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THE ECONOMICS OF PLASTIC RECOVERY FROM RIVERS:
Case of Brasilia

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THE ECONOMICS OF PLASTIC RECOVERY FROM RIVERS:

Case of Brasilia

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FOREWORD

This research on river waste recovery will cover the economic analysis of using an extraction system to reduce the quantity found in the river. The focus lies on creating a framework, trying to execute that framework using Brasilia as the case and look into possible solutions for improving the situation.

The research is based on an international collaboration project of students, academics, and industries, arranged by EU and Erasmus +. The collaboration has brought together a unique mixture of competence and knowledge from Business Economics, Production Engineers from the University of Brasilia, and Mechanical Engineers from the Saxion University of Applied Science. The master thesis is written for the University of Stavanger in Norway.

We chose our research topic to gain a better understanding of the role economics have in river plastic waste recovery. The challenge has been difficult, and the complexity of the issue has become evident to us as writers and researchers. Plastic has gained a larger focus over the last few years. This is shown in the increased research in the field of study, and the number of private companies working on improving the situation. However, we are still a long way from creating a sustainable use and handling of plastic waste. The research is still young, and many points to the same problem: lack of clean and reliable data. This issue will also be evident in our thesis. The presented finding will be more concerned with qualitative analysis, thus providing a framework for future quantitative analysis, and should be read as such. To achieve meaningful quantitative calculations, better data would have had to be obtained through more extensive research. The difficulty of acquiring data was not made easier by the many closed institutions due to Covid-19. Our work introduced us to the system surrounding plastic recovery aquatic sources. We started off looking into the best ways of extraction, but as our knowledge grew it became evident that the best solution for limiting plastic is turning off the taps that leak. When plastic ends up in the water, it is already too late. This realization led us into a reflection of our own field of study, and how our common approach to economics is a part of the problem.

"Economics is the study of how society manages its scarce resources"

- Gregory Mankiw

EXECUTIVE SUMMARY

The background issue regards the increasing amount of ocean plastics during the most recent years. Our focus of this issue will be on the plastic that is transported by rivers. We will address the problem by looking at existing river-plastic extractions initiatives, and the extraction technologies used. To look at waste plastics quantity in rivers, we found it relevant to make a choice of location and analyse the effort for specific circumstances. During our workshop of collaboration, the choice of location fell on Brasilia.

This research contains collaboration across study fields to gain knowledge of river waste recovery and local knowledge of Brasilia. This thesis will first of all, address the most relevant extraction methods where two solutions are chosen for estimations. To collect all the solutions available, it has been used public information and relevant contacts in the market to get a concrete understanding of the practices. River waste plastic recovery is a complex study and can be done from many perspectives. Our choice of focus is on cost and benefit from a private and social economic view.

The river is a part of the public environment property that is used for social activities and it will be important to address whether responsibility and procedures should be found on a macro or micro level of society. All over the world there are parties undertaking initiatives for mitigation of waste leakage and promotion of cleaning up. These are significant initiatives that involve private actors. To be able to contribute to today's position and considering the need of collaboration between the governmental and the private actors, we found it important to address the equilibrium between these two players in the benefit-cost validation.

Regarding plastic waste, we find it important to contribute to how private initiatives can better outbreak this market failure of negative externality. In the final findings we address the costs of the two extraction systems and the investment required by the system itself. We also find it valuable to see the examination from private actors and how a given initiative can receive investment from the public sector. In the final result the collaboration of private actor and public actor will be outlined as a contract containing the quantitative indicators for investment decision.

As expected, the systems will not gain positive return from income related to selling collected plastic, it will thus need government subsidies. In an investment decision inside society, there are many other qualitative aspects that have to be considered, additionally to a financial quantitative analysis. We will address a qualitative analysis of social, economic and environmental factors that impact decision and investments for collection systems in Brasilia.

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LIST OF ABBREVIATIONS

- PMMA (Acrylic or Polymethyl Methacrylate)
- PC (Polycarbonate)
- PE (Polyethylene)
- PP (Polypropylene)
- PS (Polystyrene)
- PET (Polyethylene Terephthalate)
- HDPE (High-Density Polyethylene)
- LDPE (Low-Density Polyethylene)
- PVC (Polyvinyl Chloride)
- SLU (State Secretariat of Infrastructure and Public Services)
- BLT (Bandalong Litter Trap)
- BBS (Bandalong Boom System)
- WWT (Water Wheel Trash Interceptor)
- Interceptor/ Mr. Trash Wheel)
- DRC (Depreciated replacement cost method of valuation)
- r_d (Cost of debt)
- r_e (Cost of equity)
- WACC (Weighted average capital cost)
- R (revenue)
- R_I (Revenue Investor)
- R_b (Revenue borrower)
- I (Investment)
- A (Own cash)
- NPV (Net present value)
- V (Marginal Revenue plastic recovery from nature)
- $\overline{V}$ (Marginal cost plastic recovery from nature)
- P (Price)
- Q (Quantity)
- S (Market price)
- M_{MPW} (mismanaged plastic waste)
- Pop (Population)
- W_{gr} (Waste generation rate)
- W_{pr} (plastic rate of waste)
- M_{MPR} (Mismanaged plastic rate)
- M_{APW} (Mismanaged aquatic plastic waste)
- B (Benefit obtained by shirking)
- P_H (estimated extraction with high effort)
- P_L (Estimated extraction with low effort)

1. INTRODUCTION

Plastic is one of our most popular materials. In 2018 an approximately 350 million metric tonnes were produced (Garside, 2019). As the demand for plastic increases, the struggle of plastic waste has simultaneously grown larger. Each year an estimated 4.8 to 12.7 million tonnes of plastic leak into the oceans (Jambeck, et al., 2015). A large fraction of this is transported by our rivers. An estimated 1.15 to 2.41 tonnes are transported by rivers to the ocean (Ocean Cleanup, 2018). Our current waste handling is not in a sustainable state.

The problem has gained more focus in the later years and acknowledged that the linear "use once and discard" model within which the plastic industry has been growing up, is not the ideal model. Changes in regulatory measures to limit the use of single-use plastic and restrictions on plastic waste import, have become more acknowledged tools. To improve the situation further, waste plastic needs to be seen as a valuable resource. This requires collaboration across sectors and markets to build a more profitable industry for plastic recycling.

Today a large quantity of plastic is mismanaged, with portions of this going to aquatic zones. This will continue to happen unless we improve our waste management systems. This would require a switch in how we see waste handling. The shadow costs of improper waste handling are not given the focus it deserves. The current mishandling pushes the ecological ceiling, and most of the impact effects will be endured by future generations. Our waste handling market is failing, and a correction is need earlier than later. Improved activities from government is of necessity, the private sector needs better incentives to begin research and innovation on the field. A market that has gone through big innovation in the supply side is the river waste plastic extraction. Many companies are looking at improved ways of cleaning up our aquatic sources. We need an increase in the demand side, to make this market functioning. Extracting plastic from aquatic zones is no miracle cure, it will buy time and limit the problem, but to make lasting changes an improved waste handling system is required.

2. BACKGROUND

The following parts will introduce some of the background behind our scope. We will discuss challenges and opportunities with extracting river plastic. The focus will be from a market perspective, where we will use a government and private actor, that can be seen as representative for any location. The case of Brasilia will outline the value chain from the beginning of consumers using plastic to how it can be recycled to new products. To understand both parties, we will use a business model to estimate essential costs, and a social analysis to gain insight into the cost-benefit relation for our society. Other strategic measures to improve the situation will also be discussed.

2.1. GLOBAL ENVIRONMENTAL ISSUE

Knowledge and understanding of waste generation will allow local governments to select appropriate methods and plan for future demand. With accurate data, the government can allocate budget and land, assess relevant technologies and consider strategic partnerships from private sectors or other non-governmental organizations (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018). Forecast of future global waste is expected to grow to 3.40 billion tonnes by 2050. From 2008 to 2018 the production in the world has increased from 245 million metric tons to 359 million metric tons. In 2018 9.4 million metric tons of plastic post-consumer waste were collected for recycling in Europe, this contains 17.3% produced in Europe alone (Garside, 2019).
Latin America and the Caribbean region have generated 231 million tonnes of waste per year with a 4.5 percent level of recycling. An increasing amount of waste is placed in sanitary landfills with or without environmental and social control. The waste is dumped, burned, and used as animal feed. More advanced cities convert landfill gas to energy. Other cities explore new technologies as waste-to-energy burning and anaerobic digestion with especially attention on anaerobic digestion (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018, p. 53).

Waste collection coverage in Latin America and the Caribbean region is higher than expected compared to global trends. The World Bank (2018) has reported that 85 % of waste is collected on a door-to-door basis. The study covers waste activities from 38 cities. In Distrito Federal, Brasilia the waste collection rate is said to be unexpectedly high at 98%.

In theory, there is a positive correlation between waste and income level. Waste per capita is predicted to increase by 19% by 2050, compared with low and middle-income countries that might increase by 40% or more. World Bank Group (2018) forecasts that waste per capita will increase faster than incremental income. Waste collection is a critical step, the composition differs across income levels and varied patterns of consumption.

2.2. PLASTIC WASTE MANAGEMENT

Solid waste management is a universal issue impacting individuals all over the world. Improperly managed waste is an issue in all levels of society that requires urgent action As countries develop from low-income to middle or high-income levels, waste management has been less taken care of. Growth in prosperity and urban areas are connected to the increasing waste per capita. When the population is rapidly growing, the collection of waste, land treatment, and disposal are more difficult. Today, waste management can be the highest budget item for local administrations in low-income countries. It accounts for 20 percent of municipal budgets on average in low-income countries and 10 percent in middle-income countries. On the other hand, waste management occupies 4 percent of the total budget in countries of high-income. Brazil is characterized as an upper-middle-income economy on the global innovation index (WIPO, 2019).

Waste operation is costly and complex to obtain and recover when there are more important priorities such as funding of clean water, education, and health care to compete with. Statistics find management of waste is administered by local authorities and has a limited capacity of planning, contract management, operational monitoring is challenging. Sustainable waste management is complicated for most low- and middle-income countries, the consequence is individuals often have low power managing the waste being disposed near their homes (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018).

2.3. PLASTIC FOR RECYCLING

Plastic contributes to almost all aspects of daily life, future scenarios where plastic does not play an important role can seem unrealistic. The sum of all energy consumption for production, transport, and disposal and other effects on the environment is larger if compared to the one required by other materials. Plastics are a wide extent of different particles that can be produced from three main categories: fossil origin (crude oil and gas), renewable (sugar canes, starch, vegetable oils, etc.) or mineral base (salt). The different types of plastic are sorted with respect to how it is treated, either as thermoplastic or thermosets. Thermoplastic is heated and hardened when cooled. Thermosets go through chemical changes when heated and cannot be re-melted and reformed after heating (PlasticsEurope , 2019, p. 13).

In 2017, the most common plastics were thermoplastics. Polyethylene (PE) that counts for 27 percent, polypropylene (PP) as 21 percent, polystyrene (PS) as 19 percent, and polyvinyl chloride (PVC) as 13 percent. Polyethylene terephthalate (PET) represents only 6 percent of plastic produced since it is easier to be reused (Senet, 2019).

Thermoplastic is a common term of the plastic polymer material that can be pliable and or mouldable at a certain temperature. The thermoplastic has been around for a long time and is often used for manufacturing plastic grocery bags and shampoo bottles (PE), DVD, drinking bottles, food storage containers, and eyeglass lenses (PC) (PlasticEurope, 2020). After the melting, the plastic becomes hard and can be reshaped and reheated often after being frozen. In general, thermoplastic is easy to recycle compared with thermosets. Thermosets are plastic and polymers that include epoxy, silicone, polyurethane, and phenolic. The material is often used for long-lasting products as isolating materials and contains chemically bound polymers and crosslinked polymer structure. Some materials can be defined as both thermoplastic and thermosets, as polyester is (Dutton, 2020). The main difference between these types is that thermosets materials remain in a permanent solid state and do not melt even when exposed to high temperatures. Thermosets are easy to work with, there is no heat required and carry out lower health hazards than thermoplastics. The chemical bonds are harder to recycle and to maintain good quality. Plastic recyclability is largely dependent on its input quality to satisfy output quality. Since the products from thermoplastic can be harmed before recycling, sorting of the plastic will be important to ensure quality after the process.

2.4. PLASTIC EXTRACTION

The life cycle of the products varies based on the type of plastic. We divide between the production of plastic material, converters demanding plastic materials, and manufacture of plastic materials that go into the consumption of plastic (PlasticsEurope , 2019). Since the plastic products are used within individual value chains, the amount of collected plastic is not automatically correlated with the plastic demand of the same year. At the end of their service life plastic becomes a variety of waste. The service life can vary from 1 year to 50 years. For example, Europe has the highest recycling rate of 43 percent in 2018. This consists of recycling 32.5 percent of the materials, while 42.6 percent is used for energy recovery and 24.9 percent goes to landfill. The overall mechanical recycling was 43 percent in 2018.

In a circular economy, it is asked for a shift of fundamental thinking of waste to resources. Waste as an economical value for recycling and recovery is the interest of the concept of the circular economy. The view of materials recycling in a circular economy is to minimise their impact on natural resources, where materials are recycled and reused over and over. Plastic is made from natural materials such as cellulose, coal, natural gas, salt, and crude oil in a polycondensation process. Brazil is the 10th largest oil producer in the world and the largest producer in Latin America. They are also one of the top producers of biofuel, still, plastic is highly imported to the country (Apex Brasil, 2019).

Around 4 percent of global oil and gas production is used as a raw material for plastic production (Andrady & A.N., 2009). The material itself is organic material from non-renewable resources and production of plastic is correlated with the price of oil. Making new plastic has become less expensive than the recycling processes in the last decade. Some of the reasons are that cleaning and preparing used plastics requires a larger amount of water, energy, and effort. New produced plastics are more appealing to manufacturers than recycled products, especially when the price is low (Kramer, 2016).

2.5. COMMUNITY AND WATER SECTOR

Brazil is one of the largest developing countries and the fifth largest country based on geography in the world. The country is the world's largest consumer market of services, goods, and agricultural products. Per capita GDP was 8.959.02 million in 2018, and general household consumption contains 64.3 % of GDP. The country is expressed as one of the world's most progressive countries in integrating waste pickers in solid waste management programs (Dias, 2011). Brasilia is the capital and is the third-largest city with 3 million people and the centre of development being home for major universities and government agencies (Apex Brasil, 2019). The existing capital of waste is significant for related solutions for waste collection. Financial resources are considered available, but there is a lack of political support. With a little capacity from the government, it will be continuing to hinder the implementation of investment plans, effective and efficient use of the funding. Participants in the research emphasized that the challenges of technology in the water and sanitation sector are to match available and affordable technology when targeting the need for extending water services, water quality, and safe disposal of used water. The risk associated with the public funding available, contain the discriminations of poorest sections of populations with low income, hence the perception of discrimination is also highlighted the concern in the region. In the last decade, the risk for private investment has been a lack of institutional continuity and insufficient availability of data (OECD, 2008).

The following model explains the background questions for research and what we consider as input and what we want to find as output for research. The background questions for our research can be summarized in the following model:

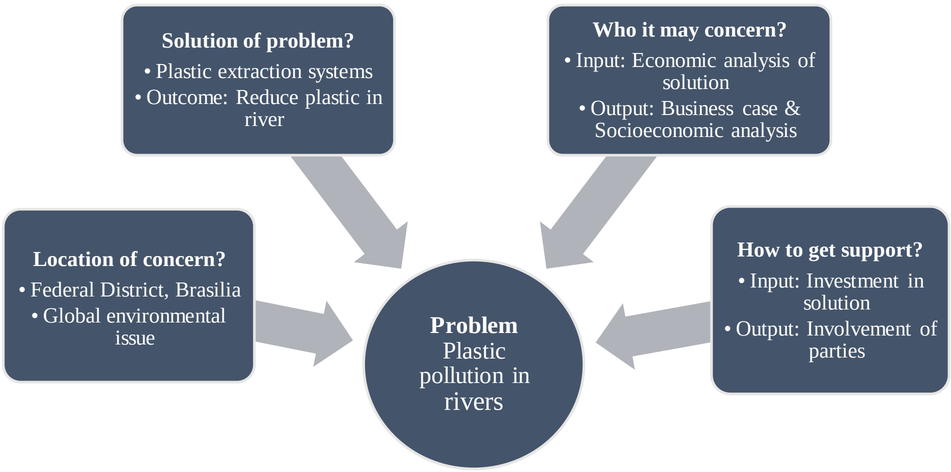

Figure 1 Scope of research

Source Self-generated figure

3. GOAL OF RESEARCH

The goal of research is to analyse plastic recovery from rivers and the case of Brasilia. The aim is to address the significant aspect of concern that can gain knowledge of how to reduce plastic pollution and who is responsible for an action. Thereby, address important aspects surrounding the plastic pollution in aquatic sources. The scope of our research can be divided into four objectives:

- Define and describe critical variables for plastic input to rivers and the value chain of river waste plastic and characteristics of this system
- Assess two extraction systems of plastic recovery and analyse the profitability for a private actor
- Perform a social analysis by setting up an economic contract between a public and private actor to gain insights of benefit and cost, uncertainty, and capital structure.
- Assess regulatory measurements necessary for private investments and activities in plastic waste recovery

The first objective of the thesis is to find out how plastic end up in the river, and how its place is in the value chain after ending up in the water. This will be done by creating an overview where all parts are presented, and the characteristics of the system. Further on the variables of interest for later performed economic analysis are defined and analysed.
The second objective is to assess two extraction system and evaluate the profitability for a project and implementation. The third objective will be to look at a potential contract between the government and a private actor. We suspect that the plastic recovery is not feasible, and governmental subsidisation might be necessary. We will also explore how asymmetrical information between the parties can change the contract. The goal of the setup is to obtain insights into capital structure, level of subsidisation and uncertainty involved. The uncertainty in variables will be explored further with a sensitivity analysis, this will give insight into the interaction effects. The final objective will define investment methods, policy and regulations existing in Brasilia, and opportunities and challenges in market situation. Implementing a system will involve governmental authorization with socioeconomic and environmental impact. Policies, regulations and instruments appropriate to evaluate and define if current mismanaged plastic level is a consequence of market failure.

4. THEORETICAL FRAMEWORK

This chapter will contain system analysis based on literature and empirical studies. We will explain the value chain and two significant extraction methods for collecting waste from rivers. The second section contains economic analysis and the relevant frameworks used to construct business analysis, social analysis, and lastly, economic measures. The chapter is divided into system analysis, economic analysis, and economic measures.

4.1. SYSTEM ANALYSIS

Due to a multitude of organizational, technological, and regulatory barriers, the plastic recycling sector is defined as underdeveloped in literature. Plastic can be recycled many times, depending on the quality of recovery waste fraction (Hennlock, Castell-Rudnhausen, & Wahlstrom, 2014). Research from Scandinavia (2018) identifies the value chain of plastic recycling and critical barriers across the regional plastic value chain. The export of plastic between countries leads to a lack of control over the environmental aspects of recycling. Technological innovation plays a vital role in improving recycling efficiency. Determining who is responsible for the collection and processes of used products, impacts the cost and benefit of recycling for individuals and society. It contains an insufficient sorting capacity and technology that create the barrier. There is a need for stronger objectives to create a circular economy. In practice, it will be a policy intervention to effectively manage the quality and quantity of collection. Manufacturers, plastic producers, recyclers, sorters, and collectors should aim for a better understanding of potential solutions. Funding opportunities can be a driver for further cooperation across the value chain.

The value chain of plastic waste recycling can be defined as the six following stages. The table is built on research on improving demand in the up- and downstream of the waste management system (Milios, et al., 2018).

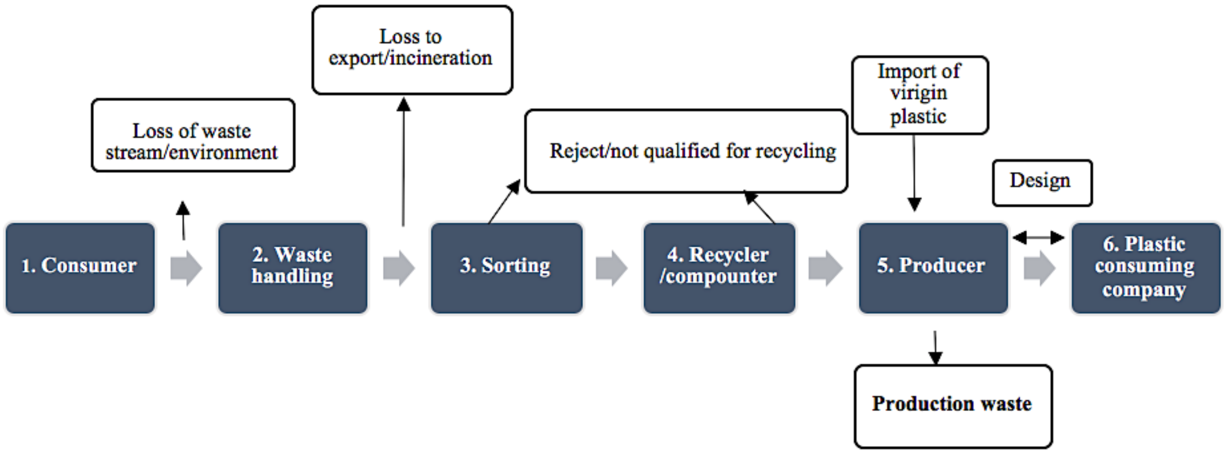

Figure 2 Value chain of plastic waste.

