration could become a mitigator of very toxic substances that could damage health and environment just as well. Here, the right technology is important to capture and take care of the toxic rest products in a safe way. But to make sure that the technology is implemented (Grohs, et al, 2018), comprehensive legislation and monitoring is needed (Mohee, et al., 2015). This will be the responsibility of the regulatory stakeholders, and therefore managed by the NSWMA and the NEPA.

Social issues will arise as waste flows were redirected from the disposal sites, e.g. waste pickers losing their income and people not adapting to the needed changes but continuing with illicit dumping. These social aspects are important for the governing stakeholders to try to avoid poor outcomes, DBJ, NSWMA and NEPA, to keep in mind for sustainable development of the SWMS (Zaccai, 2012).

6.2 Taking care of material value

The second step in the waste hierarchy is recycling, where material is circulated and not disposed of. In this scenario the possibilities and needs for increased care of material value is explored, and how it could be the next better step for Jamaica's improved resource management. This scenario is more linked to stakeholders with more environmental concern, as raised by NGOs and academics.

To take care of material value, the mindsets of people need to change (Meadows 1999). Today, many in Jamaica only see waste as something to get rid off, which is shown in the littering and disposal into nature and frequently mentioned in interviews as a cultural view of Jamaicans. Much of it originates from lack of public awareness (Bundhoo, 2018). Instead, people need to understand that waste can be a resource (Potting et al., 2017). Mindset change happens through education (Goodluck, et al., 2019) and continued awareness programs which have worked well in Jamaica thanks to NGOs. Through these measures, the goal of the system can change (Meadows, 1999). In this scenario, the goal of the SMWS should be to recycle as much as possible.

6.2.1 Sorting of waste fractions

Sorting of waste fractions is the base for material recovery, as the different materials have to be separated from each other to be recovered. For example, plastic has to be sorted out from the paper, and wood from the iron. Today in Jamaica, unsorted waste goes straight to disposal. The sorting of recyclable waste fractions can be done in three parts of the system, also shown in the system figure below with the red circles (figure 6.3): controlled sorting at the disposal site, sorting at transfer stations under the collection and transportation, or sorting at the waste generation source.

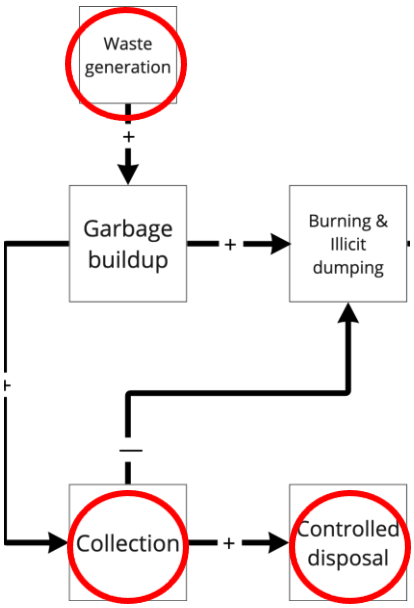

Figure 6.3. Where the sorting of waste can occur in the solid waste management system.

Sorting of waste fractions at the disposal site was a practice that was ongoing at disposal sites in Jamaica, and a changed scenario here would improve the recovery rate and the social aspect of the operations. There is a possibility for the NSWMA to improve the resource management here for the operational agency. At the same time, waste pickers were the recyclers and improving their operations could help their social status, their health and their income level (Thomas-Hope, 2015).

6.2.2 Organizing waste pickers

There are two primary options for organizing sorting of waste. Sorting can either be done by the NSWMA, or by independent waste pickers. If the sorting at the disposal site were to be done by the NSWMA, the sorting could be organized and planned in such a way that all waste that arrives is processed in an organized manner, and conducted in a safe way with safety standards and equipment. If the NSWMA were to do the sorting, building up competence in material fractions would be needed.

The knowledge of material fractions already existed with the waste pickers on the Riverton waste disposal site, as they sort out recyclable materials every day at Jamaica's municipal solid waste. So, waste pickers could be formally employed by the NSWMA (Kaza, et al., 2018). It would be a sustainable development action for the government (Zaccai, 2012) as it would be a case for both environmental care through recycling as well as social care when integrating the informal sector into formal society (Goodluck, et al., 2019). A good example of where this has been a success is in Nicaragua, where many waste pickers on the old landfill were hired in the development project for modernized waste management (Hartmann, 2017). For many waste pickers in Nicaragua it meant social and economic stability through employment with a monthly salary. By employing the informal sector, waste pickers are given more secure work and integrated into society (Thomas-Hope, 2015) while also enhancing the recycling service for society (Gutberlet et al, 2016). However, many waste pickers in the Nicaragua case were left unemployed (Hartmann, 2012), leaving many to continue to work informally and under hazardous conditions (Zapata & Zapata Campos, 2015). This case was a possible risk to avoid in Jamaica.

Some waste pickers on the Riverton disposal site also expressed reluctance in working for a company and instead valued their freedom only working for themselves. That was also a cause for many not being formally employed in the Nicaragua case, where many chose to refuse employment (Zapata & Zapata Campos, 2015).

A second option was for waste pickers to form their own co-operatives (Goodluck, et al., 2019). It would allow the waste pickers of Jamaica to continue to work with recyclables while not having to be employed, while maintaining their claim to the waste (Silva de Souza Lima & Mancini, 2017). It would empower the waste pickers, giving them more influence in the system as they would be impacting it more (Reed, et al., 2009). Co-operatives have also shown to improve the efficiency and increase the economic reward, as work can be more organized and the selling of recyclables yield better prizes when they sell together rather than separately (GIZ, 2011). At the Riverton waste disposal site, some waste pickers are already organizing themselves with one waste picker employing others and making big deals with the recycling companies for paper and plastic.

Co-operatives could be a good fit for Jamaica, as waste pickers are already doing most of the material value recovery like in the case of Pune, India (UNDP India, 2021). In Pune, waste pickers demanded acknowledgement for the positive impact of their work on the public health of the community and economic benefits given to the city. After the acknowledgement the waste pickers received official

support for their business which then helped the waste pickers improve their working conditions (WIEGO, 2012). A vital part of this transition was that the waste pickers received equipment, training and the right to collect waste directly from residents and charge for collection (Dias, 2016).