Source: (Milios, et al., 2018)

4.2. EXTRACTION METHODS

There is a lack of standardized processes designed to collect plastic in the rivers. A lack of investment and incentives leave the sector with technological barriers. A summary of 30 potential recovery systems operating all over the world have been gathered **(**Appendix 6). Some of which have been tested and created, others are only in idea phase. The methods are sorted by variables explaining the effectiveness, characteristics of rivers, and exploration. To evaluate most optimal recovery system, local factors such as plastic (Quantity & Composition) and river (4.2.4) are critical to understand. These factors should be considered together with the system capabilities such as width and depth of extraction. Holding capacity before full and operational capacity regarding time and resources. We have chosen two different recovery solutions that we deem significant and representable. The chosen solutions will be explained in further detail (4.2.5. and 4.2.6.).

We have not specified limitations for methods or location in our assessment, this is a weakness. From a general view, most extraction methods do not include a real capacity limit as long as the solutions of the collection are being maintained (NRK Recycling, 2015). If the collection contains a trap, track, or container, there will be limitation of storage, which causes waste to escape. Solutions installed in water, normally contain manual cleaning and waste collection. Water surface solutions such as boats will have a collection limit if the waste is not regularly transferred to land. Automatic transfer can be an additional solution to avoid overflow.

4.2.1. Sorting plastic

At the sorting facility, the plastic is sorted according to polymers. The sorting process can be defined into rough sorting, crushing the plastic, and cleaning the plastic. The sorting process will indicate the potential value of the collected plastic. This section will explain the sorting methods found, there can be other potential methods that can be used, for this research the following process illustrated by (Albinsson & Liovin, 2005) is chosen.

Rough sorting contains sorting the plastic by type, colour (natural, light, dark), and cleaning of any contaminants. The manual work of the process can be divided into positive or negative sorting. Positive sorting is done with non-ferrous material that can result in high-quality material products. Negative sorting eliminates plastic without specific polymer properties required. Positive sorting is a cost-effective process, while negative sorting is done at the expense of quality from materials obtained (McKinnon, Fazakerley, & Hultermans, 2017).

Automatic sorting contains mechanical and chemical methods that are divided into dry(mechanical), wet and chemical sorting. Dry sorting means that there is no contact with liquids. By using laser or air, the particles can be distinguished by weight. Alternatively, the plastic can be melted. Wet sorting contains the use of a sink that will make specific materials float or hydro cyclones that separate materials by the relative movement that divides certain materials from each other. Wet sorting also contains selective dissolution where solvents are mixed with plastic that complete separations of polymers by thermal technique (Biswajit, Pandey, Priyajit, & V.K., 2015). Chemical sorting is done by the methods of hydrolysis, glycolysis or pyrolysis. Hydrolysis is the chemical processes that convert polymers back to raw monomers. Pyrolysis is a thermal technique with absence of oxygen. The process creates fuel or raw material. Automatic sorting can also be combined with manual sorting. this will result in positive or negative sorting, followed by automatic removal or vice versa. This can be repeated to ensure quality. After the rough sorting is done, the process of crushing plastic into little pieces takes place, crushing the plastic into the size of approximately 15-20 cm (NRK Recycling, 2015). The next stage is cleaning by either hot or cold wash systems. The use of hot water systems will be more expensive and used to remove chemical components in the wastewater.

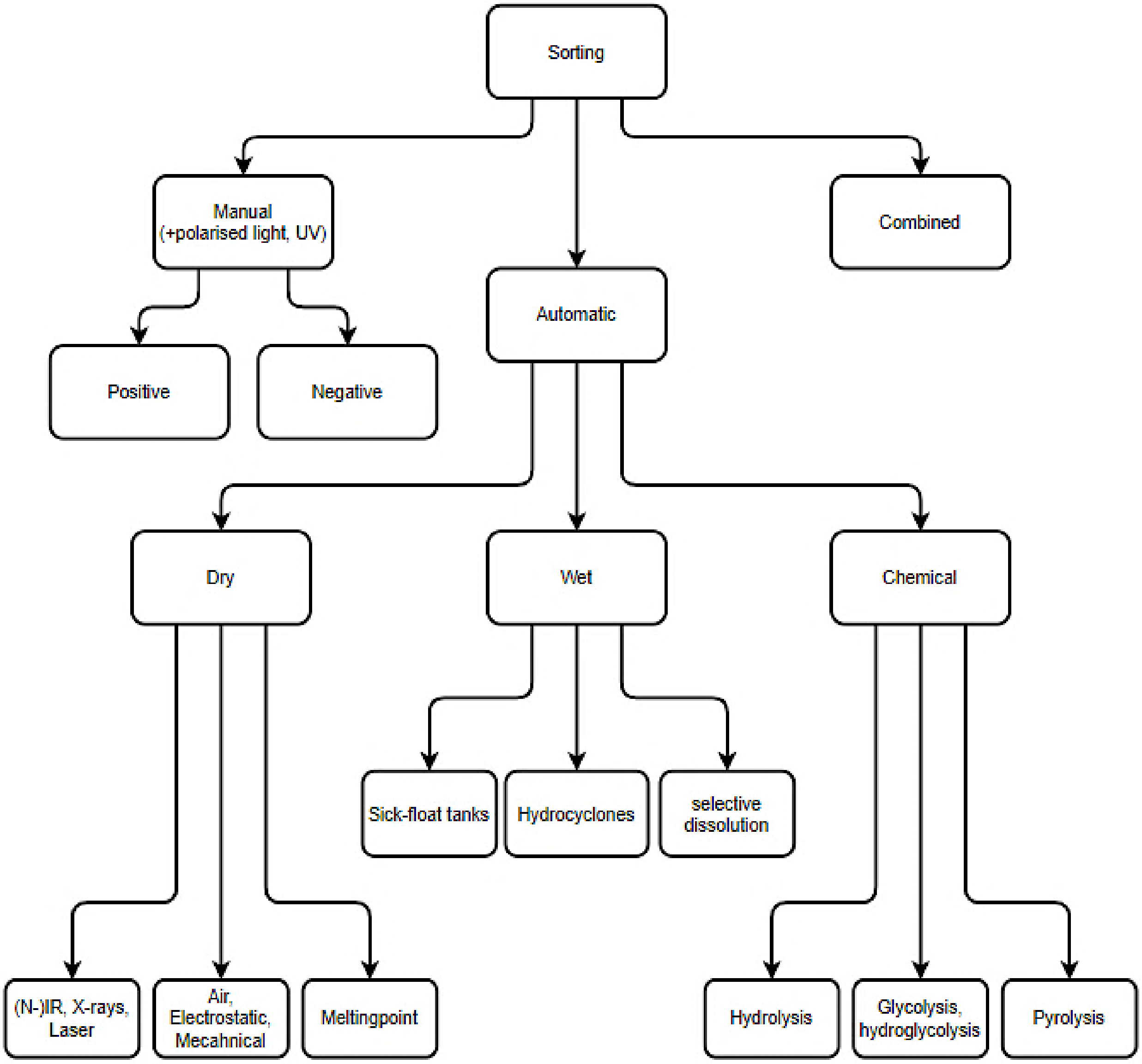

Figure 3 Sorting system

Source: (Albinsson & Liovin, 2005)

The transportation of waste in Latin America is mainly done by trucks after the waste is collected in transfer and aggregation stations. The stations are either formal or informal recycling centres, where waste pickers sort materials for recycling. After waste is collected, the distance travelled varies from 3 to 62 kilometres between city centres and final disposal, open dumping is still accounting for a large amount of waste collection with 27% of waste disposal and treatment in Latin America and Caribbean region (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018, p. 57). Landfill gas collection has become the main mechanism for recovering energy from waste. A common challenge in the transportation of waste in Brazil is that not all companies have a reasonable knowledge of the law about moving materials and future complications. In a specific region as Brasilia, it will be a different handling of waste compared to another region. The legislation explains that there are different Brazilian Technical Standards (ABNT) in the NBR 13221 compared to an official procedure by the National Environment Commission. Some companies must fill out a checklist of data about the waste, vehicle, and driver to obtain cargo clearance. Others have it available automatically in the software (Vgresiduos, 2018). Overall, the country has diversity between the organizations, inspection and control bodies, which can be the reason for more or less proper waste practices. Brasilia operated with a dumpsite as their end-station. This site has been restricted, and a new landfill have opened up further away from the city. One of the reasons for closing down the dumpsite was contamination into Lake Paranoá. Sorting is today done directly in landfills by waste-pickers employed by the government of Brasilia. When the plastic is sorted it is transported by to private actors who buy plastic in tonnes.

4.2.2. Recycling methods

Different production methods are possible to make new products after the sorting is done. The seven most used methods were chosen to explain: compression moulding, extruding, 3D-printing, injection moulding and vacuum forming, calendaring, and rotations moulding. Following is an explanation of methods for product production.

- Compression moulding makes it possible to create a product out of the lower quality plastic, by heating the plastic which is then shaped and compressed.
- Extrusion is a fast process commonly used on thermoplastic materials which gives a more homogenous material because of a mixture with liquid. This machine is perceived as more expensive and specialized.
- 3D-printing are products created a computer. The material needed in such a process has to be of high quality to create the models (Christensson, 2014).
- Injection moulding is a manufacturing of long products, like pipes and rods. This heating method is usually used on thermoplastics (Kopeliovich, 2014).
- Vacuum forming is when preheated thermoplastic is shaped and cooled down to make it hard (Kopeliovich, 2014).
- Calendaring makes thermoplastic foils that can be used for textile products. The process is sensitive and clean materials are necessary (Marcel Kooijman, 2009).

- Rotational moulding can be done in larger quantities. A thermoset granulate is often used for larger products, such as bins or barrels (Marcel Kooijman, 2009).

4.2.3. New materials from recycled plastic

The low-quality plastic can be converted to biofuel straight from pyrolysis, whereas high-quality plastic can be mechanically recycled into feedstock for any type of product. A circular model aims to sell recycled plastic that covers the cost of operation and collection. The recycling market already exists in Brazil as one of the largest producers of biofuel. Recycling low-cost products are a beneficial alternative to import plastic products from other countries. The required quality of a new product varies between producers and products. There are technological verification systems that ensure recycled material has the same quality as new products. In Brazil, these practices are contributed by CONAMA (Brazilian National Environment Council). This department, associated with the Brazilian Ministry of Environment, established in 2002, enabled recycling plant distribution and reuse of waste throughout the country (Massara, 2018).

4.2.4. River

Four dimensions bound the river - it changes in length (1), width (2), and height (3) while changing over time (4). The river's output zone can come in various forms but is often a lake or the ocean. Figure 4 shows how the output zone for smaller rivers is a lake. In this case, the map of Brasilia with Lake Paranoá has been used. The lake and rivers circumvent the city, centred around the marked green area of the map.

River behaviour is directly linked to the water cycle (Figure 5). The river can be seen as a gathering of water in transit. The precipitation falls over the land surface and follows various subsequent routes (Nasa, 2010). The routes of interest for the plastic problem are functioning as plastic conveyors leading to the aquatic environment.

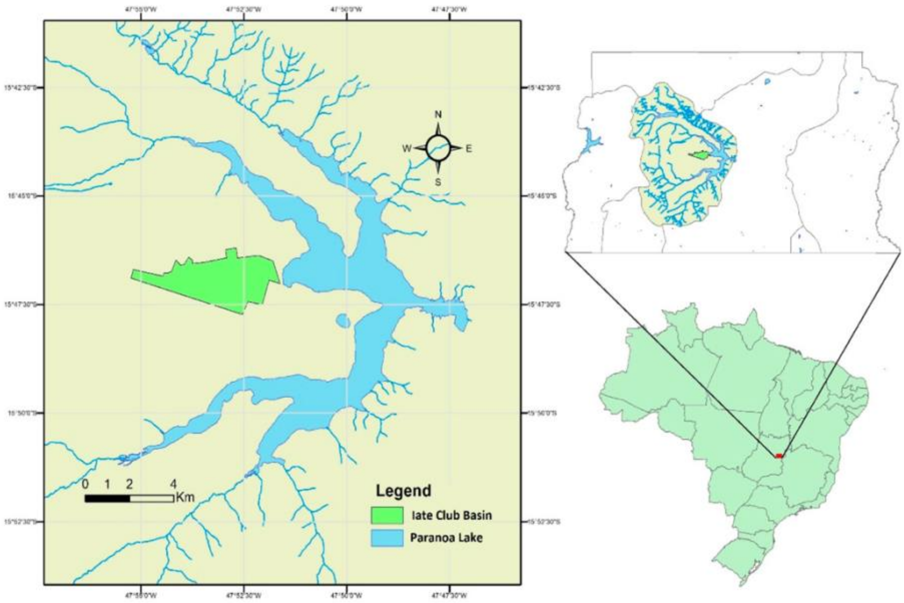

Figure 4: Map of Lake Paranoá.

Source: (Souza, Costa, & Koide, 2019)

When randomly distributed water hits the ground, the subsequent path depends on the drainage basin. A combination of land properties and human-made intervention decides the drainage basin. Water naturally seeks towards the lowest point and has the capability of circumventing most obstacles. Once the water hits the land surface, it is infiltrated in the ground level and absorbed by biological organisms that function as water storage. When saturated incoming water forms on top. This causes run-off that leads to rivers and lakes (NOAA National Weather Service, 2017).

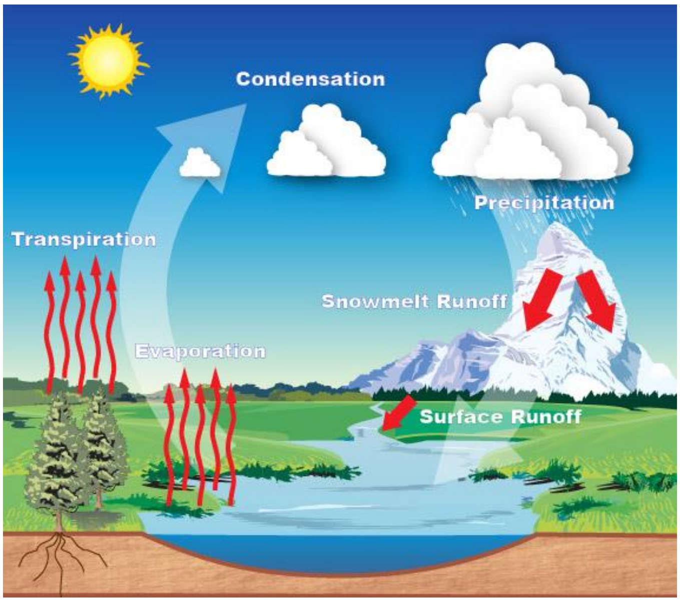

Figure 5: The hydrological cycle.

Source: (NOAA National Weather Service, 2017)

Human-made blockers like cement, stone, and asphalt hinder the process of water infiltration. When water cannot be absorbed by the natural environment, it gathers on top and moves on the least resistant path. Cities and villages have a drainage system; however, these systems are limited. When the limit is reached, incoming water will function as a clean-up system leading into the rivers and lakes. The various litter transported by water, also enter drainage systems, limiting the capacity. Figure 7 shows how increase in water flow increases the river discharge: vertical, transverse and longitudinal flow. Increased discharge has been discovered to increase river plastic (Van Emmerik, et al., 2019) (Wagner, et al., 2019).

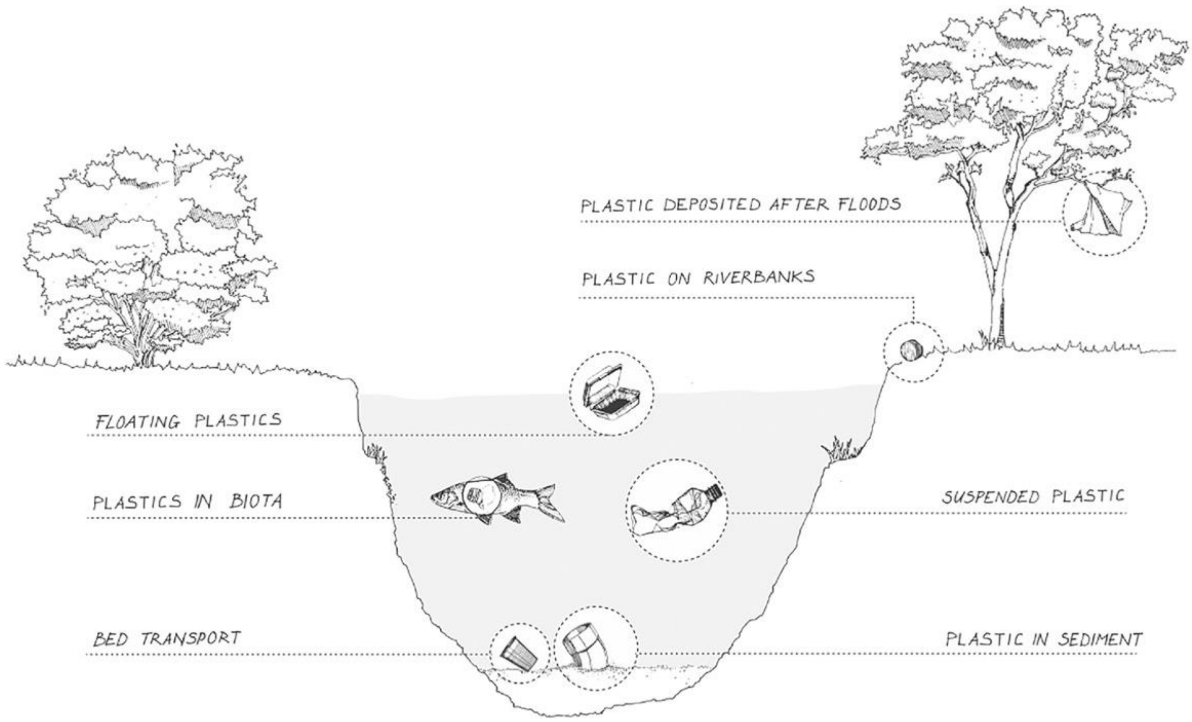

Figure 6: Vertical and horizontal plastic movement in river.

(Credit: Cher Van Der Eng., Source: (van Emmerik & Schwarz, 2020)

Plastic and other litter that enter the aquatic environment are vertically distributed based on the entity's buoyancy ability. This is dependent on the entity's density, shape, and river behaviour. Plastic material has known density; however, the containers are often shaped with holding chambers. The substance (e.g. air, water, algae) that fills the chambers impacts the buoyancy of the entity. The spatial distribution of macro-plastic in freshwater ecosystems is an understudied field (Lebrenton, et al., 2017), which makes it difficult to estimate.

4.3. ECONOMIC ANALYSIS

4.3.1. Business analysis

The decision of investment usually comprises certain core elements and the estimation of predicted values. The following model is based on the four main steps in the process: (1) identify spending proposals, (2) quantitative analysis for incremental cash flows, (3) qualitative issues not fitting in cash flow calculations and (4) decision making (Shank, 1996).

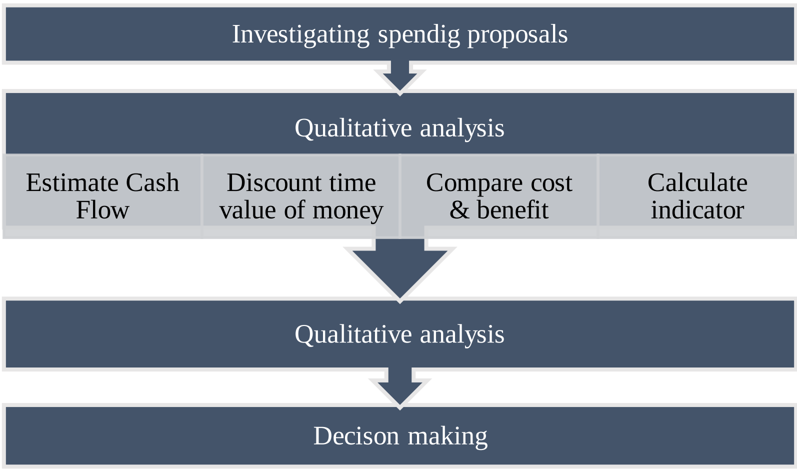

Figure 7 Process of investment decisions

Source: (Shank, 1996)

(Counihan, Finnegan, & Sammon, 2002) identifies that it might be difficult to connect project effectiveness or profitability with a benefit for society. The existence of non-economic factors is often evaluated in the qualitative analysis in social, environmental, and political and legal aspects that are the additional risk that will increase the discount rate and probability analysis. This requires detailed quantitative information challenging to obtain. (Abdel-Kader, 1999) refers to investment decisions in an advanced manufacturing system, where high risk inherent to new technologies, often leads to arbitrarily discount rates. The short-term bias can be observed in the calculation on the payback method and discount the cash flow method if it takes a longer period to become fully operational or it is promoted short-term decision horizon with a discount rate that will reduce benefits associated with later years cash-flow. The limitations in traditional evolutionary methods will make it necessary to evaluate other aspects that in not states in financial analysis of individual projects.

The basis of the investment method for the analysis is to find the monetary valuation. Shank (1996) gives critique to conventional methods of capital investment analysis for not to capture the full impact from a technology-change decision. Further critique contains that the quantitative analysis gets heavily valued and the qualitative analysis is less reliable. In the project economic framework, were a careful evaluation of choice of frame must be taken in careful evaluation, framing the choice can be seen as thinking more broadly about the business issues involved, therefore the analysis will focus on a higher evaluation of other aspects that shape the broader business context in evaluation investment proposal (Shank, 1996).

4.3.1.1. Cost-based pricing

Valuation of the project is done by three most common methods; market-based, earning-based, and cost-based. All three methods are available in several variants, some more simple and other more complex. Any method chosen will rely heavily on discretionary reviews. Based on the characteristics and environment of assets evaluated in this research, the cost-based method is found appropriate.

The cost approach, defined as depreciated replacement cost (DRC) method of valuation, is typically used in connection with accounting in R&D projects, where it is not possible to isolate future cash flows. It is also used where there is no active market for the asset valued (where there is no relevant evidence of sales transactions) and it is essential to produce a reliable valuation using other methods. The DRC calculation involves consideration of many separate elements and the essential final step is to give a resulting valuation conclusion consistent with the underlying valuation objective. This is the price that would be paid in an exchange between a willing seller and a willing buyer of the asset (RICS Group, 2018). The method is based on the economic theory of substitution. It is a benchmarking theory, that compares assets valued similar, even among products that are not directly comparable. A common solution is to make a hypothetical substitute, a modern equivalent asset (MEA). The method is based on the economic theory of substitution. It is involving comparing the assets being valued with another, even that the method can be used without direct comparable alternative. In cases of no comparable benchmark, a hypothetical substitute or a modern equivalent asset (MEA) can be created. This technique contains assessing all costs of providing MEA using pricing at the valuation date.

The valuer's tasks are to consider the key elements of markets transactions and should have specialized knowledge to evaluate: (1) understanding of asset and function in environments, (2) knowledge of specification of the asset in the current market, (3) sufficient knowledge of asset and economic and physical life of the asset and (4) knowledge of sector assess functional, technical or economic undesirability (RICS Group, 2018).

4.3.1.2. Capital Structure

In the theory of rational decision-making, a physical asset is worth acquiring if it will increase the net profit for the firm owners. This will happen if the expected rate of return exceeds the interest (Modigliani & Miller, 1958). The same statement can be said about a project; A firm should get involved in a project if the Net Present Value (NPV) of the project is positive. The NPV approach moves future cash flow to the present value, this is done by discounting the interest rate on the cash flow (Fisher I. , 1907). When we operate with uncertainty, the risk is added as a component on top of the interest rate. The created capital cost is used to discount the cash flow to find NPV (Damodaran, 2016).

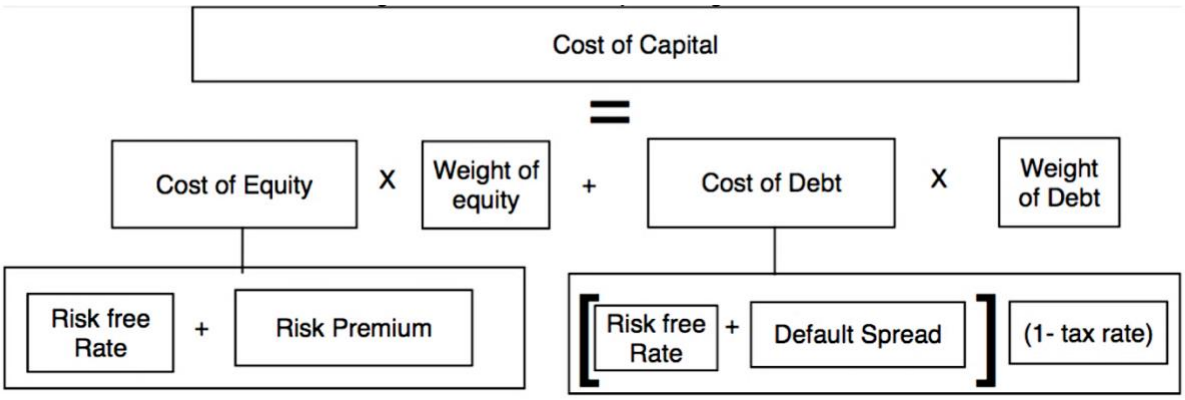

Figure 8: Main ingredients to calculate the Cost of Capital.

Source: (Damodaran, 2016)

The illustration above shows the ingredients involved in calculating the capital cost. For an equity holder, the investment would have to be compensated by the risk-free rate and a risk premium on top. This risk premium will vary according to projects. A normal approach for calculating necessary risk premium is done by benchmarking techniques, placing the project risk relative to other projects or investment opportunities. Benchmarking techniques is especially common for CAPM, APT, RN pricing. The debt holders risk lies in the possibility of default. Compensation for this is thus necessary, a company with a good balance have a smaller chance of default. Since the debtors have the first claim in the case of default, the cost of debt is often lower than the cost of equity. There is a correlation between leverage (debt) increase and the risk premium (Hostland & Karam, 2005). This means there is a trade-off by getting debt. The cost of debt is often lower, but increased debt increases the Risk-Premium. Optimal Capital Structure is the best financial mix of debt and Equity, to maximize market value. The weighted average of the two parts is the final cost of capital i.e. Weighted average cost of capital (WACC), from here on referred to as capital cost. The mixture of debt and equity is also affected by the signalling value of financing choice. According to the Pecking order theory (Myers & Majluf, 1984) it is optimal for a firm under asymmetrical information to spend internal funds as a first financing option. The second option is debt and the third is new equity. This is because a rational agent would only issue new equity if the company (project) is overvalued.

The preferred choice for a company would be to pick the project that has the highest expected return exceeding the capital cost. The capital cost can be seen as a threshold rate, that is needed to be passed by the expected rate to generate a positive NPV project. The capital cost can be seen as the expected return for the supplier of capital. By not choosing the best option, an opportunity cost is endured. This means that an Investor should always look for the project that generate highest expected return, and then move down the list until all NPV positive projects are chosen. A government have the opportunity to incentives desired behaviour by tools like subsidies and guarantees (3.3). The chosen capital cost is as mentioned discounted on the cash flow. The cash flow is the estimated value, and all risk concerning the estimations are present in the capital cost. For this project there are uncertainty in both revenue and costs.

4.4. SOCIAL ECONOMIC ANALYSIS

To understand the purpose of governmental investment in recovery solutions and other it will be important to identify the expected outcome for society. Social cost and benefit analysis are frequently used for public evaluation of projects. It attempts to quantify significant impacts from the project on society. There are many variations in methods for doing investment and performance analysis. The decision-making process and the evaluation of the success for a project are often measured by the use of financial tools. The capital cost is relatively high for R&D projects, in the literature, there are many economic measurements of return to R&D. The purpose of a social-economic analysis is to go through key fundamental questions that arise in connection with a cost-benefit analysis of environmental projects and the valuation of environmental goods. The main emphasis will be on the principal distinction between normative and descriptive analysis. The consequences of this distinction are interpretational? and practical, moreover they lead to a choice between monetary valuation and other environmental information. In the theory of cost-benefit analysis, the purpose will be to range the contribution to social welfare. The valuation of defined qualified projects is fundamental to governmental decision on willingness to pay (Nyborg, 2002). Cost-benefit analysis (CBA) is a traditional evaluation method used in the social-economic analysis. The purpose of the analysis is to help the decision-maker to make responsible choices, to determine viable investment, and compare an investment with others. CBA can be used indifferently, the theory often divides between cost-analysis, cost-effectiveness, and cost-effect analysis. These can be distinguished from each other by their ability to validate the specific costs and effects of the project. The greatest difficulty in a project decision will be to determine reasonable effects generated from the project. governmental investment benefits and costs can be a challenging measurement. essential parameters that should be outlined in the cost-benefit analysis will be explained.

4.4.1. Contract under Asymmetrical information

The economic analysis performed later is built on the theoretical framework from Jean Tirole (2006). This segment will briefly explain the theory behind, further expansion on the theory that is done for our analysis can be found further down the text (6.6.1). The Revenue abbreviated as R consists of two parts. One for investors and one for Entrepreneur. Investor acquires R_I from the project, while the Entrepreneur or borrower acquires R_b. Since this is a contract between two parties trying to maximize their own utility, the contract has to be set-up in a way that incentivizes high effort. The idea is that investors will know what compensation the Entrepreneur needs to perform high effort and based on that can decide if it is lucrative to invest or not. The decision is presented graphically underneath, with further expansion on constraints in the contract.

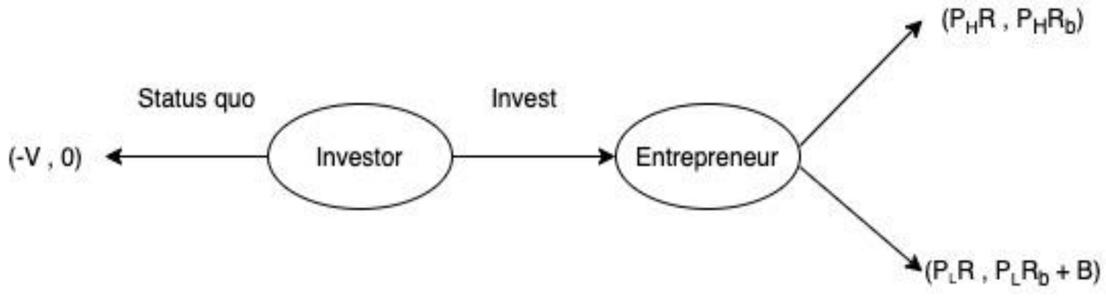

Figure 9: Decision tree

Source: Self-generated figure, induced from Jean Tirole framework

(1) $P_H(R_b) \geq P_L(R_b) + B$

IC- Condition $R_b \geq \frac{B}{\Delta P}$, $\Delta P = P_H - P_L$

This is the incentive compatibility constraint. The constraint needs to be satisfied to ensure high effort from a rational agent in a competitive environment. This means the agent would have to be incentivized with a high enough compensation to not shirk and obtain the benefit from this.

By the art of backward induction, we can use the bounded IC-constraint to infer that the highest possible income can be (R-R_b**),** giving us the Individual rationality constraint:

(2) IR-Condition $P_H\left(R - \frac{B}{\Delta P}\right) \geq I - A$

The IR-condition **(2**) show how expected revenue with high effort deducted by bounded revenue stream to incentive high effort **(1)**, must be equal or larger to the total investment deducted for entrepreneur's investment cost. The benefit (B) gained by the entrepreneur when performing at low effort can be seen as an opportunity cost. The potential effort could be reverted to other projects, that would yield a higher return for the Entrepreneur. To obtain the benefit the Entrepreneur could perform low effort and obtain $P_L R_b + B$. The benefit could then be reinvested in a similar or better project with a higher marginal benefit from the effort. The quality of the calculation will vary dependent on the assumptions and input data applied.

It is therefore of use to perform a sensitivity analysis to gain insights into the impact of changing variables (PAHO, 2014).

4.5. ECONOMIC MEASURES

The third chapter of the theoretical framework address investment methods, regulations and policy that would improve the market situation. There will also be a review of measures that affect the case of Brasilia.

4.5.1. Investment methods

To change existing production and consumption patterns there are economic instruments for pollution that are becoming increasingly important. Governments continuously intervene with supporting measures designed for environmental protection and pollution treatment. The adopted methods can either be economic measures or policies and the most used one are subsidies, investment grants, accelerated depreciation mechanisms, loan guarantees, tax exemptions, tax credit, price support of producer or consumers, preferential market access mechanism (Eurostat, 2015).

4.5.1.1. Brazilian environmental investment

In 2018 Brazilian central government invested 1249.43 million in environmental protection, defined by the Classification Environmental Protection Activities (CEPA) elaborated from the European System (Faostat, 2018). In 2018 Brazilian central government invested 1249.43 million in environmental protection, defined by CEPA. The investment includes waste management, covering collection, treatment, and disposal, R&D, applied and experimental development research. The investment was reduced by 24 % compared to 2017 (Faosat, 2019). Under the Paris Agreement, Brazil made a Nationally Determined Contribution (NDC) reduce emission with 37 % by 2025, this contains 3 % waste treatment (Federative Republic of Brazil, 2015). According to an estimate of greenhouse gasses emission and removal in Brazil, the 51.4% is caused by the solid waste disposal, 24,8% is due to industrial wastewater , 23.3%t caused by domestic wastewater and 0.29 % by waste incineration (Seeg, 2018). Brazil has made sectoral plans to reduce emissions, but the problem is that those policies and instruments are still not a part of national development planning or regulations. According to the most recent assessment of Climate Action Tracker (2019), Brazil have a need for additional policies to meet Nationally Determined Contributions (NDC) targets.

4.5.1.2. Governmental subsidies of R&D

Governmental subsidies for R&D are intended to promote projects with high returns to society although they tend to have too little private return to be beneficial for private investors. A difficult problem for government agencies is to identify the projects which are beneficial for society (Kleer, 2010). According to Klette et al (2000) and Lerner (1999), political influence and incentives often lead to subsidies in the wrong projects. If a R&D project obtain public funding, there is also a risk of being diluted by a private investment. Subsidies are also criticized because of the difficulty to measure return on investment. According to Hall (2002) there is a problem for investing in R&D projects since there is to capitalized value on the firm's balance sheet. This strengthens the problem of asymmetric information, where the firm has better information about the likelihood of success relative to the government. Since we can assume firms have a low threshold for applying for governmental subsidies. It is important to have a clear framework of subsidy distribution. According to Kleer (2010) the first barrier should define the project within two categories:

1. Basic research with a low private and high social return. These projects often have a higher risk, since the final result is unclear. The market is often unwilling to take on this risk, and it could be important for the government to intervene. The expenditures are low and can generate large spill-overs to the public market. Good examples for this can be systems that were invested in by the government, which now make up most of the smartphones.
2. Applied research projects with a high private and low social return, which will be preferred by private investors. Applied research projects contain incremental improvements. here the risk is assumed to be lower and creating enough private return to be financed by private actors. on the other hand, investments in applied research, do not involve social benefits.

4.5.1.3. Picking the winners of investment

In a market failure situation, the government should consider its involvement. If an active approach is chosen, the investment outcome should be analysed. The analysis should look at incentives, risk components and investment costs. The government should pick winners that have spill-over effects in technologies struggling markets. This is particularly relevant for technology projects aimed at improving our climate change problem. In technology the larger transformations from changing demands demand can have large effects on climate change issues (Nemet, Zipperer, & Kraus, 2018). There are many examples of initiatives and commitments to the goals of emission reduction. To help improve the prospects of meeting ambitious goals, Nemet et. al (2018) argue that governments around the world need to increase support in innovation-based and get an understanding of previous system failures and the substance of their markets. The research of 511 demonstrations projects collected timing, motivation, contribution, scale-up, performance, and markets of projects. The purpose of evaluating these characteristics was to have an insight into how decisions should contain a broader understanding of the outcome of an investment. (Nemet, Zipperer, & Kraus, 2018) also, categories four market challenges that the government should be considered when deciding on level of involvement: (1) Low appropriability could cause underinvestment, due to fear of free riders. (2) The uncertainty of scale might hinder investments. (3) A radical innovation has high risk, and the market is often unwilling to take this on. However, there are potential large spill-over effects. (4) Fragile demand-pull increases the risk of expected payoff. This is this is especially problematic for a project with high governmental involvement. Governments and policies can change.

4.5.2. Regulations and environmental policy

The Brazilian government is creating a National innovation Policy (NIP) intending to be achieved in the next ten years (Brazil Tech, 2019). The government aims to promote the creation and development of start-ups, foster the ecosystem of Brazilian creators and developers. They also stated that they want to increase the private sector investment in research and development in the next years. The national policy of Solid waste should be improved on the local community level. The Brazilian government is creating a National Innovation Policy based on the French Policy framework. In November 2019, the consultation was launched by the Ministry of Science, Technology, Innovation, and Communications (MCTIC). The objectives of the policies are to improve the economy and delivery of public services.

4.5.2.1. Policy framework for investment

Investments in green infrastructure, sustainable management, activities within environmental goods are included in the green growth policy. The policy states that green infrastructure projects remain hindered by specific investment barriers. Governmental decision processes are important here. A weak focus on negative externalities, promote inefficient use of resources. Predictable policies and regulations are a possible way to remove investment barriers. This would incentives green growth investments, by removing risk. Nevertheless, the government needs to find specific circumstances, needs, and priorities to focus on to stimulate green activities and create markets. In the policy where the cost of doing business and governmental investments are considered, the expected returns should be based on the following costs (OECD, 2015, p. 18): administrative (complying with regulations), capital (debt and equity), corruption, intermediate inputs (both local and imported), infrastructure (transport, telecoms, energy, etc.), information and search costs, labour (skilled and unskilled, adjusted for productivity), land and taxation.

4.5.2.2. Waste management in Brazil

In 2012, they introduced a solid waste management regulatory policy. The policy is aimed at a wide variety of stakeholders and creates the opportunities and boundaries of economic or environmental activity. The Brazilian national policy NPSW establishes guidelines for National, state, regional, municipal waste plans. The policy aims to encourage and promote the management of waste and improve clean technologies to minimizing the impact. The objectives are many but concerning the business case of Brasilia, three main objectives are chosen to be considered further in the research (A.B.L.Jabbour et al., 2014):

- Encourage and promote a waste management of reduce, reuse, recycle, and treat solid waste, while solid waste disposal must be complete in ecologically and environmentally responsible ways.
- Adopt, develop, and improve clean technologies as a way of minimizing environmental impact
- Invest and develop R&D into cleaner technologies

When the restructured policy was introduced, the Brazilian States and Municipalities were supposed to deliver their local compliance plans. After the deadline, 95% of the municipalities did not deliver. A review of this specified the main challenges and reason for the general poor response. The first challenge was (1) lack of coordination among manufacturers, distributors, and traders for an effective storage, collection and recycling process, (2) cost and benefit sharing across supply chain and partners was needed to be determined, (3) Lack of qualified experts' knowledge in Brazil that was dedicated to issues concerning solid waste management and reverse logistics, (4) Specific goals were vague and long-term strategies, (5) operations which the public institutions will control or periodically monitor was not determined.

Brazil is explained as the world's most vulnerable ecosystems, that needs more progressive internal regulation policy to manage these concerns. in order to make some progress to a greater evaluation of developing regulations policies and implementation has to be done. A study conducted on these findings explain a need for better support of private and public investment initiatives to obtain integrated action for more sustainable development. Moreover, municipalities have to manage waste generated by households and public departments (A.B.L.Jabbour et al., 2014).

4.5.2.3. Tax incentives for technology innovation

The extraction system will be an R&D project that will be expected to need support from the government. The chosen method of investment in my government is normally environmental tax or tax reduction. Tax incentives for RD&I was instituted to stimulate private investment in technological R&D. This included the design of new products, manufacturing process, and new features that implies incremental and effective improvements. To benefits aim to stimulate phases of uncertainty regarding the economic and financial results of creating and testing products, this is the technological risk. In the context of the collection system of industrial technology activities, the tax will be supported in machines and equipment, design and manufacturing of specific measurements, testing, standardization of products, or processes (Patria Amanda Brasil Governo Federal, 2006). The most common taxes in Brazil corporate income tax, social contribution on net profit tax, social integration program, the contribution of social security financing, and tax on industrialized products. The first tax of corporate income tax contains 15 % of all expense where the Law of Goodwill give reduce tax with 5 % if the companies use profit method for measurement that normally give 15 % tax. Companies have the option between the Law of Good incentives or to adopt incentives granted. To get access to tax incentives the rules require taxable income, expenses connected to RD&I, good and service in Brazil, clearance of federal tax, and give required documentation of benefits, projects, structure from previous years to Ministry of Science, Technology, and Innovation. There are implemented specific grants to promote scientific research through private entities. The most relevant institutions giving grants to promoting innovation is explained to be following four institutes: National Bank for Economic and

Social Development (BNDES), Funding Authority for Studies and Projects (FINEP), National Council for Scientific and Technological Development and Coordination for the Improvement of Higher Education Personnel (Innovation Centre, 2006). The opportunities come down to tax reduction, funding of revenue per unit collected, or funding for technology innovation. The aim is to measure the effect of subsidy and what level will be needed to give a positive outcome relative to the breakeven price. It is an estimated effect of the three investment methods and suggests the once more beneficial given characteristics and circumstances of the project.

4.5.2.4. Market failure

The concept of waste includes waste as material that has been purchased and paid but not been turned into a marketable product, likewise an indication of production inefficiency. Economic theory justifies policy where there is a concern of market failures. In the case of innovation, successful policies have led to radical innovation as shaping and creating direct public financing, rather than fixing the market. The classic market failure perspective can justify whether there are clear market failures as negative externalities with pollution requiring taxes. The system-of-innovation literature addresses the issue of the public investment aim market-creating process. Research (Mazzucato & Semieniuk, 2017) focuses on understanding market-making and market-shaping and concludes that the market-making agenda will be crucial for climate change driven projects with required technological changes to succeed.

Beyond fixing markets, the idea in neoclassical economic theory, where competitive markets and the optimal outcome is left to the market. The framework of market failure defines government intervention in the economy, only if it exists explicit market failures. It can arise from positive externalities (basic research requires public spending in science) and negative externalities (require public-sector taxations). It also involves incomplete information where the government provides guarantees or public funding. Besides the R&D, there is a smaller role in the public financing of innovation. System failure occurs when it is a lack of linkages between science and industry. This creates a need for new institutions to enable linkages (Lundvall, 1992). For future research, the framework will be used as a guide of discussion of innovation policy and address governmental involvement to gain market-creation support rather than market-fixing policy. Following are the key focus areas of public activities:

1. Support in public investment spread across entire innovation chain
2. Support in mission-oriented in investing activity
3. Support in risk taking across the business cycle

In the support of public investment along the entire innovation chain, there is found both positive and negative externalities. In the history of technological revolutions, there is required public-funded science, additionally with a network of different institutions in the innovation process. Public funding has been crucial, especially in the early-stage high-risk finance to innovative companies. In direct market-creating, the policy is also found important through procurement policy and bold demand policies that allow new technologies to diffuse (Perez, 2013). An example of a network in innovation landscape from the U.S. including investment from National Institutes of Health (NIH), NASA, DARPA, National Science Foundation (NSF), and small business innovation research program being active along the supply chain. There the different institutions are a source of frequently or occasionally funding through the five steps in innovation steps of innovation chain: (1) research, (2) concept/invention, (3) early-stage technology development, (4) product development, and (5) production/marketing. In a project being mission-driven, the action is directed on the action needed to solve greater problems and the process will actively create new technological landscapes, rather than fixing existing landscapes of market and environment (Foray, Mowery, & Nelson, 2012).

Market failure perspective considers climate change as a negative externality that requiring correct tax, and recommend the use of carbon tax (Newell, 2010) (Fisher, Newell, & Preonas, 2013). Funding can be implemented along the value chain, government agencies should not pick out a winner technology, but support innovation across a suite of alternatives within a given market. Public sector policies fail to tax carbon and give subsidies instead. One reason is the difficulty of agreeing on international tax-level worldwide. This results in subsidies being implemented instead. This when the public-sector policies become inefficient. The recommendation is following carbon tax and support small interventions to start private innovation. Public agencies often distribute venture capital or being active along the chain.