NGOs are important supporting stakeholders for this transition to support by sharing information for awareness (Dias, 2016). The NSWMA and NEPA are important stakeholders to provide collaboration and training as waste pickers form their co-operatives (Wilson, Velis & Cheesman, 2006). The government and the NSWMA also have to give the waste pickers legal right to the waste they sort and collect to give official support (UNDP India, 2021). Becuase according to the NSWMA Act (2001), the waste in Jamaica legally belonged to the NSWMA at the time of the study.

6.2.3 Transfer stations

Sorting of waste fractions for increased recycling in Jamaica could also be done by utilizing transfer stations and removing recyclable waste before mixing it further at a landfill. The NSWMA had several transfer stations around Jamaica, but they were reportedly not used much for sorting as they were more used as dumping sheds reportedly being frequently on fire.

Instead, as part of the collection step (figure 6.3), there could be a stop added where waste was taken first. In this stop, waste would be initially sorted to remove recyclables and organics and then sent on to controlled disposal (Hultman & Corvellec, 2012). This would change the flow of the solid waste (Meadows, 1999) thus allowing for the technical infrastructure to be supportive of the goal to increase material recycling. The structure of work would change for the NSWMA, who would be operating the transfer stations and changing collection routes so no waste truck would go directly from communities to the disposal sites but instead could improve the collection by having transfer stations spread out so the trucks wouldn't have to drive so far. This would also be affecting the haulers and, as mentioned in an interview, could help them reduce their costs for transportation (Kaza, et al, 2018). Waste pickers for hire or co-operatives could be utilized here as well, e.g. for recycling on disposal sites. In addition to giving them better access to the material, it would also improve their work environment. The transfer stations would have sheds, so the work would be shielded from harsh weather conditions, as sun, dust and rain was the biggest concern for many of the waste pickers who worked at the Riverton disposal site.

6.2.5 Waste separation in households

Sorting at source would mean sorting the waste where at the source of generation, in the top box of the waste management system (figure 6.3). Separating all fractions and not mixing different kinds of material limits contamination and enables the highest rate of recycling (Kaza, et al., 2018). For this, citizen engagement is very important (Kaza, et al., 2018) as it would be a demand on citizens to separate their household waste, which only few of the most environmentally aware stakeholders of NGOs and academics mentioned in Jamaica see as a wanted change. For this part in the scenario for taking care of material value, the change in mindset (Meadows, 1999) would be the most important, as the value of materials must be put as the base for the system. Sorting at source entails societal change, when habits of the whole country need to change, and people need to understand why and how the new system would work. This could be supported by information instruments (Zaccai, 2012) to educate in the way of sorting and the environmental benefits, and market based instruments (Zaccai, 2012) such as fines for poorly sorted waste, reduced waste collection cost for well sorted waste or establish deposit systems for single use products, such as PET bottles and aluminum cans. By redirecting waste flows (Meadows, 1999), recycling rates would go up and benefit recyclers economically. Increased recycling rates would

in turn be environmentally beneficial, and small scale composting could be scaled up if applied to urban areas and then support the agricultural sector (Mohee, et al., 2015). As there is a lot of organic waste in Jamaica, this would work very well with the municipal solid waste management (DBJ, 2022a). The change could also be supported with separate bins made available for households to throw away their recyclables in. As discussed above, the usage of more bins would also create a larger buffer for garbage build up to discourage illicit disposal (Meadows, 1999).

The sorting of waste for recycling is a good addition to the incineration and disposal scenario, as the incineration works best in combination with waste sorting to get the best combustible fractions and remove non-combustible (Makarichi, Jutidamrongphan, & Techato, 2018). Sorting also removes volumes and emissions from the disposal sites (Istrate et al, 2020) which is a wanted outcome for Jamaica's governing stakeholders.

6.3 Resource preservation

Resource preservation is at the top of the waste hierarchy (EC, 2008). For this scenario, the aim is to prevent products and natural resources from ever becoming waste in Jamaica by changing societal patterns through reduced consumption combined with enabling a new industry that can provide technical service for repair and reuse.

6.3.1 Reduce consumption

As for sorting at source in the previous scenario, to reduce the consumption is a lot about changing the goal of the system (Meadows, 1999) and affect all stakeholders' mindset of what consumption for resource preservation means. The new goal in this scenario is to reduce waste and preserve natural resources, so change the SWM to become prevention of waste instead of disposal of waste. That is to want things to use for a long time and not just a throw-away mentality for both repair and minimization of waste. Here, the assumption in society that the flow of resources are linear and infinite should change to enable a transition to a more circular resource flow (Potting et al, 2017). This includes encouraging reusing products to lessen the environmental impact (Kirchher, Reike & Hekkert, 2017) and not buying or producing products that are designed for short-time use or that are not needed (Potting et al, 2017). For that, the need is for all stakeholders to understand and for a new industry to take place to prevent waste from accumulating.

For all stakeholders to understand the need for resource preservation, education and information flows, as discussed in previous chapters, is a key leverage point (Meadows, 1999). It is still very important in all levels of the waste hierarchy as the understanding enables the mindset to change and governmental and stakeholder collaboration (Zaccai, 2012). School programmes and every other kind of communication form has been used in Jamaica, and should continue to be used to promote care for resources.

Here, the government of Jamaica and the NSWMA needs to show the way forward in this mindset change and society will follow (Meadows, 1999). This can be done by installing rules for the system, and following up with negative consequences if they are not followed (Kaza et al, 2018). It will be important to have the right rules set up and communicated in the right way, and for that the government should collaborate with other stakeholders who are already in the mindset of resource preservation, such as NGOs and academics within the field (Meadows, 1999).

An example of legal aid to reduce single use products would be for PET bottles and plastic, which covered the seafloor in Kingston harbor. By limiting these products on the market (which can be done through taxes or other financial incentives), and creating a culture to reuse bags and not buy water bottles for every new drink social change and technical change to make it more accessible with reusable products eg. taps for water.