4.5.2.5. *Producer responsibility*

Extended producer responsibility (EPR) is central in policymaking, legislation, and end-of-life management of recycled goods. A related case study reviewing 27 cases carry out a comparative analysis of the cases concerning the role of stakeholder in the upstream and downstream stages of the extended producer responsibility (Gupt & Sahay, 2015).The study identifies 13 variables used to reveal that the financial responsibility of the producers and separate collecting and recycling agencies contributed significantly to the success of extended producer responsibility-based environmental policies. The three most important aspects of the extended producer responsibility are regulatory provisions, take-back responsibility, and financial flow.

Proper management of the waste generated has been a matter of serious concern for policymakers. Despite the benefits, the recycling industry has to succeed to achieve the desired results. It is found a lack of incentives for stakeholders, information, and technological constraints is a barrier to the development of a sustainable recycling industry (Nahman, 2010). EPR argues that the producer is responsible for the environmental impacts throughout the lifecycle of the product, from resource extraction to recycling, reuse, and disposal. This is based on the polluter-pays principle (PPP) and stresses the internalization of externalities related to product and also encourages the environmental friendly design of the products (Ferrão , Ribeiro, & Sliva, 2008). The upstream stages are the product going from raw materials extraction and processing to manufacturing. Further, the downstream stages are Distribution/ retail sale, consumption and waste generation, collection of waste, and the reuse/recycling process. The first two stages are upstream, and the rest is downstream in the EPR concept. This approach shifts the financial or physical responsibility of recycling to the upstream producers and requests for incentives from producers to incorporate environmental consideration in product design, both producers and consumers are generating waste (OECD, 2001). This encourages change in consumer behavior as well (McKerlie, Knight, & Thorpe , 2006) (Nahman, 2010).

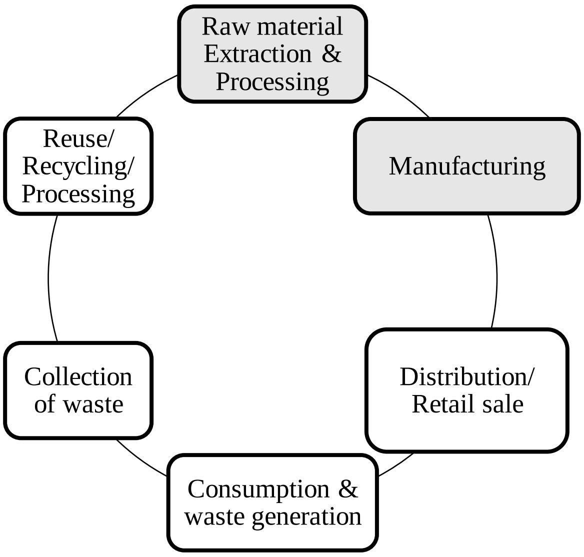

Figure 10 Upstream & downstream product life cycle

Source: Self-generated, Credit: (McKerlie, Knight, & Thorpe , 2006)

EPR for used plastic can enable a complete overview of the flow of plastic waste and recycling and reuse. Coverage and quality of waste collection and treatment are important. Taking responsibly for collection, treatment, reporting, prevention, and awareness of waste should be systematically divided between governmental and private stakeholders. Introducing the EPR policy approach for end-of-life management for packing and printed paper will include the following: (1) Causes producers to change packaging design and selection, leading to increased recycling or less packaging use. (2) It provides additional funding for recycling programs, resulting in higher recycling rates. (3) Improved program efficiency, leading to less cost providing more benefits for society. Lastly, (4) Results in a fairer system of waste management in which individual consumers pay the cost of their own consumption, rather than general tax payments.

4.5.2.6. *Tax for polluters*

To understand how the community can be able to hinder the increasing amount of plastic in the future and how the producers and consumers are involved, environmental policy and influence it has on society are significant. Environmental economists argue that environmental policy should be based on firmly using market-based mechanisms, as environmental taxes and tradable permits which make the companies responsible for environmental costs of pollution in society. In a long time, the polluters have had few incentives to reduce pollution beyond standards set by the government, where market-based mechanisms press the price constantly for improvement (Pearce & Barbier, 2000). To achieve objectives of reducing environmental pollution the marked-based instruments for environmental policy are enabling factors for economic and social objectives (Andersen & Ekins, 2009). Market-based environmental policies create financial incentives to reduce pollution either by the cost of complying with environmental standards or tax payment. From a social-economic perspective, market-based mechanisms provide that producers with a choice to continue polluting, pay increasing costs, or reduce environmentally damaging activities. The economic theory of effectively implementing the tax, argues that firms will choose the option of reducing environmentally damaging activities if the costs are less than the price charged by the market-based policy.

Ekins et al. (1990) highlight three objectives that economic instruments aim to achieve:

- Incentive tax: tax applied to change damaging behavior by increasing the marginal cost of polluting
- Cost-covering charge: particular use of environmental resources contributing to the cost of monitoring or mitigation.
- Earmarking expenditures that improve management of environmental damage caused by environmental improvement activities
- Revenue-raising tax: environmental tax yield revenue, this contributes to public finances, reduction on employment tax or product tax

5. METHODOLOGY

This chapter explains data, underlying theory, and methods used in the research. It will be described how data is gathered and how is applied based on the theoretical approach.

5.1. GATHERING DATA

The collected data collected contain primary and secondary sources. Primary sources are supervisors and participants in the research project, whilst secondary are public sources. Data of the value chain are from empirical research from Norway, Europe, and Brazil. Data on specific collection systems and recycling methods are not related to a specific region of research. More importantly, information connected to the location’s statistics, and circumstances of Brasilia come from local institutes, companies of waste service SLU, and Capital. Many of the data sources are gathered through informal requests to various institutions.

5.2. REVIEW AND ANALYSIS OF DATA

The research contains environmental, engineering, social, political, financial, and managerial aspects that give various frameworks and research to investigate. In the analysis, it is chosen a business valuation method and a social benefit analysis approach. Apart from the main analysis, the value chain of plastic is defined from consumption to become new products potentially sold. This will address the general value chain of how plastic gets into the river, to indicate the purpose of the chosen collection system in Brasilia. In the business valuation method, it is chosen sensitivity analysis and risk analysis with quantity and price. It is used a systematic approach to the business part, followed by a quantitative and qualitative analysis in the social analysis.

5.3. SYSTEM ANALYSIS

To gain insights into the system surrounding river plastic recovery, an academic readthrough was performed. Scopus and ResearchGate were used to find relevant articles on the field and to map the scientific branches of interest. The reading gave a clear overview of the problem, and by combining information from multiple sources a system flowchart (5.1) was created. this one is built based on academic read throughs and the author's best understanding of the recycling system. We further used backward induction to understand variables of interest for our economic analysis. The knowledge obtained from the scientific review, quickly made it clear that the many parts of the full system have an interaction with the price and quantity of plastic variables in an aquatic environment. These variables are set as exogenous when used for economic analysis (5.5) on the aquatic model (5.1.3).

5.3.1. <u>Price</u>

The secondary waste plastic market is not a mature open market where prices are easily obtained. A further study into how this market works and its inefficiencies would be of value. After a collection of data from various sources, three stood out as the most reliable. The European price (Eurostat, 2020) for plastic waste, which is a weighted average between various plastic types that have been sorted and cleaned. The second source is a closed American marketplace (Recycling markets, 2020) that gathers price information from various scrap dealers. After correspondence with the marketplace, a one-day membership was obtained, and prices downloaded. The representative price for the market is a weighted average for the different plastic types. The plastic is cleaned and sorted roughly before sold. This price is chosen due to the quality differences among the types which makes it more representative of what is expected to be found in the rivers.

The third price used is a weighted average of types from a Dutch Company called (Kunststofenrubber, 2020) that sells recycled plastic products (pellets, flakes). This is the highest price and also on the most advanced processing stage. The quality of plastic is of importance, and it is likely that much of the plastic found in rivers do not possess needed quality. The price is used to show the roof for recycled plastic price. The prices used should not be confused with what is the actual one for aquatic waste plastic. Good data for this could not be obtained and should be researched more extensively. The three prices are meant to represent three different levels of the processing chain, showing how far the business is in itself from breaking-even. The real price of recovered plastic is expected to be between zero and price estimated from recycling markets.

5.3.2. Quantity

Quantity Estimation for Lake Paranoá was estimated based on a yearly mismanaged plastic calculation. Yearly mismanaged plastic is calculated by the use of the framework from (Jambeck, et al., 2015) and (Lebrenton, et al., 2017):

$$M_{MPW} = \left(Pop * W_{gr} * W_{pr} \ \ * M_{MPR}\right)$$

M_{MPW} is the yearly mismanaged plastic waste in tons per year. Mismanaged is defined as littered or inadequately disposed of waste (Lebrenton, et al., 2017). Pop is the population. (for Brasilia we have used the official number from the governmental institution IBGE). W_{gr} is the estimated waste generation of kg/capita/day. This number varied from different sources, (Jambeck, et al., 2015) operates with 1.03, for 2010. World bank statistics operate with 1.6 as estimated for 2025 and (Abrelpe, 2016) estimation on 1.54. The best methodology, and what we would give the highest reliance is from the Brazilian Report (Abrelpe, 2016). These data are obtained through consultations and surveying various municipalities within Brazil. There is uncertainty in the number due to the quality of counting. However, it is from a primary source, hence the most accurate data found on the subject. Due to the uncertainty, we have three levels in our calculation; The reported number (1.54 kg/person/day) for Federal District (Brasilia), and an upper (1.75 k/p/d) and lower (1.25 k/p/d) level.

W_{pr} is the percentage of plastic in the waste stream, it can be interpreted as universal relative to national GDP. For Brazil categorized as an upper-middle-income country, 16% is used (Jambeck, et al., 2015). Given the uncertainty in the data point, an upper and lower level of estimation with 4% increment jump have been created. The number for mismanaged plastic rate (M_{MPR}) has been obtained from the World Bank statistic (Hoornweg & Bhada-Tata, 2012). Their methodology describes a universal method that estimates mismanaged plastic rate based on GDP. It is likely that an Environmental Kuznets curve or similar model have been used. A universal model approach will create variance between actual and estimated value. It is thereby, created a level below and above with 2% increment jump. The equation gives the mismanaged plastic, which we then distribute to end stations using World Bank data (Table 2). $M_{APW} \sim M_{MPW}$, where M_{APW} contain the aquatic plastic waste. To estimate how much of the mismanaged plastic becomes aquatic plastic waste, we set the station classified as "other" under mismanaged plastic in the world bank report equal to ending up in Lake Paranoá. For a more accurate result, drainage basin (4.2.4) and cultural behaviour would have had to be taken into account.

5.3.3. Plastic Types

Type estimation of plastic in aquatic environments was done by data collection from coastal clean-up initiatives (Ocean Conservancy, 2020)[1] of the most common plastic products found. The quantity of plastic products is multiplied with an estimated weight to create a distribution (Table 3). We have found general consumption by plastic-type to measure the quantity and weight of mismanaged plastic in Brasilia, presented in Appendix 3.

5.3.4. Cost Data

According to DRC calculation of pricing assets, the cost of the solution will be estimated by the hypothetical substitute method (MEA). The four stages of evaluation will be

[1] Data filtered between 27/05/2019 and 27/05/2020

understanding asset functions, specification of asset in the market, economic and physical life of the asset, and in the end asset functional and technological aspects. The three hypothetical substitutes are solutions of Bandalong Litter Trap with Bandalong Boom system (peer 1) and Water Wheel Trash Interceptor (peer 2). The cost will be an annual comparison of investment cost, maintenance, and capacity. Ocean Clean-up (peer 3) and Edmonton (peer 4) is added to get an indication of the cost distribution of start-up from one to three years of operation. The model of DRC method and expected cost that the government will consider is evaluated to find a suitable model in this research. DRC includes installation cost, commissioning and preparation, planning, professional fees, contingency allowance, and pattern of payment.
In assessing the cost of the replacement asset, all the costs that will be expected to be incurred by the potential buyer. The initial stage of estimation of the gross replacement cost should reflect the cost of a site suitable for a similar size and similar location to the actual site (RICS Group, 2018, p. 12).

5.4. ECONOMIC ANALYSIS

The first step in our economic analysis is a feasibility analysis for a single-standing private actor. This is done by the use of following profit function:

$$\pi = \sum_{i=0}^{n} (P * Q - C)$$

The methodology behind input variables price, quantity and cost have been explained under the system segment (4.3). The other variables used in our analysis follow in this segment.
The capital cost was set by the use of heuristics and conferring with professors on the topic. Due to underdevelopment, and potential market failure, benchmarking techniques to find capital cost were not possible. Further research into finding a better estimate for capital cost in this market is recommended. The expected lifespan for an Extraction solution is also uncertain. No public statement on expected lifetime can be found, and it will depend on factors such as maintenance and weather conditions. Without real data, an assumption of expected lifetime had to be made. An assumption of project lifetime for 5 years for both solutions were set. This assumption is controversial, as the price and quality of the two chosen solutions vary. It is assumed the Investment is partly financed by debt that is paid off in equal increments over the project lifetime. The debt rate has been set at 5%, which is arguably low for a project of this risk. The private company in the business analysis is

assumed to take up debt to finance Machine cost + first-year maintenance. Further costs are covered by their funds.

The social analysis uses the same input as the business analysis. The difference lies in the introduction of the government as a second party. The framework is built on Jean Tirole's theory of corporate finance (3.2.2.1). The introduction of the government input a new revenue stream that we have labelled V. V can be seen as the shadow cost of littering in nature, or the value of nature itself. The marginal cost ($\underline{V}$) calculated in the social analysis (5.4.2.1) should not be misunderstood as us trying to price nature. The introduction of the government will change the capital structure (3.2.1.2). Since the Government functions as consumer and investor, it makes no sense to introduce a debt rate. It only increases the price government have to pay for covering debt costs. However, for the sake of performing a sensitivity analysis, a rate of 1% has been set. All currencies were converted to Euro using the closing date price on 11.06.2020.

6. ANALYSIS

The analysis will be presented in three parts. I) A breakdown of the complex system, explaining where the water system fits in relation to the traditional recycling path and potential sequences the plastic waste can take. II) an economic analysis. in this part. The first step will be a break-even analysis in regard to the quantity of two chosen extraction systems. The analysis will show that the potential to reach a breakeven point for an extraction solution is very unlikely from a competitive standpoint. This will lead us to a social-economic analysis where we introduce the government as the second party to the extraction company. The last part of the economic analysis will be a factor analysis, with emphasis on sensitivity. III) A qualitative analysis of how potential economic measures could improve the situation, with a short review of measures taken by the Brazilian government.

6.1. SYSTEM ANALYSIS

An analysis of the system surrounding river plastic recovery is performed to gain a better insight into how the system connects, risk factors, and variables of interest. Our main economic analysis (5.4) will be performed on a closed model and extracted from a larger recycling system. The complexity of the closed system will be analysed more in depth, with variables of interest (5.1.2). Our analysis is done with a short-term perspective and cannot be considered as a finite solution, merely a limiting measure to our aquatic plastic problem. To reach the ultimate goal of limiting plastic waste in aquatic sources, the economic analysis (5.4) is recommended to be performed on the full system (5.1.1). It will likely exist more efficient approaches than river extraction systems to limit plastic in aquatic stations, however, such changes will depend on more long-term strategies.

6.1.1. Recycling system

The recycling system has a dynamic complex nature, the interconnection between individual parts produces a pattern which makes it a system. The relationship between individual parts shape system behaviour, where stock and flow are core elements. Entities will be stored and released from parts of the system, and the level of storage and flow will change over time. The interconnection between stock and flow is called the feedback loop. A feedback loop is a complex dance between reinforcing and balancing systems (Raworth, 2017). Reinforcing feedback will amplify the level of entities in the system, while balancing will reduce it. In the presented recycling system, plastic can be seen as the entity: Each item produced increases the amount in system. If plastic is not taken out, this is giving a reinforcing feedback. To balance this, plastic has to go out of the system by recycling process (3.2.3). The variables in the system are continuously changing and the relationship between input and output changes non-linearly, making it complex.

The graphical explanation of the complex system is shown underneath. The economic analysis is performed between the thick green lines inside the blue rectangular shape. The aquatic system is dependent on other parts of the full recycling system. These parts will be treated as exogenous factors and are connected with yellow lines in the figure. Some areas of the model have been omitted, and will not interact with our economic analysis, this is shown with red lines. The focus lies on plastic that escapes the first-best sequence and ends up in the aquatic environment. To understand the aquatic system, it is important to understand that the aquatic system is not a stand-alone system. It is connected to the larger flow of plastic from the total waste handling system.

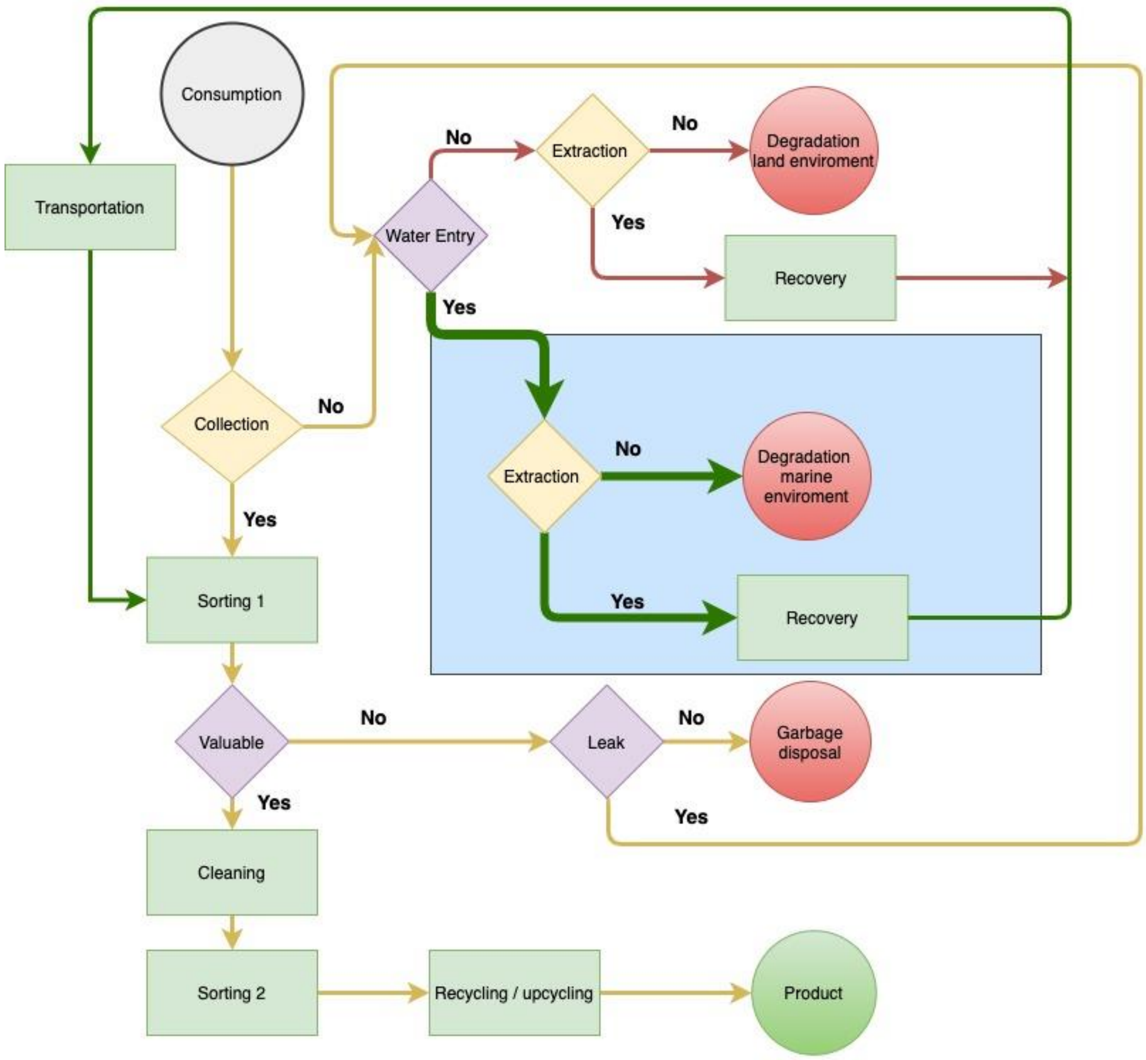

Figure 11 Flow chart of recycling system

Source: Self-generated figure (data from various sources)

Consumption is the beginning of the recycling system. It is logical to assume that the best way to limit plastic littering would be to limit consumption by lowering the production of plastic. However, the trade-offs by such a change are not in the scope of this analysis, we will assume the consumption of plastic as an exogenous constant. When consumed, the sequence will be dependent on the consumers decision and end up in either the collection system or nature. This is graphically shown by a decision node. The decision Is affected by education, personality traits and level of effort for collection. It can be argued that both education and effort for correct behaviour is partially a governmental responsibility. A government should arguably be held accountable for the distribution of tools like knowledge and public trash systems.

To continue the logic of the model, the explanation will follow the set of sequences that contain the first-best collection. The stations following after the first-best collection are the same ones that will follow in the sequence where plastic has been extracted from either land or the aquatic environment. Extraction from land or aquatic environment will be seen as a second-best collection. One could argue then that the third-best collection will be nature's collection i.e. degradation in the natural environment. The two variables of difference between first and second-best collection are Plastic Quality and Cost of Extraction. If plastic is collected in second best, we expect a decrease in quality, which is a property of price. At the same time the cost of collection increases, a lower value for a higher cost make it second-best.

To explain the various stations in the sequence after collection a brief description will come. These steps are not in the scope of this analysis, but they are important properties for plastic waste price. The first step after collection will be a market choice on whether or not the plastic is valuable. If it is not valuable it is sent to the output station disposal. This output station varies with local waste handling. It is either disposed of by storage or incineration. Countries with less investment in recycling centres often store this plastic. The recycling quality and level of mismanaged plastic waste are often correlated to a countries GDP (Barnes, 2019). If the plastic is stored in open and exposed environments there is a potential leak. Heavy precipitation, increased river flow and wind can transport plastic away from storage facilities. Leaked plastic often ends up in land or aquatic environments. The same qualities that make plastic a preferential choice to many other materials are also the same that create the problem. A strong material with low density and weight is a good combination for transportation by air or water, often leading to a long life in aquatic end-station.

6.1.2. Aquatic System

To measure the amount of plastic that is in an aquatic zone is a challenging task. It includes knowledge of origin, accumulation zones (Stock) and pathways (Flow). The success of how much trash is being captured is highly dependent on where the system is installed relatively to the waterways in the river. Plastic operates as the entity, with a distribution of type, quantity and quality. The plastic entities are following a stochastic sequence in the system. This means the plastic does not have a predetermined set of stations that it will follow. There are various possible paths the plastic can take, leading to different outputs in the expanded model. Even with large parts of the full recycling model treated as exogenous factors, the system remains dynamic and complex.

As mentioned earlier the aquatic system that will be looked upon in this analysis, is part of the recycling system. The input threshold has been bounded to when plastic enters the water, before that it is of no concern to the analysis. The output is bounded to either extraction or degradation in the aquatic environment. The limitation created by bounding degraded plastic to the aquatic environment is a simplification. Aquatic biology cannot be separated from land biology, as they interact with each other. Plastic that is absorbed by aquatic life will also eventually be absorbed by land-based life. This connection is not in the scope of the thesis, but of vital importance for environmental impact costs (4.5.1.1). The limits of the model make us treat various variables and constants as exogenous. The most important ones here are the input of plastic quantity, and price of plastic output.

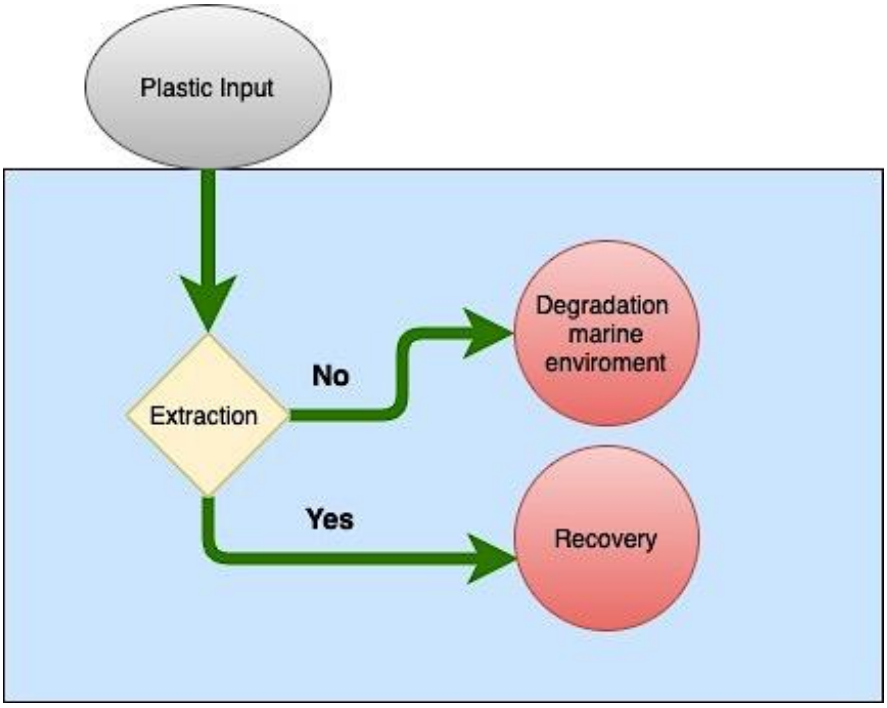

Figure 12 Flow chart of Aquatic system

Source: Self-Generated figure

With the surrounding parts from the full recycling model treated as exogenous factors, the aquatic system can still be characterized as complex. Plastic entity properties and the input channels to the aquatic system, which is discretely distributed, follow a stochastic pattern. The river (4.2.4) function as a conveyor, with a continuous change in level, rate and dimensional flow. Somewhere on the conveyor, an engineering resource (4.2.1) is placed to extract the entity. The combination of stochastic input and continuously changing conveyor makes the system dynamic in nature. The uncertainty in quality and path makes the relationship between input and output uncertain. Quality refers to the physical state of plastic, whilst path refers to the uncertainty in whether or not the processing station is part of the sequence the plastic is going through. There are also exogenous variables, most importantly the price of the entity that is continuously changing based on market demand. The potential sequences in the model lead to two different outputs, one of which is the desired output that leads plastic back into the recycling sequence the desired output is recovery leading plastic back into the recycling sequence. The alternative is the degradation in the aquatic environment.

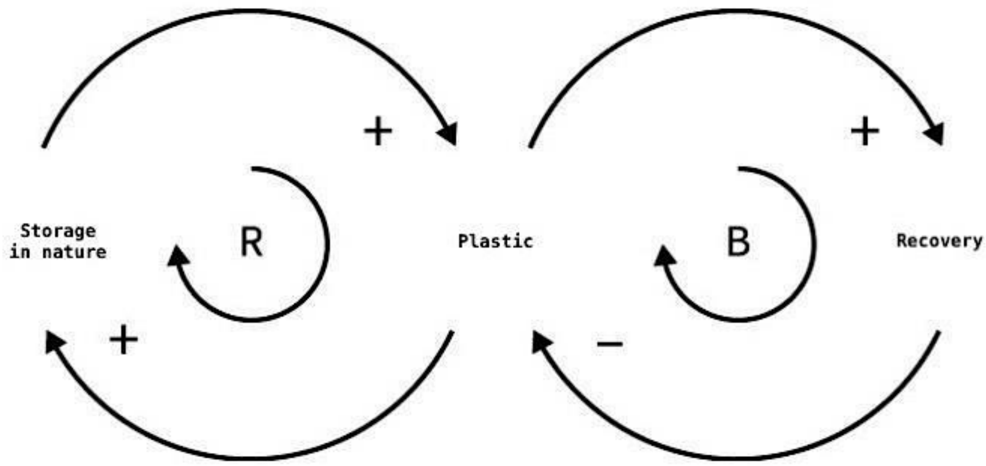

Figure 13: Feedback loop of plastic waste handling.

Source: Self-generated figure (Adaptation from (Raworth, 2017)

The choice of end station has effects on the feedback loop. For each entity of plastic left in nature, we have reinforcing feedbacks meaning more plastic is added to the cumulative weight. This requires more usage of energy and more virgin plastic that is likely to have a percentage ending up in the aquatic environment. The right-hand side of the figure is the counter-effect. It is the balancing feedback. By recovering plastic, we can both reduce the amount and recover material or energy.

The elements of interest for our economic analysis are plastic as a resource, river as the means of transportation, and the engineering solution as a resource for extraction.

Plastic (Entity)	Extraction (Resource)	River(Conveyor)
•Quantity •Quality •Type •Price	•Extraction capacity •Effectivity •Holdning Capacity •Price	•3D •Speed •Level •Rate •Entry points

Table 1: Overview of important properties in aquatic system

Source: Self-generated table, data from various sources

The table above shows some of the variables of importance behind the system. The following part of the analysis will state quantitative estimations for the variables, where they are possible to obtain. The area of choice will be Brasilia. Estimations of river behaviour were deemed too complex, and therefore omitted from the following estimations. It is important to highlight the importance of river variables (3.2.5) that we have in this system. The interaction between river, plastic and extraction solution, makes it a vital part of a complete analysis when looking for optimal impact solution.

6.2. PLASTIC

This following section will present and explain estimations for quantity, type, and price of plastic. The estimations are presented in tables, with the following description of findings, and potential for improvement.

6.2.1. Quantity

There is a lack of data on plastic quantities in Brasilia. Because of this, an estimation using assumptions from universal models were created. The uncertainty in input numbers used and expected mean variance from correlation with the water cycle, three levels of estimations was created.

Estimation quantity					
Level of quantity	**Population**	**Generation rate (Kg/capita/day)**	**Plastic in waste stream**	**Mismanaged plastic %**	**Mismanaged plastic (ton/year)**
Min	3015268	1.25	0.12	0.09	14857.73307
Estimated	3015268	1.5	0.16	0.11	29055.12245
Max	3015268	1.75	0.2	0.13	50076.06331

Table 2: Estimation of mismanaged plastic ton/year.

Source: Self-generated table (data from various sources)

Mismanaged plastic in this definition is everything that is not recycled properly. All storage of plastic in other garbage zones will be counted as mismanaged. The value is an expected value based on the cumulative probability distribution taken from (Hoornweg & Bhada-Tata, 2012). It is an estimated value but will not be referred to that later on in the text. We will assume the estimated value is the real value. Since we are only concerned with the plastic that ends up in the water a cumulative probability distribution of M_{MPW} is made and the quantity that leaks into the aquatic environment M_{APW} is gathered from this.

$$M_{APW} \sim M_{MPW}$$

Cumulative distribution of place				
Distribution	**Percentage**	**Minimum**	**Expected**	**Maximum**
Landfill	91.3%	13568.67615	26534.30002	45731.46406
Compost	1.0%	142.1885055	278.0575218	479.2279259
Recycled	1.4%	207.8596856	406.481163	700.5641257
Incineration	0.1%	19.76078498	38.64331286	66.6011642
Lake Paranoá	6.2%	919.0993677	1797.349875	3097.705276

Table 3: Probability distribution of mismanaged plastic in tons

Source: Self-generated table, distribution % data from (Hoornweg & Bhada-Tata, 2012)

The potential waste disposal and treatment in Brasilia is defined in the following figure based on the percentage of usage in 2018. The estimation methodology is a universal model based on GDP. There is there for potential large variance between estimation and actual data. I.e. large variance between the regression line and residual. Since no trustworthy data could be acquired from the city of Brasilia, we will use the estimated value stemming from Brazil being classified as an upper-middle-income country (Hoornweg & Bhada-Tata, 2012). The estimations operate with both a dump and landfills. As mentioned earlier (6.1) there are potential leaks from disposals. Brasilia as a city has recently moved over from dump disposal to a landfill system. The dumpsite in Brasilia is no longer operational, one of the reasons was the high risk of contamination to the lake. Since it is no longer operational, we assume that potential leaks of plastic have already happened and are not something we expect is leaking in large quantities anymore. The new landfill in Brasilia is at a distance and placement that it is not connected to the river basin of Lake Paranoá. Level of mismanaged plastic going into dumps, can be assumed placed at landfills instead. We thus assume a zero leak from landfill and dumpsite into Lake Paranoá. This means that the estimation for "other" disposals is what is set to enter the lake each year. Improvements to this estimation could be made by taking the drainage basin into account. A better monitoring system of the plastic flow or data gathering from the lake would also improve the estimation.

By looking into possible extraction methods (6.3) it became evident that most methods are limited to top-side extraction. The estimated value of plastic entering thus requires a vertical distribution. Again, there is a lack of available data, and standardized monitoring or testing. The most reliable source we found was for micro-plastic (Erni-Cassola, Zadjelovic, Gibson, & Christie-Oleza, 2019), as this is the most studied field. We acknowledge that the use of micro-plastic distribution has faults. The ability to float for a piece of plastic will depend on more than just its density. The form of the piece surface and possible containment of air will change buoyancy. Due to the lack of data, the spatial distribution in water for plastic have been omitted. The estimation shows the estimated levels of plastic input to Lake Paranoá. Since we have little information of input areas, and river behaviour a spatial distribution of the plastic has not been done. A further investigation into input zones should be done, to find most impactful areas of recovery. This could be done by creating a cumulative distribution chart with kilometres of the lake (circumference) on the x-axis, and the cumulative probability on the y-axis.

6.2.2. Type of plastic

The Weight distribution has been simplified to concern the 4 most typical plastic types. PE contains both LDPE LLDPE and HDPE. It has not been vertically distributed, as there is not enough information to perform such a distribution with confidence. We recommend more thorough research of spatial macro-plastic distribution, with a standardized approach. Plastic type will affect end value, we have thus weighted the sales price of plastic with the type distribution.

Type distribution	
Plastic type	**%**
PE	56%
PET	23%
PS	11%
PP	10%
TOTAL	100%

Table 4: Type distribution of Plastic

Source: Self-generated table (data from various sources)

6.2.3. Price

There is a limited market for waste plastic. The prices acquired had little information about quality and state. We obtained three prices of waste plastic to show the value at different stages of the value chain. For further description of the prices, go to the methodology section (5.3.1)

Prices		
Recycling markets	**EU**	**Kunststoff**
€ 102.88	€ 319.00	€ 500.52

Table 5: Waste plastic price at different processing stages

Source: Self-generated table (Data from various sources)

6.3. EXTRACTION

In the following section it will be presented to two solutions with a focus on explaining variables of interest.

6.3.1. Extraction system 1 (BLT)

The first solution is made by Bandalong International The main solution is called the Litter Trap and is suitable for rivers of smaller rivers. An additional solution called the Boom System can be added as an extension, this is better for wider rivers. The company offers full-service in installation and manufacturing, and multiple site-specific extraction methods (Bandalong International, 2020). Testing done by the University of Kentucky, show an efficiency of topside extraction of around 80 % under medium flow conditions (Storwatersystem, 2015).

Figure 14 Bandalong Litter Trap

Source: (Bandalong International, 2020)

The Litter Trap (BLT) is designed to be installed for a shorter period or permanently. The system floats on the surface with the help of strong and durable polyethylene pipes around the cage. It is attached to ground anchors and fitted to rider poles for canal installation. The sampling is done by netting the beneath water surface to prevent waste escaping under the main floats. If the river is too wide, two booms are installed. The optimal placement for the installation requires understanding of river behaviour. The BLT is made by HDPE and is delivered in two standard sizes; however, it can be made for other required sizes. The small size weighs approximately 275 kg for two-meter width and the larger size is 500 kg for six meters. Both sizes need minimal 200-250 mm depth to keep floating (Strom Water Systems, 2020). The solution is already launched in Australia, USA, Nigeria, Singapore, Malaysia, and New Zealand and is known to be efficient under various circumstances and easily adjusted to fit most locations. BLT is only collection waste floating on top or below the surface, it only collects floating waste on 200-250 mm below the surface. The solution is most effective with flowrate on 2.5-3 cubic meter a second, it is possible to adjust the Litter Trap to work with higher flowrates.

The BLT has no anchoring to the bottom and has no nets or fencing underneath, which means there is almost no impact on river life, except for the fact that the amount of trash around the water surface intensifies close to the Trap. If there is only used one trap, passing and transport will not be possible. If there is more than one navigability will be possible, the obstruction will be to sail around the traps.

Maintenance is required to keep BLT running, depending on the intensity of waste in the river and the number of traps implemented. Using more than one trap will require cleaning more frequently to avoid overflow and waste sailing around the trap. The average time of maintenance is 10-15 hours per month with the estimated cost of 28.000-44.000 dollars equals a range of 8-10 dollars per kg of waste. Investment cost contains 50.000 for BLT without the Boom system and can increase to 100.000 dollars stated by U.S. Environmental Protection Agency. In a period from March 2011 to August 2011, the system collected 2.54 (Appendix peer 2) (EPA, 2015). Giving these costs, the solution is cost-effective compared with the market. The system requires is able to operate 24 hours a day without maintenance (Bandalong International, 2020).

The construction prevents macro-plastic from floating away or out of the trap, it is still possible to micro-plastic to sink and pass underneath. The BLT solution helped remove a yearly 77 tonnes of trash in the Anacostia River, with a two-week cleanout schedule (The Connection, 2020) (Appendix 5.3). With a city with the size of Brasilia, the schedule could be assumed doubled, and give an estimated 150 tonnes of trash each year.

The Bandalong Boom System (BBS) is an additional solution that can be added to the BLT. It is a length construction of floating polyethylene spread over the entire width of the river (Strom Water Systems, 2020). The solution is under the same patent as BLT and is more suitable for medium and large rivers sizes and collects in approximately 200 mm depth. 20% of macro-plastic is likely to slip through the trap and micro-plastic would be collected on a 0-20 % level. Together with the BLT method, maintenance would increase to 30 hours a month. The investment cost of the Boom system would be 1000 dollars a meter.

Figure 15 Bandalong Boom System

Source: (Strom Water Systems, 2020)

The maintenance of both extraction methods is offered by Litter Removal Service, where they establish cleaning routines at set intervals for a specific location. Cleaning is often executed by crane, lifting out the basket containing the waste which is captured by BLT. Manual cleaning is also an option when access to the basket by crane is difficult (Bandalong International, 2020).

6.3.2. Extraction system 2 – WWT

Clearwater Mills is the company behind the Water Wheel Trash Interceptor. The solution has been used since 2014 in Baltimore, Maryland, United States among with many other locations

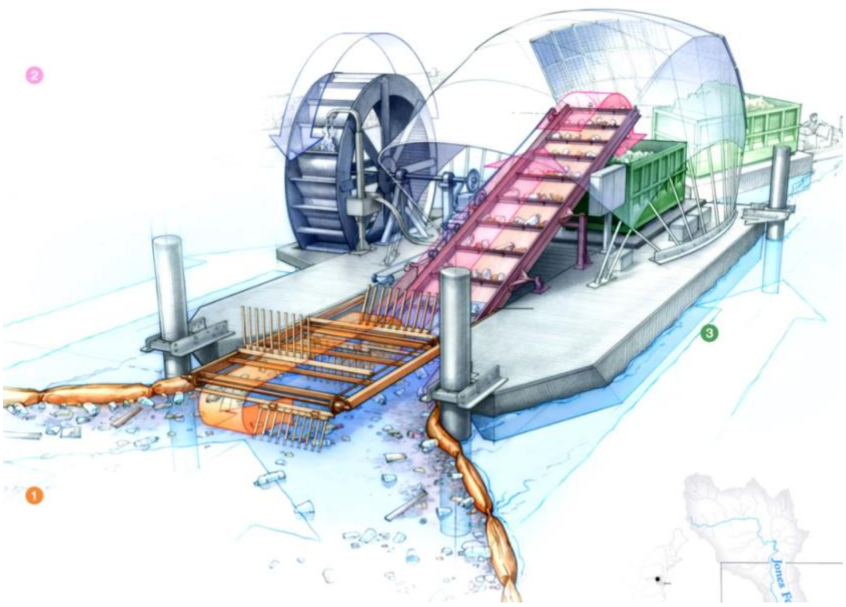

Figure 16: Water Wheel Trap Interceptor.

Source: (EPA, 2015)

Data from the project are used collection level in our economic analysis. The solution uses renewable resources (solar and hydro) and operation through the internet, thereby require less resource hours than a skimmer boat. Initial findings from the project show that WWT is a cost-efficient solution, and it is still under operation today.

WWT is a 15-meter-long machine with a weight of approximately 45.000 kg. It contains two booms from its body, guiding rash flowing from the tributary towards the mouth. The conveyor belt carries the trash up on a ramp and deposits it as a dumpster located under the canopy. There is an automated rake that helps trash to go up the ramp (Clearwater Mills, 2015). When the dumpster is full, a boat takes it to a truck that transports to a facility nearby. The burned waste is further used to make electricity for the population in Maryland. Overall the solution has given a result varying between 24 to 900 tons, which commonly has been plastic bottles, polystyrene containers, cigarettes buts, grocery bags, chips bags, and sports balls (EPA, 2015). Since installation in Jones Falls Stream, Inner Harbour (2014) the solution has averaged around 200 tonnes per year (Waterfront Partnership, 2020), and will be the representative quantity used in following economic analysis. The WWT is capable of intercepting both micro and macro-plastics. The containment boom will guide toward the trash interceptor, even that the solution collects all kind, it only collects around and below the water surface. It will effective in collect almost all trash on the surface, however, trash deeper than 60 cm will not be collected. The maintenance cost is especially high for WWT, since empty the entire boat is time-consuming the estimated average cost is $ 100.000 a year (Tullo, 2018). The investment cost is approximately $ 650.000 to $ 700.000 (Viviano, 2019).

In the process of choosing an extraction method, it is necessary for local stakeholders to choose an aquatic trash strategy for the targeted geographical area and recognized that there is not one universal best solution, but an individual best fit. For further development, it will be important for local stakeholders to reflect on their particular data that may concern in finding their needs of the system (Glass & Holloway, 2012).

6.4. ECONOMIC ANALYSIS

The economic analysis will consist of a comparison between two representative extraction solutions. Both solutions will be taken through the two steps of our analysis. The first will be an open competitive market where private business is the only investor and acquire full revenue from the project. It will be shown that this is very unlikely to be a profitable setup. Hence, the government is introduced in the second analysis, as an actor that will subsidize the company. The government has an extra revenue stream in protecting the intrinsic value of nature, meaning it is willing to pay extra for the extraction of plastic. The study will show an equilibrium contract between the two parties, where the goal is for the government to pay as little as possible to extract plastic. At the same time, a private company will need enough pay to perform a high effort job.

There is a lack of data on the interaction effect synthetic polymers have on biological organisms, making it difficult to evaluate the environmental impacts. There is evidence that macro and mega plastic have an effect on the ecosystem mainly from animals' entanglement and consumption of the plastic. However, it is challenging to evaluate the effects and value damage. Economic studies trying to quantify how much plastic litter in the aquatic environment cost our society tend to focus on the direct economic impact. It will further in this segment, be given descriptions of what social, environmental, and economic impacts. The argumentation follows a holistic view. Unfortunately, we lack the capacity and data to perform an impact analysis that plastic has on environmental, social, and economic factors. Following in the tradition of an open competitive market, the economic analysis is done between two representative parties of various interests. It will be presented in a framework where one actor functions as the principal (investor), and one actor functions as the agent (entrepreneur). A cost breakdown for a representative company in the sector will be presented. Showing us the cost of implementing a clean-up initiative. This will give the necessary input to perform an analysis that will give insight into price and quantity thresholds. A net present value setup for the government will then show the cost of implementing the extraction solution, with gains from extracted plastic. We will look into various differentiation in the contract set up, and how this potentially could affect the behaviour of the extraction company. To continue with the competitive market approach the analysis will be presented on the backbone of an asymmetrical contract situation between two parties.