6.3.2 New industry

With the new goal of resource preservation, the technological support of the societal and legal aspects needs to be in place (Grohs, et al., 2018) to move towards a more circular economy based society and materials and products stay in use longer (Benton, Hazell & Hill, 2014).

In Riverton Meadows, next to the Riverton disposal site, there was informal reuse and repair activities. Reuse of material could save on costs for businesses and consumers as reusable products often are cheaper on the market (Selvefors, et al., 2019). If the formal market demands for reusable products would grow, then well-paid jobs could grow through refurbishment and lift Riverton Meadows from poverty. This was shown in Brazil where formalizing the informal sector of SWM led to increased socio-economic benefits for waste pickers and the associated network (GIZ, 2011). However, reuse can also put the refurbisher in contact with hazardous material during refurbishment, so to prevent diseases and harm these refurbishers should get access to training and education on how to do their job more safely (GIZ, 2017). This could be well combined with the sorting of waste fractions at source, where waste for recycling and products for reuse would be separated, so products that are now going from Riverton to Riverton Meadows to markets would be less contaminated and more easily taken care of. Furthermore, just as waste pickers, the informal market for reuse should be integrated into society with economic and legal support (Gutberlet, et al., 2016) to further expand the circular economy concept to the whole island.

Circular economy needs to be economic to stay motivated. Many stakeholders in Jamaica working with recycling and reuse today say that it can be a challenge and wish there was more support for the circular waste business. So, the business could get economic support with subsidies (Meadows, 1999) and reduced market prices and lower taxes on reused products (Zaccai, 2009) to motivate more companies getting in on the reuse market.

6.4 Consequences of a public-private partnership

Under the PPP, the NSWMA adopts a regulatory role and operation of the system will instead depend upon the capacity of the private partner. The following sections explore the forms of interaction between the previously constructed problem systems and the coming PPP (Figure 6.3), assessing its capacity to address the shortcomings of Jamaica’s SWMS and what kind of governance is needed to support sustainable development in the SWMS. Table 6.1 summarizes the planned PPP engagement with the SWMS.

Table 6.1. Assumed attributes of the Jamaican PPP.

Attribute	**Assumption**	**Source**
Provisions	Sanitary landfills, WtE facilities, transfer stations, electrified vehicle fleet, closure or conversion of existing landfills	DBJ, 2022 Interview
Contract duration	25 years	DBJ, 2022
Contract partner	Single corporation or consortium	Interview
Payment mechanisms	Electricity tariff from power purchase agreements and gate fees	DBJ, 2022
Recovery targets	No	Interview
Competence transfer	Unknown	
Collection	Private, regulated by the NSWMA	Inferred
Collection charges	utility fee, payment by weight/volume or tax-funded	Inferred

The red circles in figure 6.3 shows where the private partner will be able to affect the system as described by the DBJ. The PPP can affect technical and economic aspects, being a private company contributing with new technology and a different economic structure compared to the NSWMA. With new organizational efficiency from the private sector the collection could improve, and the incineration and sanitary landfilling could reduce the leachate, greenhouse gas emissions and fires previously endangering people and the environment (Aracil, Fuentes-Cano & Gomez-Barea, 2018; UNEP, 2021).

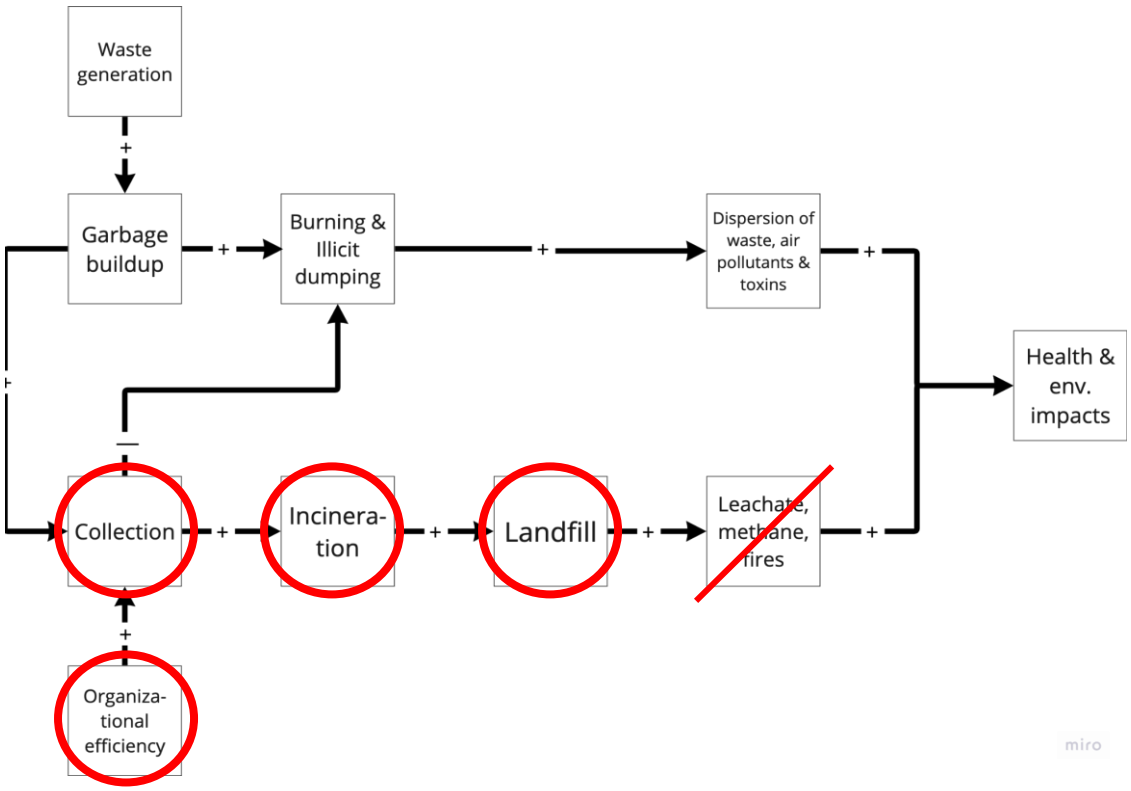

Figure 6.3: The effect areas of the PPP in the solid waste management system (expanded from fig.5.3 with incineration added for the PPP)

The system is not affected where there are social aspects that need change, such as waste generation and illicit dumping. These will have to be improved by governance of governmental agencies. Legal aspects will also always be the governments and its institutions' role, so the private partner will not be able to directly affect that. Instead the PPP would have to be supported by regulations and law built up for this new governance collaboration to protect the environment and human health in Jamaica (Zaccai, 2012).