A project of extracting plastic from the aquatic system obtains financing if the project itself generates positive NPV from a purely monetary perspective. A profit function calculation for a free-standing private actor will demonstrate why this problem needs a different perspective than a pure economic growth lens to be solved. Alternatively, the project generates positive NPV from a more holistic stakeholder view. The last option requires investment from actor(s) with excess money. In this framework that actor will be represented by the government. That does not exclude the possibility of private actors doing philanthropic investments.

6.5. BUSINESS ANALYSIS

In this section e will identify the main factors that is used for our Profitability analysis. The business analysis will explain the necessary information for reliable and valid cost analysis of the collection system in rivers of Brasilia. The purpose of estimations is to address the scope of implementing the collection system. The project contains risk in terms of unexpected costs and calculated budget based on assumptions. Calculating essential costs is necessary to meet the financial commitment for a successful project.

6.5.1. Risk and uncertainty analysis

Various risk factors will interfere with a river waste plastic recovery investment. This will be reflected in the Risk-Premium and Default spread (3.2.1.2). An overview of chosen factors will follow. Technological risk is present because of uncertainty around the extraction solution. The most present risk factors are from uncertainty about maintenance costs, and longevity of the machine. Operational risk mainly comes from uncertainty in measurements. The estimations of both expected extracted quantity and river behaviour have variability and stochastic tendencies. Weather risk will affect all other risks. The largest unknown in this system is river behaviour (4.2.4), which is directly correlated with weather behaviour. Market risk affects the demand and price of plastic. Legislative risk is present due to changes in laws and the distribution of resources. Exemplify, a company living of extracting waste plastic, a single-use plastic ban would be bad for their business model. A Risk Premium of 13% has been set, signalling the intrinsic risk of the project. The risk-free rate is set at 2%. Giving us an equity cost of 15% and debt. Since the Government function as both lender and customer for the private company, we have omitted the cost of debt. In reality, a debt premium would just mean the government has to pay itself for the risk.

6.5.2. Profit function

The private company is assumed to take on debt for paying of initial machine cost + maintenance of the first year. The remaining funds are paid off with the companies own funds. The structure in itself is not so important, however, the funding is structured the outcome will end up similar. The profit function uses earlier discussed prices, with expected extraction quantity assumed from the two chosen projects (5.3). The capital cost used is calculated with the following formula:

$$\frac{E}{D+E} * r_E + \frac{D}{D+E} r_D = WACC$$

This gives us a capital cost of 11% for BLT and 7% for WW. The capital cost differs due to the differences in the machine cost. Since WW is a more expensive machine, the debt coverage will have a higher fraction. The cost of debt is set to 5%.

Profit function			
System	Recycling markets	EU	Kunststoff
BLT	€ -164,167.29	€ -42,830.73	€ 59,078.27
WWTI	€ -717,797.16	€ -539,631.93	€ -389,993.28

Table 6: Feasibility calculation for the two extraction systems

Source: Self-generated table

As seen above the project in itself is only profitable for BLT extraction system with the price of plastic after processing (flake, pellets). This clearly shows that a project of extracting plastic is not feasible in itself, and a second party will have to intervene to increase incentives. Since there is uncertainty in the quantity extracted, a table underneath shows the level of quantity that is needed to be extracted with the same prices use.

Breakeven quantity (tons)			
System	**Recycling markets**	**EU**	**Kunststoff**
BLT	576	186	118
WWTI	1,893	610	389

Table 7: Needed quantity to reach break-even.

Source: Self-generated table

The table shows how much plastic that is needed to be recovered by the solutions to reach break-even. When taking into account the historic data of extraction (6.3), and potential market price (Table 5), it furthers strengthen the statement above that second-party subsidies are needed. This leads us into the social analysis.

6.6. SOCIAL ANALYSIS

6.6.1. Quantitative analysis

We have demonstrated that it is highly unlikely to obtain a Positive NPV project in the current market. It will therefore be necessary for the government to help with market creation. The government should have a willingness to pay for such a market, because it will help protect the national environment. In the investment contract presented underneath, we assume the government incentivize the market with subsidies to create a positive NPV project. The asymmetrical properties of the project are priced in to make sure high effort is performed by Entrepreneur. The Full contract will be explained further, both with qualitative analysis, and with a quantitative contract set-up where variables estimated earlier are used. Further Assumptions are either explained with the analysis, or in the connected methodology section. Due to weak data, the output from the quantitative analysis have little meaningful. When datapoints improve, the framework can be updated with simple changes, and give better quantitative answers for all dependent variables of the contract. The variables will be analysed further with a performed sensitivity analysis. This will highlight interaction effects and give insight into which variables the government could target to improve the situation.

6.6.2. **Contract of parties**

The payment of the project must be higher than the investment to the Investor. Anything else will not be a beneficial investment. The return, in this case, will be the social benefit of collecting plastic, instead of letting it enter the marine environment. One of the largest problems is the weak or non-existing recycled pricing of plastic globally. For the atmosphere, we release huge amounts of pollution without any costs. In the marine environment plastic is the main source of pollution that brings problems. This is due to its high usage, lightweight, and long degradation time. There is a threshold to the amount of plastic that flow down the aquatic system, the government want to ensure the entrepreneur performs at its highest capability to extract as much as possible. The largest investment will be the capital cost and maintenance of the extraction equipment, but to obtain the best possible extraction method it is important to realize the problem is more complex. A big part of plastic recovery from river is understanding the variables (Table 1) that make up the complex system (Figure 14) to ensure optimal extraction equipment and placement. This is a process that requires data, experience and analysis. The risk stemming from uncertainty in these variables are captured in the Risk Premium (4.3.1.2). We have previously discussed the IC and IR constraints (4.4.1):

The bounded IC- Constraint:

(1)

$$R_b = \frac{B}{\Delta P}$$

Giving us the IR-Constraint:

(2)

$$P_H\left(R - \frac{B}{\Delta P}\right) \geq I - A$$

With the entrepreneur putting up own cash:

(3)

$$\bar{A} = A \geq I - P_h(R - \frac{B}{\Delta P})$$

$$\bar{A} = I - P_h(VQ + SQ)$$

The minimum level of own cash that the E have to pay is conditioned on the natural valuation(V) of extracting plastic and the value the government can get from selling(S) the plastic to the market. The higher the price in the market, fewer subsidies are needed

If plastic extracted goes above the expected quantity, this will increase NPV for both parties due to the split Revenue stream.

(4) $$NPV = R - I$$

(5) $$R = R_I + R_b$$

Due to the uncertainty in revenue and potential unforeseen cost, the Entrepreneur will require a risk compensation (6.5.1), and the debtholder a default spread (6.5.1). For Equity holder, the risk will be presented as a discount factor

(6) $$A = P_h(\delta \frac{B}{\Delta P})$$

The willingness to pay for an expected cashflow is captured by the discount factor (δ). The factor contains a risk-free and risk-premium component.

By insertion into **(2)** and binding the restraint we get:

(7) $$P_H\left(R - \frac{B}{\Delta P}\right) = I - P_h(\delta \frac{B}{\Delta P})$$

A higher Benefit increases the price the government would have to pay for each quantity of plastic picked up. Due to the risk premium, the Entrepreneur requires compensation for idiosyncratic and systemic risk. Revenue (5) consist of a part for the Investor and Entrepreneur. R_I is the revenue stream for investor, consisting of the non-economic value from plastic recovery V, recovered plastic price from market $S * Q$ and debt income (DI). The Entrepreneur obtains revenue stream R_b, which is a fraction of the pre-determined price government pay per tonne ($P * Q$) of recovered plastic. The other fraction will pay of debt. This means that the government is paying off debt with the price it pays for extracted plastic. Reason for this is to incentivize Entrepreneur to extract more, as a higher initial investment from Government could make it more beneficial shirk on effort for Entrepreneur. The cost of the project (C) is covered with two capital streams. Following the Pecking-order theory (4.3.1.2) the project is financed with own funds (α) from Entrepreneur and debt[2] $(1 - \alpha)$ from an outside investor (Government). There are also two costs endured by the government for the subsidized price it pays for recovered plastic $P * Q$ and the uncompensated risk in debt (Opportunity cost). The profit function for the individual actors can be isolated.

[2] Assume senior Debt with covenant to restrict dilution possibilities.

Entrepreneur

$$\pi_E = (R_b - A) * \delta^n$$

Investor

$$\pi_I = (VQ + SQ + DI) - [(I - A) + (R_b - SQ)]$$

(8) $$\overline{V} = V \geq \frac{[(I-A)+R_b-S-DI]}{Q}$$

Equation (8) states that the minimum threshold level ($\overline{V}$) of governmental entry, is where one tonne of plastic recovery is equal or higher to the Investor (Cost + subsidy)[3] paid.
I.e. the Marginal revenue (V) is equal or higher to the Marginal cost ($\overline{V}$).

(I-A) = Debt used for financing project
(R_b) *= Revenue demanded by Entrepreneur to secure high effort*
$(P - S)$ *is the subsidized price government pay for plastic recovery over market price. Where fraction* α *goes to Entrepreneur, and* $(1 - \alpha)$ *goes back to Government*
DI = Income from debt payments.

6.6.1. Contract setup

A setup of the framework with estimated values are presented underneath. The variables in the equation are listed with their given values, subchapters of estimation or explanation of value given are listed at the end. Estimations and assumptions made for this analysis are marked with * and made underneath the table.

[3] Opportunity cost of foregone investments is omitted

Contract setup			
Variable	**Abbreviation**	**Value**	**Further Explanation**
Market price for plastic waste	**S**	€102.88	Table 6 (Recycling markets)
Subsidized price	**P**	BLT: €420.68 WWT: €1,1156.54	**Formula (1) ***
Quantity	**Q**	BLT: 150 Tonne/year WWT: 200 tonne/year	5.3.1 5.3.2
Success probability under high effort	P_H	BLT: 100% WWT: 100%	**
Success probability under low effort	P_L	BLT: 50% WWT: 50%	**
Benefit for shirking (year)	**B**	BLT: €22,143.20 WWT: €58,740.00	***
Cost of Equity	r_E	15%	5.4.1.3
Project Duration	**n**	5 years	4.4
Cost of Debt	r_D	1%	5.4.1.3
Technology Cost	**C**	BLT: €89,000+€39,160 WWT: €623,000+ €89,000	5.3.1 5.3.2
Investment (total)	**I**	BLT: €286,630.61 WWT: €1,079923	5.3.1 5.3.2
Own funds from Entrepreneur (total)	**A**	BLT: €192,549.57 WWT: €510,782.61	**Formula (6)**
Weight Equity	α	BLT: 67.18% WWT: 47.30%	
Debt from Investor (total)	**I-A**	BLT: €94,081.05 WWT: €569,140.39	**Formula (2)**
Weight Debt	**(1-α)**	BLT:32.82% WWT:52.70%	
Project income (total)	**P*Q**	BLT: €315,513.05 WWT: €1,156,540.39	
Subsidies (total)	α**((PQ-SQ))**	BLT: €160,118.19 WWT: €498,360.90	**Formula (8)**
Marginal cost of recovery/tonne	$\bar{V}$	BLT: €192.36 WWT: €484.52	**Formula (8)**

Table 8: Contract Setup

Source: Self-generated table

* Since α(P*Q) = R_b, insertion can be done to find P as the only unknown.

** The probability of success is set at 100% (achieving estimated pickup) when high effort, and 50% at low effort. The low effort will be present in sporadic maintenance schedule and analysis.

*** Benefit is an opportunity cost. It come by shirking on maintenance of unforeseen costs spending and investing in alternative projects.

The capital structure changes with project variables and assumptions. We observe a big difference in structure between the two solutions. The entrepreneurs are compensated for the level of asymmetrical information and equity cost. A potential investor in this project is recommended to gain more information on opportunity costs and limit asymmetrical information for creating a better capital structure.

The two variables of main interest are NPV for Entrepreneur and $\overline{V}$ which is the marginal cost of plastic recovery per tonne for Government. The Entrepreneur wants to maximize profit, while the Government wants to pay as little as possible per tonne extracted. A governmental investor should always invest in the projects that have the lowest marginal cost since the revenue gained will always be the same (One tonne less plastic in the aquatic environment). Due to the uncertainty in output numbers, a sensitivity analysis is done to give more insight into the interaction between variables in the contract.

Due to the uncertainty in market price for river waste plastic, a calculation with zero worth was done. This is to show the roof of subsidisation for the analysed extraction system.

Maximum subsidy from government	
BLT	**WWT**
€ 212,076.60	€547,425,71

Table 9: Maximum subsidy for government

(given assumptions and solutions) Source: Self-generated table

6.6.2. <u>Sensitivity analysis</u>

The sensitivity analysis give insight to impact independent variables have on variables of interest. It is done by changing one independent variable, holding all else constant. Formula used for calculating sensitivity: $\frac{\%\Delta Y}{\%\Delta X}$. Where $\%\Delta Y$ is percentage change in dependent variables, and $\%\Delta X$ is percentage change independent variables. The base-case for calculations can be found in Appendix 2.

Independent Variables	I	A	I-A	P	NPV	$\overline{V}$
			BLT			
Q (1%)	0%	0%	0%	0%	734%	-6%
r_d (+1%)	1%	0%	2%	1%	0%	0%
r_e (+1%)	0%	-13%	27%	8%	49%	0%
P_H-P_L (1%)	1%	-99%	205%	-8%	-99%	-152%
PC (1%)	32%	8%	80%	29%	8%	12%
OC (1%)	68%	92%	20%	71%	92%	141%
S (1%)	0%	0%	0%	0%	0%	-53%
N (1 year)	69%	100%	0%	-23%	64%	0%
B (1%)	-1%	100%	24%	9%	100%	153%

Table 10 Independent variables BLT

Source: Self-generated table

Independent Variables	I	A	I-A	P	NPV	$\overline{V}$
			BLT			
Q (1%)	0%	0%	0%	0%	714%	-8%
r_d (+1%)	1%	62%	2%	1%	0%	0%
r_e (+1%)	0%	-13%	12%	6%	49%	0%
P_H-P_L (1%)	0%	-99%	90%	-6%	-99%	-120%
PC (1%)	59%	21%	92%	56%	21%	26%
OC (1%)	41%	79%	8%	44%	79%	96%
S (1%)	0%	0%	0%	0%	0%	-21%
N (1 year)	43%	100%	-9%	-45%	64%	0%
B (1%)	0%	100%	10%	6%	100%	121%

Table 11 Independent variables BLT

Source: Self-generated table

An increase of Quantity (Q) is lucrative for both parties. The government obtain a diminishing marginal cost for extraction ($\overline{V}$), while the Entrepreneur can pocket it as profits. It is expected to be a correlation between maintenance and quantity, this has not been taken into account in the performed analysis. The output effects are likely to be overestimated. An increase in cost of debt (r_d), only reshape the timing of payment for the government since it functions as both customer and investor. A change in debt increases the price the government pay. If the price were sticky, an increased interest would be covered by the Entrepreneur, making it less profitable. This show that governments have a possibility for function as a risk-taker, to push innovation. Increased equity harms the marginal cost of investment. We observe that this cost fall on the Costumer (Government) and increase threshold for valuable entry ($\overline{V}$).

The performance variable P_H-P_L show how dependent the project success is on effort. A higher delta will make it less lucrative for Entrepreneur to shirk on effort, meaning Investor pay a smaller incentive compensation. A higher production (PC) or operational (OC) cost leave more room for shirking. The increased benefit(B) of shirking requires a higher payment from the government to secure high effort. Under these conditions, the Government is incentivized to stimulate competition among producers. Competition would reduce market power for individual Entrepreneurs, and is also likely to cut costs, leading to lower needed investments from the government.

There are Potential Agency problems due to moral hazard. We can observe with High benefit (B) from deviating, and a low likelihood ratio $\frac{P_H}{P_L}$. The two factors are the asymmetrical component. With higher benefit or low likelihood ratio the Entrepreneur must be compensated higher for incentivizing high effort. The more asymmetrical a project is, the less lucrative it becomes for the Investor. By increasing the market price (S) the government can pocket a direct profit due to lower marginal cost. Government is thus Incentivized to look into measures that improve price, such as increased demand (6.7.3.3). Improved treatment post-recovery will also make it more lucrative to recover plastic. An increase in operative years (N) will not change marginal cost, as we have not implemented discount values for extracting plastic. The extraction company obtain profits from the extra year because the heaviest costs have already been paid off. The government will increase its revenue stream by quantity extracted.

6.6.3. <u>Qualitative analysis</u>

The third step in an investment decision (3.2.1) should contain a qualitative analysis of the aspects that cannot be stated in the financial analysis of extraction. If the intangible costs and benefits are not evaluated, the final decision can be misleading. In this section we will further present reasons for problem, and the impact of plastic waste. We have earlier shown problems caused by financial factors, in this section we expand with the market and responsibility distribution. The problem discussed can be targeted by the government to improve the situation. It will likely be an endured cost for active measures. However, it would also bring in a benefit from the diminishing shadow cost of having less plastic in nature.

6.6.4. Economic impacts of plastic in aquatic environment

It is common to divide impact of littering into a social, environmental and economic component. All three will be briefly discussed. It can be difficult to classify an action into one sub-group of impacts, since it is often containing a combination between factors. In the following part of analysis, it will be explained the impacts of waste in rivers. By extracting plastic from aquatic zones, the negative impacts are saved. There are also positive economic impacts by removing waste plastic. The impacts presented are the components which make up what we earlier presented in the benefit of plastic extraction for government (V) in the (6.6.2) of social analysis.

6.6.4.1. Social impact

The social analysis of impact is often focused on the positive effects like job-creation and public health. Negative impacts are often more difficult to measure. Macro-plastic creates a well-being loss in polluted living environments. According to Sing & Sharma (2016) the chemicals within plastic can cause interruptions in biological functions. This can affect humans by disruption of thyroid hormone axis levels.
can often delay or change the process, in some cases even cause cancellation.

6.6.4.2. Environmental impact

Environmental impact can be addressed as the physical environment which includes geological and geographical characteristics of the location or the possibility of nature damage. Plastic pollution is harming lands, waterways, and ocean. Some of the effects of mixing plastic with biological life are reduced fitness and reproduction, and in some cases death. While the water enters the ocean, the chemicals will also be damaging birds, fish, crustaceans, turtles, whales, dolphins and other biological organisms. The effects of plastic are still an understudied field. It is often easier to see the effects of Macro-plastic effects; however smaller plastic particles will also have impact on our environment.
Reduced impact from pollution would improve water quality and benefit the ecosystem and individuals that use and enjoy the river.

6.6.4.3. Economic impact

The plastic pollution causes a financial burden. In a study by the UN, ocean plastic causes an annual $13 billion in damages to economies worldwide (Ocean Cleanup, 2019). Proper collection and further recycling of waste management give a potential reduction of production costs for producers, demand for landfill related facilities, saves energy, natural resources, and generate employment opportunities. Direct cost of plastic are degradation and damage to machinery operating on water, destroyed ecosystems and loss of nature.
Waste is a negative environmental externality of products and services. Authorities with the responsibility to provide infrastructures and policies should encourage waste collection in local communities. The economic environment is having a significant influence on the financial system.

The government should analyse cause and effects of plastic in rivers. By doing this they can start targeting effective measures to reduce plastic waste in an economical efficient way. The next chapter will discuss economic measures that can be implemented to improve the situation. Relative to earlier parts, the measures will should be targeting at improving problem areas, that will cause fewer negative impacts. In the financial analysis this will be done by implementing measures that change the desired variables, to reduce the marginal cost of extraction. The benefit of plastic extraction has to be decided outside the realm of financial analysis.

6.6.1. Causes of the problem

The responsibility of plastic in our environment must be shared. Individuals have a consumer responsibility, while corporate and governmental actors should look at social responsibilities in improving the situation themselves. Underneath are some of the reasons that are important for understanding our plastic waste problem. According to Dey (2001), one of the larger challenges to create a strategic waste management program is the lack of data. There are challenges in the national data gathering of waste production and management practices. An improved system would make it easier to know which areas to target for an improved system. A project of this type can be characterized as a research project and would bring a higher social benefit than private. This means that the government can expect to pick up most of the costs for implementing an improved data gathering system.

It would be possible to move some of the responsibility over on the corporate side. By implementing extended producer responsibilities, companies would take a more proactive part in reducing plastic waste. This was introduced in Brazil in 2010, with a law that provides the legal framework for solid waste management. According to (Gupt & Sahay, 2015) the law is built on the standardized EPR approach and defines stakeholder responsibilities across the value chain for selected products. The private sector in Brazil are also known for its high technology capabilities. This is shown in high innovation numbers within the country boarder. However, a lot of the innovation is adopted from other countries, and as a result, in 2018 the ministry of Brazil warned they wanted to cut costs in R&D investments for the private sector. Lower levels of R&D in markets that already suffer, will have negative effects, this is the case for river waste recovery. The Structure and collective work toward solving a problem will influence the operation and ability for success. When there are social inequalities, lack of political priority and issues of policy structure, there is a risk of discrimination of the poorest section of the population (OECD, 2008). The government have a responsibility of giving all areas of its society the necessary tools.