6.4.1 Consequences of a public-private partnership: Collection

The main challenges in the PPP with collection are collecting enough material to ensure effective incineration, economic costs and the accessibility for waste collection. A lack of fuel quickly reduces any profitability found in incinerating waste. The whole business model for incineration is generally built on collecting enough material, and doing it efficiently to reduce costs (Mutz, et al., 2017). The NSWMA had many issues with the waste collection, so it has been a proven challenge in the system. However, the private haulers in Jamaica have shown that it is possible to do it effectively, as they have been managing to operate, make a profit and satisfy their customers by collecting waste. With the PPP, the organizational management would therefore be similar, when driven by economic incentives (Koppenja, 2015). PPPs operating waste collection has also been proven efficient in other LMICs (Milik, 2021).

The large costs of SWM is a big risk for the private actor in the PPP, and the cost for collection is often the largest expense in the SMWS (Kaza, et al., 2018). The NSWMA has explained it as the limiting reason for lack of waste trucks and reduced monitoring of collection which results in waste not being collected. The DBJ explained that the goal was for the private partner to be economically self-sufficient by reselling electricity. But there is a big risk that it will not be enough to make a profit (Mutz, et al., 2017). An added income for the PPP could be to have users pay for the collection (Iskandar & Tjell, 2009).

To limit illicit disposal, all the technical support the private partner could do would be to have enough collection to eliminate the need for citizens to burn or disperse household waste into the environment. However, accessibility is a challenge in areas with a lower degree of urbanization and informal settlements in Jamaica, as in other LMDC areas such as these often lack the most waste collection because of poor infrastructure. The infrastructure re-construction as discussed in 6.1.1 will not be under the control of the PPP, and so the challenge for trucks to access these communities will remain until the government has improved living conditions (Kaza, et al., 2018), as changing the waste flows can be a long process (Meadows, 1999). In the meantime there can be a collaborative action to come up with a short term plan (Zaccai, 2012). So the affected and affecting stakeholders - citizens, informal sector, the government and the private company - could together come up with a solution on how to best access these vulnerable communities.

Stakeholders affected by the change for collection and organizational structure in the SWMS are the NSWMA, private waste haulers and citizens of Jamaica. The NSWMA will go from a waste hauler to regulating the hauling market. The private waste haulers who have previously been competing with the NSWMA will now be competing with the PPP instead. If the PPP does improve the collection, then the private waste haulers will have even more competition for the commercial solid waste that they are

handling today. Lastly, the citizens will be affected, hopefully as they will get rid of their waste frequently and reliably.

6.4.2 Consequences of a public-private partnership: Disposal & incineration

The challenges for the PPP for disposal and WtE are: reducing the volume going to landfills, having energy efficient incineration and reducing the environmental impact with the new technology for the disposal and WtE.

Reducing the volume going to landfill is one of the reasons that DBJ and the government want incineration. Incineration could reduce the waste going to landfill (Mata-Lima, et al., 2021), and that way it would also be easier to manage the operations of a sanitary in a safe and sustainable way instead of 60% of all the waste ending up without any treatment at the Riverton disposal site (NSWMA, 2015). However, there is also a risk that the planned sanitary landfill operations do not work. This was the case in Egypt, where no WtE facility or sanitary landfill was established despite the PPP plan and the waste kept going to dumpsites (Milik, 2021).

Efficient WtE facilities will be of key interest to the PPP, as the second reason for the want of incineration is that electricity can be produced and reduce the country's dependency on fossil fuels (Mata-Lima, et al., 2021), which like many other SIDS Jamaica has to import (UN, n.d.b). The risk for the efficiency lies with the amount of waste collected, to ensure enough fuel within the municipal waste. The waste composition in Jamaica risks being too high in moisture as the food waste fraction is the largest waste fraction by far (DBJ, 2022a; Makarichi, Jutidamrongphan, & Techato, 2018). The high moisture content would reduce the efficiency, thus limiting the electricity production. The electricity that can be gained from incineration is already restricted to only 20% of the energy that can be used from the process (Mutz, et al., 2017). There is a large risk that just collecting all the waste and incinerating it without sorting will be ineffective, thus resulting in a very low energy contribution and low revenue for the private company. Meager possibilities to make a profit is not motivating for a private company to invest, and will make it hard for the company to operate without additional funds (Brett, 2003; Mutz, et al., 2017).

Incineration can be a good option for reduced climate impact as it lowers greenhouse gas emissions, CO2 and CH4, for the SWMS in Jamaica and reduces the amount of land needed for SWM (Aracil, Fuentes-Cano & Gomez-Barea, 2018; Diaz Barriga & Themelis, 2011). But the PPP will also have to handle the toxic waste products, such as NOx, SO2 and ash, emitted and left from incineration so that it does not disperse into the environment (Mutz, et al., 2017). This could be secured by legislation, demands for modern technology and continuous monitoring. Demands for modern technology and monitoring of toxic gases emitted will have to be made in the contract for the PPP and a transparent information flow for the government - NEPA or the NSWMA - to monitor and hold the company accountable (UNESCAP, 2009).

Stakeholders that are affected by the change of disposal management are: waste pickers, the NEPA and the NSWMA. As a result of the waste being incinerated, hundreds of people will lose their income as waste pickers will lose access to recyclable material (Hartmann, 2017). To avoid that, the PPP can either employ them (Kaza, et al., 2018) or cooperate with them to increase the value of the waste to be incinerated (Silva de Souza Lima & Mancini, 2017). NEPA and NSWMA will be regulating the PPP and support the private company with monitoring and legislation to ensure commitment to the undertaken responsibilities and protect the public interest and environment (UNESCAP, 2009).