For Individuals education is a minimum requirement, for consumers a stronger education and incentive system could change behaviour to be more conscious about their usage. More people could substitute their one-time plastic products, with products of a longer time rate. Creating habits within a society to exchange useful products that have still have service life would save time, money, energy, and resources. Understanding the consequences and spread information among the population through legislation, acts, and rules can help to bring the situation under control. (Singh & Sharma, 2016) mention that the guidelines given to environmental authorities require future products to be more robust and biocompatible to give products a longer service life. A familiar challenge in developing countries is that land property rights are either informal or non-existent (Tietenberg & Lewis, 2016). This means that the land around the rivers is often acquired simply by occupying it and not buying and leasing it. The lack of clear property rights gives problems to efficiency and equity. It can be hard to distribute environmental responsibility with informal property rights.

The discussed problems are just some of the reasons for our plastic waste problem. We have also earlier explored financial problems, with negative NPV, high risk and low levels of support. Underneath we present the overview, that present some of the causes that lead to the plastic waste in our river. It is sorted by suppliers, surroundings, systems, and skill with an indication of resource allocation and not responsibility.

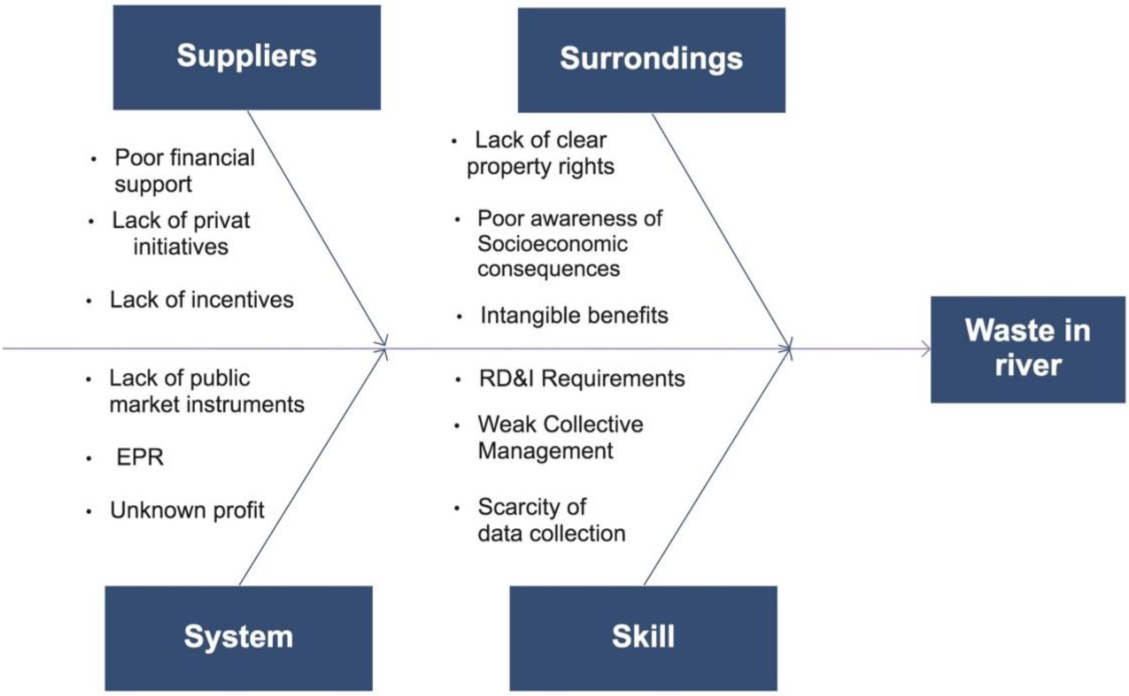

Figure 17 Socioeconomic overview

Source: Self-generated model Credit: Ishikawa

6.7. ECONOMIC MEASURES

The following chapter will investigate potential economic measures and policies that would improve the market situation. To analyse how involved the government should be with their measures, an analysis of the market state will be made. The chapter will touch upon areas such as market failure and possible market creation, appropriate investment methods, and evaluation of regulations and environmental policies.

6.7.1. <u>Market failure</u>

The economic measurement will contain a certain bias since it contains adjustments and unfamiliar costs that are often occurred for a first adopter. The extraction method can be categorized as applied research, since it is trying to solve practical problems while acquiring new knowledge. Notably the solution is based on existing technologies and processes that have already been tested in other locations. As explained (3.5.2), applied research is expected to have a higher costs and private return than social return. This often give enough incentives for private actors to enter the market (Kleer, 2010). However, In the case of market failure, this is not the case. In a state of market failure, it is not possible for private investors to become profitable. It is then necessary for the government to intervene in the market to secure a functioning market. This is likely to come at a cost for the government. The analysed extraction systems gained no positive return without governmental support, and we can therefor state that extracting plastic in aquatic zones suffers under market.

6.7.2. Market creation

There is an increasing supply market for technical extraction methods. But many governments have yet to show a willingness to pay for extraction. There is no doubt room for improvement in governmental action to become a market maker or creator on the demand side. By choosing focus areas for public activities the market-creation support is likely to benefit a broader set of negative externalities. This includes activities that is not able to document income or expenses but can prove a motivation for social environmental actions. The demand for environmental activities is increasing, but it also created a demand-pull. This give Entrepreneurs more market power, and they can require a higher expected return. This I often observed in high capital costs, especially for radical innovations that is creating a new market.

There is as increased awareness for aquatic plastic waste. This can be observed in media attention, research publications and pioneering work trying to find problem solutions. The innovation process of Mr. Trash Wheel (WWT) is illustrating the beginning of a market in creation. WWT was a new-born invention in 2014, five years later the solution has gotten global recognition. Other similar stories have also gained global recognition. Perhaps the most famous one is from the non-profit technology company Ocean Clean-up, who launched their “interceptor” In October 2015. It is important for efficiency as the global development continues that information is shared and collaboration among developers are established. Most importantly, the governments should gather data they can share, so companies can start looking for optimal solutions in the specific areas. The scaling potential for the market are indicated by amount of plastic in extraction zone, and potential of extraction by machine. A competitive firm want to expand scaling possibilities by acquiring multiple zones. There is thus an opportunity for companies to position themselves as market creators by entering pilot projects, and then scaling their extraction when they gain recognition. With a larger environmental demand, and more and more governments and institutions speaking of green economy, the coming years are likely to bring a larger market for plastic in aquatic zones.

6.7.3. Economic instruments

The government have various economic instruments to intervene in the market. When choosing instrument, the government want to maximise impact. In the following parts a brief evaluation of traditional economic instruments for governments are discussed. The preferred methods will vary between governments and nations, it is often a political question. The methods explained involve cost reduction, taxation and increased increase demand for recycled plastic. The chosen instruments will be relevant for the source of funding and responsibility distribution.

6.7.3.1. Cost-covering charge

Cost-covering charge can be done by cutting the production- (PC) and operational- (OC) costs. Reduction of expenditures is a method used in R&D projects where the support is given to a specific part of the innovation process. In general, we assume that the government prefer to subsidise basic- over applied research, due to the expected higher social return. Even when the project has higher risk and a more uncertain outcome of commercial application (Kleer, 2010). By defining steps of the process, it will be easier to clarify costs connected to each individual stage (Foray, Mowery, & Nelson, 2012). Traditional stages where governments have helped out with funding are within research, technology development and testing & implementation. It can be challenging to distribute the costs to individual steps, as they often have activities that cross over. The cost of total investment is analysed as potential funding or potential area for cost reduction. The following table show a general breakdown of how a standardized budget can enable regulations of investment. The distribution is based on collection systems and litter prevention projects (peer 6 and 3) where R&D contains 16.31% of costs that can be fully or partly funding by the desired fragment, even if the cost is being spread over different stages. Further details can be found in Appendix.

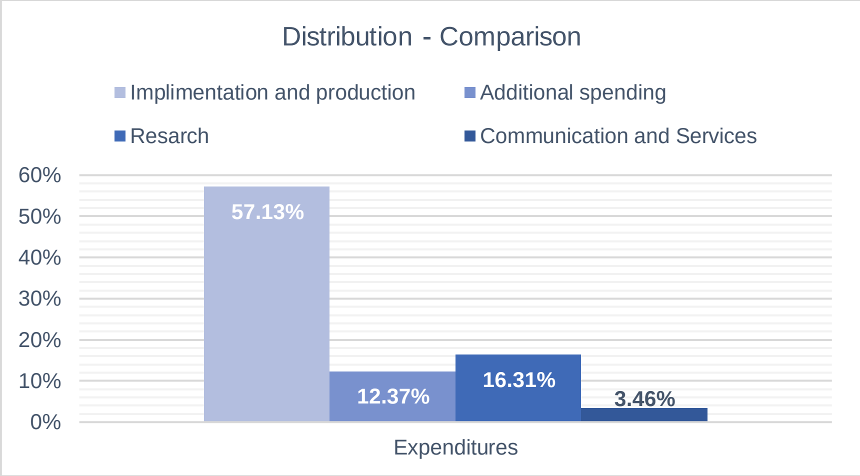

Figure 18 Distribution of costs

(Data from: (Edmonton, 2017) (Ocean Cleanup, 2018)

6.7.3.2. *Incentive tax*

An Increase in the price of products is a type of incentive tax (Ekins et al., 1990). To correct a market failure of negative externality, producer responsibility can be implemented. A concrete solution is the polluter pays principle (PPP), where tax is added on products to change behaviour. Alternatively, products can be tagged by their footprint (waste, climate, change). This has also shown to change consumer behaviour, the logo informs consumers of their contributions to the cost of recycling or recovery. The system is financed by a green dot license fee, paid for by the producers of products. The partaking producers are incentivised to limit their unnecessary packaging to cut costs. These taxes are called Carbon/Energy tax and Environmental taxation (ETR). Energy or carbon taxes have the effect of reducing end-use energy consumption under specific conditions. The energy savings gained through taxation shall ensure the achievement of the energy-saving target. Environmental taxation (ETR) reflects market failures, tax added on products will increase the efficiency of resource use in the market and will decrease the demand for plastic. Overall, tax will take environmental implications into account when manufacturing products and reflect the full cost of production (EEA, 2016).

Brazil has implemented producer responsibility for tires, which is possible to extend to other products most common to find in rivers. This effort requires improving logistics systems which must include the capacity to return the waste to the supply chain of the industry. This will not be federal regulations that influence private industrial practices, it will also require public practices especially at the municipal level (Jabbour, Jabbour, Sarkis, & Govindan, 2013). Giving incentives for producers to use fewer materials and designs to cut costs can also create incentives for R&D in recycling and reuse, moreover incentives for repair and remanufacturing. The disadvantages of introducing PPP, are fixed price increase that will relatively hit harder for those with less money. Evaluation of which product to choose will be important to not create social justice issue in a diverse population of income. This could slow down technological innovation (Green Partners, 2010). In Brazil, the government give tax reduction to projects characterized under R&D and qualifies under certain objectives. The Federal government in Brazil have a tradition of supporting through grants or subsidy to reduce total expenditures. Specific practices explain that support of each unit collected is another funding method in waste collection projects. The investment methods evaluated are grants, reduction of expenditures, or income support. Additionally, giving direct funding the government is able to gather taxation by the producers of the products being collected in water that can be allocated to cover the spending used to get the waste back into to supply chain in the industry.

The tax system can be used to promote recycling by taxing virgin materials. An example of the effect in the European approach to waste oil recycling have resulted in the collection of up to 65 percent of available waste oil. Introducing the same approach in the United States was less successful (Tietenberg & Lewis, 2016). Many governments are using tax policy to subsidize the acquisition of recycling in both the public and private sectors. This incremental mechanism can be presented on different authority levels. First of all, it can be introduced on a global level as a required national policy. Second, it can be decided by the government to be implemented as tax before import for larger producers of plastic.

6.7.3.3. *Increase demand of recycled products*

In the contract setup, increased demand of recycled plastic will increase level of S. It is important to be aware of common circumstances where the supply of recycled materials far exceed the demand (Tietenberg & Lewis, 2016). Further effort to increase the recycling will flounder unless it is forcing a new market where recycling materials become substitutes to new materials. The benefit from established demand of green products make consumer take part in environmental action. In the cases of dumping, recyclable materials remain stored until the price level is sufficient to cover the costs. In many cases recycled commodities compete with virgin prices (Biddle, 1993). From a public-policy perspective, recycling issue of collection and processing require technology and system refinement. To build profitable partnerships, suppliers and distributer can guarantee competitive price and volume of sales over time, to ensure lower prices. By giving appropriate incentive to recycled products, the marked failure can be corrected. The demand of recycle plastic is driven by suppliers and greater the demand of plastic products, the greater demand of recycling plastic will be. Demand curve for recycled plastic slopes downward which means that demand of recycled increase as the price falls. Increased demand will also increase the marginal cost and highly depending on volume of sales, that is predicted by a guarantee of annual production. A demand pull could be created by enforcing production companies to use a certain amount of recycled plastic in their production.

6.7.4. Regulations and environmental policy

This sector will contain analysis of distribution of investment by government, focus areas for the government on public activities, consequence of picking winners, key aspects to review in policies of concern and choice of instruments.

6.7.4.1. Distribution of investment

Governmental Involvement in market-creation is central, and the objectives that the government pursue are the basis for community action and opportunities to make changes. In terms of a single project, there are three key focus areas for public activities, stated in section 3.6.4. For optimal innovation policy, it should be analysed the potential choices of the objectives from the government when choosing "winner of investment". A study from 2005-2008 on governmentally supported firms and non-supported firms, stated that there is a negative relationship between size and R&D intensity, the samples where based on 243 firms from PINTEC. PINTEC is a survey of innovation that collects national indicators on innovation actions implemented by Brazilian enterprises (IBGE, 2020). Due to PINTEC's selection procedure small sized firm are more likely to have higher R&D intensity relative to larger. The results state that the size of the firms affects directly the R&D intensity, while the governmental support does not. (Rocha, 2015). The reason why public support is not outlined to provide higher R&D intensity, is said to be a consequence of a wide variety of instruments used in Brazilian innovation policy across regions, that give different levels of effectiveness. Since 2019, the aim has been a national innovation policy, that may give the opportunity to standardize the policy across sectors. In fact, Rocha (2015) states that previous literature has found a positive correlation with R&D intensity and some of the instruments.

For further development, a selective evaluation of instruments by effectiveness should be practiced in the national innovation policy.

6.7.4.2. Focus areas of public activities

The policy for green growth includes investment. An extraction system meets the hinder of weak pricing of negative externalities, and inefficient resource use, it also requires increased support in private investment. The overall barrier contains a need for investigation of circumstances and needs in this underdeveloped market. During 2019, the Municipal of Brazil has specified that a national innovation policy will involve the next ten years (Brazil Tech, 2019). The existing policy is not giving a framework that is able to stimulate research innovation and promote competitiveness. A steady policy for business and investment should reflect the position of the market and, therefore, evaluating where to support is highly beneficial. For governmental support of a single company or project, there should be three focus areas for sorting appropriate activity for investment: wherein the innovation chain to support, what is the mission of investing activity, and, finally, the risk associated along the business cycle.

The effect of investment in S (market price for plastic waste) will be beneficial to recover plastic in the water. Selective investment in the value chain and timing of project process is of importance when evaluating funding. As explained in 3.6.4., the investment can be placed and bonded to one or more of the five steps along the supply chain or innovation process (Foray, Mowery, & Nelson, 2012). This gives the government an increased insight and opportunity to standardize requirements of an ethical selection of projects. Before choosing which part of the value chain to support, the sectors, companies, or projects should be addressed by mission and risk so not only the larger technologies become a priority. In the position of market failure, a carbon tax is recommended, however, it will not be able to support the beginners if they are not in an existing position of paying tax. The supporting methods analysed in this is therefore stated to comprehend other relevant taxation and substitution mechanisms. They are seen as instruments for market-creation remove investment barriers.

6.7.4.3. Picking winners

When analysing the waste market with almost non-existent competition, the failures are important learnings that should be taken into account. The evaluation should be taken in four steps. It is important to evaluate the project based on spill-over effects that can increase the speed of innovation to other areas. Research show that projects with increased governmental support gain higher R&D intensity. The project should also be categorized as either end-product or process, which will say something about the potential for profit. An extraction system in Brasilia can be categorized as a radical innovation that involve high risk. It is of importance to look at economic factors. In the beginning a reliable project is preferred to gain better knowledge of future improvements. The last challenges contain fragile demand-pull and expectation of payoffs. This challenge is especially important for environmental technologies where the government is involved. The reason contains that if the policies are uncertain the market contains an imbalance in aggregate supply and demand, the prices will get upward pressure on prices of supply.

In the history of revolutionary technologies from tech companies like Apple, the development was funded by the government. The secret behind every innovation can be explained by the risk-taking partners supporting early-stage finance and government-funded research activities. In the case development of iPhone, venture capitalist entered only after the government funding where critical proof of concept of the company (Mazzucato M. , 2013). If the innovation or invention meets the criteria of social benefit-cost, it is important that the government is willing to take entrepreneurial risks where the market will not reach. Radical innovation as GDP, smart-phones is extraordinary examples of the success of tech companies with governmental support, however, it will be important to not only pick the winners industries while it can end up ignoring other valuable possibilities for economic development from public-private joint efforts and public leadership (Raworth, 2017, p. 73). Along, a second direction according to risk is considered public acceptance. Projects that are typically unfamiliar is unlikely favourable. Considering public acceptance, there should be an of combinations of certain sceptics to reach benefit-cost criteria, as well as a certain tolerance of risk and failures (Krause, Carley, Warren, Garham, & John, 2014) (Geels, Berkhout, & Van Vuuren, 2016).

6.7.4.4. *Policies of concern*

The national innovation policy (3.4), the policy of green growth (3.4.1), and solid waste management regulatory policy (3.4.2) are relevant laws and regulations that have been discussed in this research. There may be other policies that will be even more important to discuss, from other stakeholders relevant to the research problem. It has been analysed and discussed how these policies can be improved by defining clearer objectives and the creation of an ecosystem in the waste market that enables better collaboration among parties, competition, and culture for the creation and development of the waste market. Collection of plastic and selling recycled plastic is a potential market, as well as a market of the technical solution of collection.

Extended producer responsibility (4.5.2.6) is central in the policy improvement. Producer and consumers are the sources of generation of waste, where the policy needs a systematic collaboration of private and public actors. More precisely, producers should be a selective decision of material to reduce packaging and increase reuse as much as possible. The government should aim higher recycling rates by funding recycling programs in a cost-effective manner. Tax implementation for producers with less recycling and reuse will higher cost that decrease demand for these products. The consumer will be responsible for the choice of choosing a product with recycling companies in front of others. The optimal market will be lower prices for second-hand products compared to new. To get there, the collection and recycling process has to be cost-effective and plastic has to be easily converted into the required quality level. If the policies are uncertain the market will be imbalance and that gives upward pressure on prices of supply.

6.7.4.5. *Choice of instruments*

How the government aim market-creation and governmental intervention in the economy define the market. Focus areas from the government are the drivers that set the standard for the lower levels in society and faction taken. As the government is reducing funding of R&D in the private market, it will not be creating incentives for technology innovation as some of the main objectives while introducing the national innovation policy. Market-creation can contain a framework of regulation and support and it will be important to have instruments that meet all industries regardless of existing development. The choice of instruments that will support the project will crucial for (P) and the level of debt from the investor (I-A). In the section of investment methods, we have outlined the market instruments seen more relevant to implement to stimulate private actors to develop a solution for collection. Cost-coverage charge, and inventive tax will also make start-up, developing, or small companies better off, like larger companies and well-structured industries, are today. Picking the winner is a normal practice failure. A project with governmental support is positively correlated with higher R&D intensity and can be assumed to create more value for the return. It is said that tax relief is found to provide more stimulus to business R&D that direct support (OECD, 2007). Since tax reduction is not relevant for a negative project, direct support in the R&D phase of the process may be the substitute (4.5.2.4.) (Foray, Mowery, & Nelson, 2012).

6.8. SUGGESTION OF IMPLEMENTATIONS

In the research of empirical studies, there are several valuable objectives and recommendations worth mentioning for further research. In the literature and empirical part of this research, objectives for Brazil and challenges are addressed. In the following chapter, we have gathered some implementations to apply in the local community through the collaboration of private and governmental authorities.

6.8.1. Evaluation of existing extraction systems

In our process of research, WWT and BLT are two solutions that are chosen to address among the 30 solutions that have been identified (Appendix 6). These two solutions are not said to be the optimal solution for Brasilia, but they are tested solutions that may define early entry in the waste market. As a first step, the existing solutions should be analysed before making a decision as these companies are established institutions and have been working in the field for almost a decade, they have significant technical and practical knowledge that should be spread worldwide to solve problems in local communities. As mentioned before, the examination of the cost data (5.3.4) comparing size and production level, will give valuable information on where the struggle can occur. Consequently, it can give an indication of where the innovation process public funding can have a crucial role, giving guidance for marked creation support instruments in market failure of negative externalities (Lundvall, 1992). We defined the valuer as the government or a relevant actor in Brasilia. By analysing we will gain an understanding of asset and functions in environments, knowledge of specific asset in current market, physical life and functional, technical and economic undesirability as more outlined in theory (3.2.1.1) (RICS Group, 2018).

6.8.2. Policy

To get the full benefit of applying producer responsibility policy in society we can focus on some specific objectives. (1) the preparation of reuse after collection, (2) set the responsibility on the individual level so the producer manages his own waste and (3) making the producer financially responsible for arranging waste collection and management on a physical level. It can be shared between customers and producers or fully given to this latter. The terms can be binding or non-binding market-based instruments. The decision-maker should analyse the prediction of policy action and the physical and economic consequences based on the processes involved. Policymaking seeks to minimize the risk of harm, especially for the most vulnerable people in the face of uncertainty. We cannot predict the future of the waste market, either can the system be fully controlled, but there are opportunities to redesign it around the market to better meet the upcoming development.