6.4.3 Consequences of a public-private partnership: Material recovery

For improved material management in the SWMS in Jamaica, material recovery is desirable. It also offers many possibilities to improve the incineration and disposal while at the same time moving up in the waste hierarchy and expanding the PPP business model. The possibilities for the PPP are: separate organics and non-combustible waste for recycling and more efficient combustion, and increase profit by trading with recyclable material (Bundhoo, 2018).

By separating organics from the combustible waste more efficient energy transformation can be achieved when incinerating municipal waste (Makarichi, Jutidamrongphan, & Techato, 2018). There was no industrial composting in Jamaica (NSWMA, n.d.d), but anaerobic digestion could work well in Jamaica as several test projects have shown (CaPRI, 2015). With the high organics content (DBJ, 2000a) and the warm climate, there is the possibility to extract biogas and soil (Bundhoo, 2018). It would have the possibility to increase the energy from the waste, as the outcome would be biogas in addition to more efficient incineration (Mohee, et al., 2015). The solid rest product of the composting could provide the agricultural sector with fertilizing, like is done on a small scale today in peoples own households in the countryside. The private company running could also use the soil left to cover waste on the sanitary landfill that they would operate (Pendely, 2005).

The separation of recyclable material works well with the need to remove non-combustible waste for increased incineration efficiency. Glass, metals and WEEE (DBJ, 2022a) are waste fractions that are non-combustible and had an established recycling market which the private company in the PPP could enter if they sorted out those valuables (Bundhoo, 2018). Incineration works best with a holistic approach, where each material fraction is used to its best potential, which for many fractions is recycling instead of lowering the combustion rate or becoming bottom ash (Margallo, et al., 2019). Removing the recyclables from the mixed waste stream further reduces the volumes going to landfill (Mata-Lima, et al., 2021). Incineration is however in competition with paper and plastic, which are established and by stakeholders valued recycling flows in Jamaica but also combustible. There is the potential to make money for the private actor in the PPP who owns the waste by selling the recyclable material, bioenergy and compost (Hultman & Corvellec, 2012). This could help reduce the economic risk of incineration, it being a costly investment and process (Mutz, et al., 2017).

Stakeholders affected by the PPP operating with material recycling are: waste pickers, existing recycling companies and NEPA. Waste pickers are affected as the waste they were sorting will be owned by a private company who might want to trade with the material themselves. The expanded business model does however create job opportunities for waste pickers to be employed by the private company. Existing recycling companies in Jamaica may face increased competition or get a new partner on the market. The competition may increase if the PPP enters the recycling market and could start trade with material that the recyclers previously got from waste pickers. The second possibility is that after the PPP removes non-combustible waste from the rest they can sell it to existing recyclers who have established their recycling businesses and permits. However, the partnership would only work for metal, glass and electronic waste, whereas the competition might be tougher for recyclers trading waste fractions that are combustible, such as plastic and paper.

6.5 Governance for improved sustainable solid waste management

Good governance needs to be achieved for the sustainable development SWM in Jamaica (UNESCAP, 2009). This is done to support the PPP through transparency, accountability and rule of law to ensure efficient PPP operations and environmental protection.

6.5.1 Governance and the public-private partnership in Jamaica

To make sure that the PPP achieves the wanted results for Jamaica's SWM, good governance is important (Zaccai, 2012). This means that the Jamaican government cannot renounce responsibility of the SWM once the PPP has been established, but the regulatory part of the NSWMA Act (2001) of putting the responsibility of SWM to the NSWMA will have to be followed. The categories for good governance that are discussed here to improve the governance for the future PPP are: participation, transparency, accountability, rule of law, consensus oriented and inclusiveness, and they are all interlinked (UNESCAP, 2009).

Participation in Jamaica's SWM has at present been minimal. The waste pickers were working on their own on the disposal sites and the NSWMA had not reached out during the pre-study for the PPP. The workshop held during this field study was the first interaction between waste pickers, governmental representatives and the recycling sector to discuss future changes in the SWM. Even though a PPP is a kind of participatory governance (Weiss, 2000), the challenge with poor SWM should be tackled with increased collaborative action (Zaccai, 2012).

Participation for good governance is usually between key stakeholders in a system (Riermann, et al., 2012). In the case of the PPP a new stakeholder is being brought into the system instead of collaborating with the existing key stakeholders in the SWMS, such as NGOs and existing recyclers. The PPP can be made stronger with increased participation and focusing on the aim for good governance to include stakeholders to work for the long term for all in society (Brett, 2003). It has to be a collaborative action for sustainable development (Zaccai, 2012). As discussed in 6.4, many stakeholders are at risk of being affected in a negative way, especially economically. They need to be part of the solution and not left behind (Weiss, 2000). So, through participatory actions, affected stakeholders need to be empowered by increased collaboration between regulatory stakeholders, the private partner who operates, the users and other operators in the system (Reed, et al., 2009). Because other collaborative actions, like waste picker cooperatives and partnerships with recycling companies, are possibilities for the PPP. Only by getting all sectors to participate in change planning for the system can the best way forward be achieved.

6.5.2 Transparency and accountability

Transparency and established information flows are important to support participation (UNESCAP, 2009). There has to be transparency between the DBJ and the public for the PPP change, what changes will be made and how that will impact other stakeholders. This will make it easier to change the behaviors or actors and align them with the new system (Meadows, 1999). It is also important that the private actor in the PPP is transparent to the government and the users in the SWMS.With good communication and information about the system, as well as shared reporting, builds a stronger participation in the system. Transparency is also important as it is essential for accountability (Biermann, et al., 2012).

Accountability for the private actor as well as the NSWMA in charge of the regulation of the SWMS is vital for the PPP to work (Brett, 2003). The NSWMA has to ensure that the requirements of the contract

are fulfilled, and the private actor doesn't avoid societal and sustainable aspects to increase profit (Milik, 2021). The NSWMA through the NSWMA Act (2001) has to be able to enforce regulations on the private partner if or when there is a problem (Rodic & Wilson, 2017). For the same reasons, the NSWMA has to be held accountable. The NSWMA should be held accountable by NEPA and the users of the SWM through democratic institutions. To ensure accountability, tools that can be applied to the PPP are exit options, voices to users and creating a mutual dependency (Brett, 2003).

Mutual dependency relies on transparent communication channels to make accountability easier (Biermann, et al., 2012). Therefore it will become important for NSWMA to be an active regulatory partner in the PPP and not only give everything up to the private partner. Then the government would be losing a voice in the collaboration and their power to affect the SWM would decrease, giving more power to the private partner thus risking the services to decline (Lissah, et al., 2021).

Without accountability in the PPP, there was a risk that the same issues and dissatisfaction that was present for the NSWMA operation will continue but no accountability is enforced, as waste wasn't collected and even though NEPA withdrew the permit for Riverton disposal site there was no change in management and continuous environmental decline (Office of the Public Defender, 2015).

6.5.3 Rule of law

Rule of law with comprehensive regulations for control, transparency and accountability will have to be installed to support the PPP (Zaccai, 2012). Laws and regulations will have to extend to new SMW technology and new participation models. Incineration and sanitary disposal introduced in the PPP will need to be covered through a comprehensive legislation. The new incineration laws will have to push for low emissions and emissions control through monitoring (Makarichi, Jutidamrongphan & Techato, 2018). As there was no hazardous waste regulation in Jamaica, to the discontent of academic stakeholders, regulations on hazardous waste management will have to be assembled to make sure the very toxic waste products from incineration are handled and disposed of correctly. The laws for landfilling operations should additionally be updated and monitoring should be demanded for the wanted sanitary landfill, for hazardous waste as well as other operations (UNEP, 2021). The goal for the governance of the technology has to be focused on protecting social and environmental aspects to ensure sustainable development (Weiss, 2000).

The governance in Jamaica needs to strive to be transparent and inclusive, listen to all views and work for what is the best path for the whole society (Koppenja, 2015). The government, through DBJ and the NSWMA in this case, has to work out details with the stakeholders (Blühdom & Definiorian, 2018). Otherwise there are risks of unwanted effects, such as the poorest communities becoming even more vulnerable or the technology not working as it was intended due to unforeseen consequences. Unforeseen problems have often been the case with change in wicked problems, and public participation is a tool to prevent it (Cuppen, 2012). The study found that in Jamaica haulers don't want to be replaced, recyclers don't want to be faced with unfair competition, waste pickers don't want to lose their part in the recycling value chain, NGOs want the illicit waste disposing to be stopped and academics see the need to recycle and reduce single use products. And none of these stakes were included in the plan for the changed SWMS and PPP. So, all these stakeholders, especially waste pickers who are most vulnerable to the effects of the PPP (Goodluck, et al., 2019), have to be invited to form the changes for improved SMW (Biermann, et al., 2012). The government has to take the lead role to include all stakeholders, or there can be no sustainable development and the whole society in Jamaica will be affected by it (UNESCAP, 2009).

6.5.4 Ensuring efficient public-private partnership operations

Ensuring efficient operations for the PPP in Jamaica's SMWS includes market feedback loops and enabling exit options for users, as well as improving operations for environmental sustainability with collaboration with NGOs (Zaccai, 2012).

The NSWMA could improve the governance of the PPP by opening feedback loops to give voices to users (Meadows, 1999). Setting up systems accessible to the public to allow them to report when their waste hasn't been picked up or there is a need for more frequent collection in a neighborhood would allow for feedback. The NSWMA as a regulator could monitor if the private partner was fulfilling its job or take actions if they were not. Another controlling negative feedback loop in the system would be if communities were allowed to choose their own waste hauler, instead of the situation where NSWMA has claimed all the household waste and will pass it on to the PPP. With an open market, the voices of users would be clearly heard if they exited the agreement with the private partner in the PPP and chose another hauler or to work with waste picking cooperatives.

To enable exit options, the competition on the market should be kept (Zaccai, 2012). The planned PPP by DBJ has focused on creating a monopoly for one single private partner instead of a larger participation project (DBJ, 2022b). The governance could benefit from extending the collaboration to the already existing market of waste haulers and recyclers, so that there were alternatives for services on the market and exit options were there if the PPP fails in services (Oteng-Ababio, 2010).

NGOs could also govern for sustainable SWM in the PPP in collaboration knowledge sharing but also information flows (Zaccai, 2012). NGOs could support the NSWMA and NEPA on the needed additions in the regulatory framework. They can also be very useful if the PPP chooses to do more sorting and recycling and the governance seeks to change people's mindsets about waste as a resource, or in partnership with the private sector to help them adapt and follow social norms to be more accepted in society (Hamman, 2020).

6.5.5 Governance for environmental protection

The PPP does not have an effect on preventing waste generation. Reducing waste generation would instead be achieved by use of governance tools, to supply the knowledge and change the paradigms in society to promote resource preservation (Meadows, 1999). Through collaborative work with NGOs and supporting their work for increased environmental awareness for the public and cleanups, the mindset around waste can change. The paradigm shift would result in increased recycling and decreased illicit disposal in Jamaica, since citizens care about the environment but the understanding of what to do to help and how is needed (NEPA, 2016).

Ensuring resource preservation would be part of the effective and efficient category for good governance (UNESCAP, 2009). It should be a priority for the government of Jamaica to ensure resource preservation as it is the base of society. SIDS being especially dependent on natural resources and vulnerable to climate change (Birchenough, 2017), the loss of biodiversity that greenhouse gas emissions and waste is already causing Jamaica's mangrove forests and coral reefs, should make the government prioritize the enforcement of environmental laws against illicit dumping and poor landfill management.

To contribute to strengthening the control in SMW governance, the NEPA should inherit the mandate of enforcement (McCaulay, 2018). Unless urban development is controlled and SMW regulated, through permits and enforcement given out by NEPA, the system for collecting waste and reducing emissions will not meet the needed efficiency for environmental protection.

7. Discussion

Strengths and weaknesses of this study are connected to literature chosen and how it contributed to the research. There is also a strength in the method that was used, with some weaknesses of the stakeholder analysis described below. This chapter also discusses the contributions to the field of waste management in LMICs, and how it confirms the results of similar studies, as well as differ due to this specific case study.

7.1 Strength and weaknesses of the study

The strengths in the study lies in the qualitative data collection from the field study for the case in Jamaica, reinforced with literature to frame the method and support the discussions in the analysis. The study was however limited by time and circumstances out of the authors control, such as stakeholder availability for the study and Covid-19 restrictions.

7.1.1 The literature

Strengths in the literature include comprehensive on solid waste management in low- and middle-income countries, governance and stakeholder participation. This provided valuable knowledge within the field of study and support for the conclusions made in this research. Solid waste management in LMICs is a field of study taking place all around the world. This study has taken advantage of many reports with authors who have compiled results from several case studies on waste management in LMICs as well as dumping, low-managed landfilling and the informal waste management sector. This contributed to better understanding of the field of study and as background to the study, as well as related cases in the analysis. The literature on solid waste management was gathered from trustworthy sources.

The literature on governance is also diverse, ranging from sustainable governance to covering the public-private partnership of this case. The different aspects of governance complement each other, and support this study to understand Jamaica's SWMS and connect this study to other cases of PPPs in SWM. The literature on solid waste management was gathered from trustworthy sources.

The strength in the stakeholder participation literature lies in the many articles used to describe and understand the topic. Different authors share similar views on the importance of stakeholder participation in decision making processes. It also connects to good governance and the importance of stakeholder involvement in complex systems such as the waste management systems.

A weakness in the existing literature was the limited research available on Jamaica and the Riverton waste disposal site and the waste management system in the rest of the Caribbean. Much of the previous studies made were old, dating back from 2001 to 2015, giving outdated information on some parts of the operations and issues of the waste management.

7.1.2 Aim and method

The approach chosen was to do a stakeholder driven analysis to handle this wicked issue and get holistic problem solving, as well as getting qualitative data to explore the system. The results from the interviews are therefore all based on the level of opinion and knowledge of the various participants, treated as stakeholders and representatives of stakeholder groups in this study. The study’s conclusions have therefore been shaped in accordance with the participants who were interviewed.

As none of the authors had previously conducted a stakeholder driven research, this study has been a learning process as well. The lack of experience was compensated with an extensive literature review and conversations with researchers in the field of stakeholder management in low- and middle-income countries in the initial phase of the research project. The literature supported understanding of the method used for stakeholder analysis, for example the different perspectives needed in a stakeholder driven study and the important role it plays for the.

However, because of the learning curve occurring during the project, the data gained from the first interviews might not have the same depth as the last interviews, or the stakeholder might not have been asked to share as many perspectives as in the later interviews. This due to the increase of understanding of the waste management system in Jamaica after the first interviews, and so more follow-up questions were asked during the later half of the interviews. A countermeasure to this is possible weakness in the study is the workshop. Many of the initial interviewees were invited to the workshop to allow for additional views and feedback from them and make sure their perspectives were well represented in the study.

The workshop would have benefited from the attendance of all the stakeholders who said they would attend, and for them all to have arrived on time. This would have allowed for all important perspectives to have been represented throughout the whole workshop. Some important data was gathered from the workshop even so, and the participants got new contacts and insight into the SWM system through information sharing. If more time would have been available, the study could have benefited from more workshops, as it could have generated more collaborative results in terms of disagreements, generated ideas and additional perspectives on the issues.

Another weakness of this study is the missing interviews from some identified key stakeholders, such as plastic recycling companies and a member of parliament responsible for budgets. The perspective of the plastic recycling sector in Jamaica is missing from discussions regarding incineration, recycling obstacles and wishes from the SWM system. If an interview could have been made with a representative of parliament, or someone else with insight into the budget management for the NSWMA, some clarity might have been gained in regards to motivation of budget and an additional perspective of the perceived low priority of SWM from the government. Lastly, the study could have benefited from interviewing more residents in the Kingston area. This would have given a clearer view of what the population thinks are issues and would be willing to do for a more sustainable system. For the same reason, that part of the study could have been made as a quantitative analysis through a survey to confirm and add to the study's findings. The amount of stakeholders that were interviewed during the field study was also in some part restricted due to the limited time in Jamaica.

A strength to the method of choice was the amount of perspectives on the problem it generated. Stakeholders were very willing to share their views, opinions and knowledge, and perspectives on the problem that had now been initially in focus for the questions were brought forth anyways. No questions were aimed directly at politics or governance, however, that was brought up by many stakeholders anyways. This shows that the method allowed stakeholders to present the important views and thus for reliable data collection.

7.1.3 Delimitations and Assumptions

Due to the limited number of participants, perspectives might be missing. This can also be seen as a negative consequence of choosing to do a stakeholder driven analysis. Time is a great limitation to a field study. More time in Jamaica could have allowed for more interviews, more visits to observe WM operations, as well as additional workshops to generate more data and allow for further discussions and feedback on the system dynamics.

There have been no assumptions made in this study that all opinions and perspectives expressed in this study are shared by the stakeholder groups the individual stakeholder could represent. However, the views can be expected to be shared by others. Furthermore, due to an extensive stakeholder identification process, many perspectives were captured in this study.

The study was also shaped by the following important choices:

1. The study was constructed with the goal of sustainable development as defined by the UNs Sustainable development goals (United Nations Conference on Sustainable Development, 2012).
2. Studying solid waste management in Jamaica as a wicked problem in a complex system and exploring it in scenarios (Grohs, et al., 2018).
3. Problem framing of the challenges in the solid waste management system in Jamaica and goals were defined based on stakeholders' perspectives (Hemmati, 2002), in addition to insight from the literature and similar cases around the world.
4. Points of change in the system were technical process, societal change or governance for sustainability (Meadows, 1999; UNESCAP, 2012; Zaccai, 2012).

7.1.4 Generality and validity

A strength of the study's method is the generality. It is possible to use the same method that was used in this study around other waste disposal sites. However, the results will probably differ somewhat depending on the structure of the solid waste management system and other local circumstances, such as the political and financial state of the country.

The stakeholders to interview would also differ between different case studies. Even though the same stakeholder characteristics should be strived to interview, missing or additional stakeholders would give the study another view. It would therefore be important for similar studies to construct their own stakeholder identification and characterization.

7.2 Contributions to the field

This research contributes to the field of waste management in LMICs as it fills in knowledge gaps on the situation of solid waste management in Jamaica. It also shows how system dynamics can support in forming a holistic view of a WM system. Furthermore, parallels to previous work and be drawn to study confirming and contradicting results.

7.2.1 Knowledge contributions to the field from the study

This master thesis contributes to the wide study on how LMICs can move towards more sustainable and circular SWM. As a case study, the findings in this study are in part limited to the geographical area of Kingston, Jamaica, where most of the focus of the study was located. It is important in these studies to

note that the improvements to a SWM system should be applied to fit each region and there cannot be any assumption that one system works everywhere. Culture, infrastructure and governance differ between each case and so different changes will be wanted and needed in each different system. Nonetheless, this case study contributes to the existing body of research and can be learnt from in the next case, on methodology and possible existing opinions on municipal disposal sites with poor landfill management and waste pollution. As a wider application of this study, SWM actors in Jamaica can take part of this knowledge to get a holistic view of the system and get a sense of which direction an improved SWM system could take to improve sustainability.

The application of system dynamics to solid waste management has not previously been attempted in Jamaica, to the authors' knowledge. Although the important choice not to pursue quantitative data does slightly limit the scope for interpretation of the study's results, the method provides an interesting basis for future studies, wherein cause-effect networks and/or system factors can be compared with other low- and middle-income countries and SIDS worldwide.

7.2.2 Results confirming or contradicting previous result

As much of the literature pointed to the environmental hazards of poorly managed landfills, so did the interviews with different stakeholders. The case study in Kingston around the Riverton waste disposal site thus confirms that the environmental effects are felt by the community around, especially when it comes to ocean pollution and unsolicited littering.

The study is also confirming the many results from previous studies regarding waste management in LMICs. According to the description of waste management in LMICs by Kaza, et al. (2018), even though Jamaica is a upper middle income country by the definition of the World Bank (2020), the waste management has many aspects of a low-income country. That is because of an existing high rate of illicit dumping and waste burning. Similarities to middle-income countries of the report are also identified in Jamaica, as there are dedicated landfill areas with covering operations and a MSW collection. Other common traits of LMICs described by Bundhoo (2018) is the public's low awareness of poor waste management. For some stakeholders interviewed, this is not the case. Many stakeholders seem to know that low landfilling on Riverton is a health and environmental threat. However, it is often mentioned that Jamaicans have an attitude of not caring about the waste and not seeing a value in used materials, and that this notion is a cause to the continued littering and illicit dumping. There is also a lack of knowledge on how the SWM system works in Jamaica. To remedy this, this study expresses a need for national education on proper waste management for environment and health benefits as well as recycling possibilities. Education programs are also seen as fundamental to increase awareness, as mentioned by Goodluck, et al. (2019), as well as important for the government to communicate how the system works and improve citizen engagement as discussed by Kaza, et al. (2018).

Another confirming result from this study compared to previous studies is the important role of waste pickers in regards to material recovery and recycling in LMICs., and the need to keep them in the economy for sustainable development of cities As concluded by many sources informal workers are doing most of the recovery, with it in the Kingston area occurring on the Riverton waste disposal site and then sit on valuable knowledge for improving formal recycling (Kaza, et al., 2018, Thomas-Hope, 2015, and Dias, 2016).

Furthermore, the study confirms the frequent lack of care or understanding from the waste pickers of the health risks they are exposed to as expressed by Wilson, Velis and Cheesman (2006). As the waste pickers on the Riverton waste disposal site perceived the sun as the harshest part of their work environment, there seemed to be little regard for the toxic landfill fumes and heavy manual labor.

For some of the previous articles read, this study presents several contradictions. No waste pickers live on the Riverton waste disposal site, but most of the waste pickers live right next to it in Riverton Meadows. Furthermore, there are small fires occurring every day, both on the dumpsites and due to backyard burning, but there are more rarely large fires on the Riverton waste disposal site since they increased the waste covering.

As the study did not look into the amount of waste being generated, there are no contradictory results on the sizes of different types of waste. It does, however, further emphasize the displeasure many Jamaicans have regarding the management of the MSW on the island.

During the study it has also become increasingly clear that many stakeholders want to see a private company taking over and that the Jamaican government together with the DBJ is serious and moving forward with its plans to invest in waste incineration.

8. Conclusion

The study has provided material to contribute to improvements of the solid waste management system in Jamaica by evaluating options for increased material circularity and improvement made with a public-private partnership. The solid waste management system can improve for better resource management with improved collection, integrated recycling and established reuse market. Improved collection will decrease the waste being discarded into the environment and enable it to become new resources. Recycling supports not only material circularity in itself, but the separation of fractions also improves energy recovery and facilitates sanitary landfilling. A public-private partnership, where a private company manages all waste, could improve the operational management in the solid waste management system, but has to be supported by governance for sustainability. To ensure improved solid waste management - such as eliminating illicit dumping, providing citizens with waste collection and protecting health and the environment - the government has to design a comprehensive legal framework and policy instruments that allow for monitoring and enforcement of environmental law.

Other conclusions:

- To motivate and anchor the changes in the complex system of solid waste management, increasing public participation between the operating and regulating stakeholders is needed. It is crucial for the establishment and long term success of the new system.
- Waste pickers in Jamaica possessed extensive knowledge regarding recyclable material as they were doing most of the material recovery by collecting valuable material from the disposal sites. This competence should be utilized in a formalized system to improve the solid waste management and give the waste pickers improved working conditions. Whether they should be directly employed or helped to form a cooperative should be further discussed with the concerned stakeholders.
- Most interviewees were to some degree aware of the environmental degradation caused by poor SWM. This indicates that Jamaica was ready to move towards a more structured recycling and reuse market.
- In order to reach a paradigm shift and a future where all citizens take ownership of the solid waste issue, more public participation in terms of education and involvement is necessary.
- Environmental monitoring must be accompanied by the proper infrastructure, or enforcement will lack both support and legitimacy.
- The economic incentive is strong, and household waste collection should be made cheap for the citizens, or there is a risk that many will continue to burn or dispose of their waste in other illicit ways.

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