6.8.3. Solidarity recycling

Existing national innovation policies in Brazil tend to favour larger companies. Lei do Be, and Lei da Informática, is the two main federal laws administration R&D tax credits but are basically more accessible by large firms. Data from MCTIC form 2012, explain that 81 % of the hardware and related electronics firms received tax credits under Lei da Informática and contained over 500 employees (45 larger firms). This was 160 times more beneficial to larger firms that small firms with less than 500 employees. In 2017 Lei do Bem 92% of the support were given to larger firms (Dutz, et al., 2017). This historical data explains that the project of the extraction system with lower than 500 employees, is less likely to receive a tax credit. Unfortunately, innovation programs beyond R&D tax credit with the purpose to foster productivity growth also appear to benefit mostly large firms. The benefit programs PIE, BNDES, FINEP targeted certain sectors with typical domain of large corporations as defence, energy, mining, and petrochemical. In 2016, the BRL budget from PIE of total 32.9 billion, only 1.8 billion was given to SME. 66 % in subsidies credit, 19 % as grants, 12 % ad equity investment by Criatec Funds. The rest 3 % was given to decentralized intervention delivered by local governments (Corder, Buainain, & Souza Lima, 2016). In relation to the business case and if the project turned out to give a positive return on investment, these benefits programs are not likely to reach the start-up companies. The 3 % support to decentralized intervention from local governments reflects today's practice and the low probability to receive funding. The introduction of the National Innovation Policy hopefully gives a better distribution among all sectors.

6.8.4. Evaluation of existing instruments

Investment promotion authorities and revenue collection agencies have shared responsibilities. But often working towards different objectives, especially in the context of developing economies as we find in Brasilia. It will be important that the policymakers have a holistic view of the waste collection market and how the tax, social development objectives, and the need for investment is balanced. In today's position of tax reduction, we see that tax support mainly sustains firms with more than 500 employees and companies that can prove a solid technology development. This will make the start-ups or projects companies in any sector stand-alone with no position to receive needed support. The tax system should ensure to cover all sectors and be arranged in a standardized manner. The method mentioned as an effective instrument is the tax for polluters (Extended Producer Responsivity) where tax payment is used to cover the cost of management of the waste collection. A way to look at waste policy instruments today, is that the policy is not designed to support the starting research process and innovation for small companies. A well-known motto in economic philosophy from late-twentieth-century states; "Nations have to push through the social pain of high inequality if they want to create a richer, more equitable society for all" (Raworth, 2017). The government should have a clear focus that is reflected in the choice of instruments and regulations of their policies. The few interactions Brazil have with its private actors are not enough, and there are potential for large improvements.

6.8.5. Waste management

In addition to innovation policy, the solid waste management policy is the regulatory policy on national, regional, and municipal level which is relevant for the practice of waste handling and recycling (Jabbour, Jabbour, Sarkis, & Govindan, 2013). The most important aim of the policy, concerning the river extraction system, is to encourage and promote the management of waste recycling and to develop clean technologies for minimizing environmental impact (3.6.2.). The policy has met several challenges with delivering a local compliance plan to the local communities. Issues such as a lack of coordination between the parties involved in the recycling system, a scarce presence of experts with knowledge in solid waste management and the difficulty in establishing specific goals and long-term strategies, and these should be addressed with specific measures. It is stated clear objectives for the policy; however, further public and private development is needed for progression. Long term strategies will increase understanding and make it easier to distribute responsibility. Further, collaboration will enable better awareness for the causes behind the problems that are increasing plastic in the rivers.

To improve waste management, several social activities outside of collection systems are needed. This thesis has focused on methods of aquatic plastic extraction. Evaluating the opportunity cost of investment is responsibility of decision-makers and the waste management policy. Moreover, it will be important to create clear objectives and responsibility for businesses and individuals, so each level of society understands how to contribute solving the problem.

To explore the opportunity cost of implementing an extraction system, we will look at three different activities with documented effect. The first projects took place in Maryland, Virginia, and the District of Columbia (U.S). Alice Ferguson Foundation arranged workshops between governments, non-code enforcement agencies, sheriff offices, local police, neighbourhood service, transportation and environmental services with the scope off increasing social-environmental awareness of the effects littering has on the community, economy, and law associated. The outcome was agreeing on actions for reporting concerning litter, illegal dumping and keep track of any citation. From 2012 to 2013 the citation issued was reduced from 850 to 643, which is a decline of 24%. The second project arranged in 2013, tried to improve the cleanliness of neighbourhood's and service for illegal dumping by implementing recycling bins instead of containers in the most affected neighbourhoods. During 2014 the recycling increased from 26-37 % (EPA, 2015). The last priority action contains returning bottles, multi-use bags as an effective upstream measure. Ensure the plastic has a price by applying a deposit found to bottles and charge tax of plastic bags that will reduce consumption and contribute to a circular economy. This action is recognized and research by the parliamentary Environmental Audit Committee found deposit return schemes recycle about 80 % to 95% of plastic bottles. From 2001 to 2017, 95 % of plastic bottles was recycled in Norway while only 56 % were in England (Parliament UK, 2017). In England, they have also implemented single-use plastic carrier bags that resulted in 83 % fewer bags (reduction of 6 billion) from 2016 to 2017. This taxation resulted in retailers being able to donate around 16 million to research and other good causes in 2017 (gov.uk, 2019). It can be further discussed best practices to ensure savings, distribution of waste management system, choice of a key local authority in charge of waste collection, and whether the council will be responsible for the waste disposal. If EPR schemes were adopted to make producers more financially responsible for packaging disposal, the local authorities will bear less of the cost.

Program	Per year
Municipal Trash Can Pilot	$ 12,000,000
Litter and Illegal dumping	$ 6,000

Figure 19 Potential social activates

Source: Self-generated table, data: (Parliament UK, 2017)

6.8.6. <u>Support of private sector initiatives</u>

In 2018, the ministry of Brazil warned they wanted to cut costs of R&D investment in the private sector because the patent level is low in Brasilia. It was argued that most of the innovation carried out there, derived from improvement or adoption of technologies from other countries and that therefore the innovation is not much likely to occur inside the country. This brings a two-sided evaluation of today's position of innovation level in Brazil. The patents do indeed reflect the level of innovation in the country, but it is not the only factor influencing it. The capability of implementing innovation from other countries can be explained by having a high level of absorptive capacity that could give in the future the possibility of creating innovation. In a global overview from 2019, Brazil is mentioned as one of the most top science and technology clusters among the U.S., China, Germany, India, Iran, Russian Federation and Turkey (WIPO, 2019). Using patents data as output measure does not necessarily represent a commercially exploited innovation, in some cases, patents are better indicator as input to innovation process rather than output, since the invention that is patented differ greatly in quality (Griliches, 1990, p. 1670).

6.8.7. <u>Recycling initiatives and relations in Brazil</u>

Historically, as other developed countries, Brazil has a large number of workers engaged in commercialized material collection from streets and dumps. When studying Brazilian recycling, the informal waste collectors should not be taken for granted. In the past decades “solidarity recycling” organizations have spread rapidly all over Brazil from a few in 1980 to 900 companies in 2010. It has incorporated municipal recycling programs that have been recognized in National solid waste policy. Cooperatives and recycling associations in Brazil have already obtained a knowledge base of the field. Studies on how the heterodox form of organizing recycling has been spread over the country explain that most organizations aimed to promote recycling models with normative orientation. From the perspective of strategic action field (SAF) (Flingstein & McAdam, 2012) it will emerge a need for: resource mobilization, political process, and fashioning of new relations among existing collective actors to make a larger change of social structure inside the country. SLU is an autarchy of the Federal District government connected to the State Secretary of Infrastructure and Public Services managing urban cleaning and solid waste. This company has been responsible for a wide range of services in many years and has been an important human and physical resources.

To gain a better collective output of the system, the responsible authorities should search for practices in other localizations of technological systems and empirical research.
Data collection in a global standardized manner will increase the value of data and increase awareness of the total effect of recycling. New relations across actors are being triggered by demographic and technological shifts, the extent of social organization, and state actions. For each location, this relation occurs nearby. For the field to become established in Brasilia, the parties involved have to achieve a certain degree of consensus. It will include what waste collection is about, who is a part of it, what the roles and comparative status of these components, what rules govern interaction is and how the actor in each position should behave (Silvio, Soule, & Neto, 2019). The group of actors should contain certain field frames of skills and power with shared identities, meaning, and concepts of interest.

6.8.8. Local goals and long- term strategy

Based on theoretical research (A.B.L.Jabbour et al., 2014), the three recommendations for improving solid waste management in Brasilia contain (1) address the specific waste management an litter behaviour in location, (2) categorize plastic found in lakes and (3) find the residence time of plastic and what plastic is expected to be found on the surface and on depth. These recommendations are beneficial to follow. A global database needed, with standardized research methods. Brasilia should take part in this. After Solidarity recycling was introduced there have been some companies that have become the main supporter and promoters of the “Brazilian model of recycling” and have been promoting it as a way to combine environmental conservation with the social inclusion of collectors. One company taking this position is CEMPRE, an association consisting of major multinational companies engaged in stimulation recycling in Brazil and is a central actor concerning this research. Following there are other actors find with a significant position as Periódicos CAPES that is databased maintained by the Brazilian Government compiling National and International databased. They are also representative of the National academic production. According to the work of these actors, it is fair to assume there is a limitation of available information on existing data collection. In terms of increased awareness and initiatives of improvements in waste collection, it is found that significant data of waste is not open source. This is seen as a hinder for the society and researchers not being able to clarify and get insight into this relevant information.

6.8.9. Data collection

Studies from Europe (Wintson, Anderson, Rocliffe, & Loiselle, 2019) present the most prevalent macro-plastic items in freshwater. Due to a lack of standardized data collection methods, the sample sizes are not satisfactory. It is often difficult to compare studies. From a scientific perspective, a universal standardized approach would improve the situation. A large standardized database would increase the quality of research done on river plastic. There is demanded collaboration to merge the data sources on the regional and international levels, for how to take action on the reduction of plastic in freshwater. Further effort is recommended to focus on (1) different waste management, (2) difference plastic found in tidal rivers and non-tidal rivers, and (3) depth specific residence time from different items on the surface and deep.

Identifying the benefit from an available source such as national accounts published data and background data sources is difficult if it is not at a very aggregated level as an institutional sector. The process of data collection can be in various forms; however, the period will be less important to state in the aim of this research. The following table outlines the data arrangement, participants, and collect practice as three mains filed of work. Concerning mentioned challenges, after solid waste management was introduced in 2014, collection of data is expected to improve (2) Lack of qualified experts knowledge and logistics and (3) vague goals and long term strategies (A.B.L.Jabbour et al., 2014). The concern of data is already stated in studies on Sao Paulo, Pernambuco, and Brasilia from the Federal University of Sao Carlos (Silvio, Soule, & Neto, 2019). Creating a network of actors and determine responsibility by policy and find hinders of why specific data is not systematically collected, will easier distribute logistics and objectives to local authorities.

Field	Short term	Long-term	Primary	Secondary
Improve documentation data	Evaluate period of diffusion	National databases	Investigate gap of secondary data	Interview and participant observation
Assess organisations	Actors and field interconnection	Local goal and long-term strategies	Evaluation of participants	Pioneer recycling organisations
Collect literature & nearby practices	Assess nearby field	Influence Federal Government Solid Waste Policy	R&D and Institutional reports	News published in media

Table 12 Data collection process

Source: Self-generated table

Data collection can be separated into these three fields of improvement; improve documentation data, assess relevant organizations, and collect nearby practices and research of data that already published, according to the aim it is specified short- and long-term objectives. To create a reliable national database, the primary work should be to investigate the gap of collected and what should be collected. Secondary, arrange interviews on how to get the process going. The next aim of having local goals and long-term strategies will include assessing interconnection that exists already, evaluate the participants, and choose pioneer organizations that will lead the work. The last aim to make changes in the policy of data collection, it should be chosen field and practices for observation. Sources to obtain this study will be institutions and publishes both nationally and internationally. The exact data that this research suggests being collected and shared in public is the following:

- Annually waste collected per year
- Categories of plastic types found in river and land (by region)
- Annually average recycling prices of plastic types
- Annually average mixed plastic price

7. VALIDATIONS

7.1. SYSTEM

There is not a single solution that will solve the problem of unmanaged waste. It is also likely that there are other aspects of the situation in Brasilia that is not covered or discussed in this thesis. All suggested solutions and implementations are based on public information and the general framework of the field, that realistically require deeper analysis. It can be a difference in geography, culture, and behaviour among suppliers and consumers or technology variation between countries that make the findings inconsistent with reality.

The system analysis shows an irrationality treatment of our plastic resources. Each sequence that is leading to a different output than recycling will create a reinforcing feedback loop, increasing the output stockpiles even further. This means that a plastic product is thrown away, and not recycled properly will be stored in either nature or manmade storages (Landfills, dumps). When the energy that is still captured in this product is not used, further energy extraction is needed to create a new product. This product will then end up with the same fate, and ever-increasing our stockpiles. The feedback loops are seen as fundamentals of complex systems and highlight the importance of broader system thinking when making economic decisions.

7.1.1. Limitations of measurements and data in of system

Previous research on environmental accounting contains a lack of a standard definition of environmental costs. In the case of environmental protection projects aiming to prevent waste or emission, the outcome is not directly valued. To understand the cost of system, the comparison between different accomplished projects and related organizations providing waste service and collection solutions was used to understand the distribution of the potential solution. The cost-based pricing method can contribute to opportunity costs of investment being ignored or consumers' role ignored in the overall market.

BLT will contain developing a system that acquires new knowledge since the knowledge of waste generation, in general, is stated as underdeveloped. For countries that have a long history of research on waste collection, this research can be stated as basic research. Moreover, the system will be based on existing knowledge to prove, test, and demonstrate the process and system that will define the research as experimental development research. The purpose of defining the research type will determine if research qualifies for tax incentives given in Brazil. Law of good will be applied to companies with taxable income and operation acquired in Brazil, still, it is specified that most of the incentives apply only to companies that adopt profit methods to pay the income tax. For a project that is not generating revenue yet, the tax benefit is less possible in these projects even they fulfil further requirements. This is where the policy can be confusing while trying to support market-creation due to always have representative accounting.

7.1.2. Estimations

The estimation of Plastic quantity follows similar framework to most cited papers on the subject. We tried to make the estimations based first-hand local sources. Compared to more complex studies (Lebrenton, et al., 2017) our limitation come from us omitting the water cycle and drainage basin variables. We also had to use data from the world banks universal models due to non-existing local data. Other papers who perform similar estimations often rely on same source. To improve the estimation, more quality in input data would be necessary. This would require better data gathering from local sources.

The distribution of what type of plastic that is expected to be found in rivers were also an understudied field. Most of the research done on plastic types are on micro-plastics. A metanalysis by (Erni-Cassola, Zadjelovic, Gibson, & Christie-Oleza, 2019) finds the 95% mean confidence interval for micro-plastics by using data from 39 studies. Their distribution is different from the once we have estimated. There will be differences in the topside composition of micro- and micro-plastic due to buoyancy differences. No significant meta-studies were found for Macro-plastic. The data we found to be most reliable were from the international coastal clean-up day. They count picked up pieces from all over the world, and store that data in a set online. The dataset lists product found. With a quick search online of their average weight and polymer type, distribution of type was created. This distribution is not perfect and will contain errors. They weight of pieces was unknown, and the composition will never be 100% of one polymer type. We, therefore, recommend further research and more extensive data collection of macro-plastic collected in rivers to improve the estimations used in this analysis.

Quality has been omitted from our analysis as no data on the matter could be found. Quality will be of importance for understanding what potential uses river plastic can have and is thus something that should be extensively researched more. There is very little knowledge of plastic degradation in aquatic environments. The quality that is expected to be found in aquatic sources, will directly interfere with the market price of recovered plastic. Since there is no clear value on plastic recovered, three estimations on other stages of the value chain were created. It is fair to assume that the real price of recovered plastic will be below the lowest price used in our calculations. Even with what is likely an overestimation of price, the story is still clear that this is not a feasible operation.

7.2. ECONOMIC ANALYSIS

The economic analysis evaluates the collection system, required investment where the level of collection and cost based on previous projects. Therefore, it is important to evaluate the given estimations further. The collection of waste also contains general waste and plastic that can recycle and not. Waste collection is a wide topic that requires much work to do detailed research in every step, this remains some limitations during the period of research. The benefits of analysing a location from a distance, contain seeing the problem from a new perspective and theoretical view than from the inside. On the other hand, it takes a longer time for outsiders to establish a basic knowledge of Brasilia.

The crucial problems with our economic analysis lie in uncertainty from estimations and assumptions. As pointed out many times in this thesis, the data for reliable calculations does not exist. This high level of uncertainty in input data weakens the output numbers to such an extent that they can't be used in current state. The uncertainty moved us over to our final sensitivity analysis, this analysis is the most meaningful and valuable. The interaction between our uncertain input and output variables of interest are likely to have similar behaviour as more reliable data would have. It is a fair assumption to state that variables in our model will have similar interaction effects as they will have in the real world. The strength of our analysis is in the framework used and interaction output from sensitivity analysis. As better data is collected, the variables in the model can be easily updated for an improved output result. The financial variables of interest rate were also weak. It is a difficult discipline to create risk analysis in a market that is suffering under failure. The rate used was according to Damodaran (2016) on the edge of the 95-percentile of premiums observed in the market. It signifies a very-risky project, but we cannot state that the rate used will reflect the risk in this project. For such a statement more analysis and datapoints would have had to be integrated.

Both the business and social analysis suffers under input data. For the social analysis there is also an added component of asymmetrical information. We have little to non-information of potential benefits from shirking, and how dependent the project outcome is on effort. The framework highlights that these are elements in a contract of two parties. How large the problem is would require more extensive research of operational risk. The numbers used, is thus only based on heuristics, and contain no significant reflection of the market.

7.3. ECONOMIC MEASURES

The collaboration between private and governmental is an ideal solution for implementing the extraction system. In the optimal market of collection of plastic and recycling, it would be created a competition and enough private return to operation be financed by private actors.

Policies, funding, and regulations that are addressed, as well as the issue of inequality of funding. Since there is more than one policy that appears relevant, there can be other relevant policies or instruments that may support research and innovation projects that are not addressed in this thesis. In the concern of social and environmental sustainability, there is a need of ensuring that policy is improved along with the market development. Innovation and research generate positive synergies in terms of growth, efficiency, and equity. The key technology trends are often associated with existing well-established industries. It is important to support the new development of the waste collection industry. It is not found economic return for a business operation with current policy or investment from government, although it is found a clear social benefit opportunity in Brasilia, that is relevant in socioeconomic growth and aims environmental emissions in the long term.

8. CONCLUSION

Looking at a broad set of the relevant academic literature, we could not find other studies that are comparing river plastic extraction. There is however an increasing literature that address the harm of plastic, and importance for taking action. Further there are an increasing number of studies of plastic in the aquatic environments, showing the topic is gaining more and more momentum. Our thesis has analysed many aspects of river waste extraction, we will conclude our findings by answering each of the four goals in order.

The relation between the value chain of recycling and the various elements involved in plastic recovery were presented as the full recycling system. This system was shown to be of a dynamic complex nature. The economic analysis was a fragment of this system. We recommend that a government looking for optimal strategic waste management should acquire the necessary data to perform similar analysis on the full recycling system. By performing complex analysis, it would increase the reliability of the data, for finding optimal economic measures. analysing on the complex system, no variables are treated as exogenous. Our analysis of Brasilia highlights a need for improved data from all parties of the recycling system to create any meaningful quantitative output data of measures. Improved data collection mechanisms should be implemented across the value chain of recycling. It is also recommended that the city open up the model and give Lake Paranoá an economic status. The current approach with the lake as a non-economic reservoir, will continue to push the environmental ceiling due to reinforced feedback loops.

Our research combined financial and operational analysis of two solutions extracting plastic from rivers. The findings emphasized a need for collaboration between private actor and public sector. The private sector is in need of support to reach economic feasible plastic extraction projects. The business analysis was done by the use of NPV and estimations of breakeven quantity to benchmark the quality of the project in financial measures. The analysis highlighted the need for governmental interference. The market has a high level of risk, and the uncertain climate make it difficult for a private actor to enter. We analysed a governmental subsidization case in our performed social analysis. The benefit of investing in this market for the government were untraditional financial factors. A government should have a willingness to pay for decreased environmental harm, and by which turn a negative NPV project into a positive. Their willingness will depend on governmental characteristics and objectives. The viability should be considered by other objectives than only financial entities, since the project is subject to legal constraints, competitive advantage, and future growth (Stewart & Mohamed, 2002). We discussed the impacts of having plastic in our aquatic environment, for the above stated reasons we have not try to quantify nature. The government's willingness to pay for the protection of nature is a question for other disciplines.

The plastic waste market in Brasilia, like most other places, are suffering under market failure. This is shown in the levels of mismanaged plastic that end up in our environment. We argue there is room for better collaboration across private and public institutions, to improve the current market. It is important that an evaluation of the effectiveness of current policies and potential market instruments are performed to better understand how to increase support for entrepreneurs and market entry. Policies should be focused on increased interaction across relevant stakeholder to establish a market. It is important that policy makers consider alternative market instruments to increase the balancing feedback loops by lowering market entry threshold and improving R&D intensity support. The current tax reduction measures taken by the government of Brasilia have been shown to be too little. It should be facilitated a better collaboration between the waste management system and the nations tech- and production industries. This could create new developing industry that would work towards socioeconomic goals through innovation. Local authorities should make a standpoint towards waste collection development. Better publicly stated aims of increased recycling and reduced environmental harm, would likely improve long-term effects. Corporations and businesses should think more holistically with a corporate social responsibility perspective. And the government has to facilitate so these behaviours can be done without too high effort. And individuals have to increase their awareness of waste handling and take an active part in the collaboration.

8.1. FUTURE OF SYSTEM AND RESEARCH

Research on the economics of commercially available technologies is needed to give a broader knowledge available development of the waste collection. Research on risk factors for an extraction system company to better understand capital cost and limit the asymmetric information. Impact analysis of chosen economic instruments for waste handling, to get a better understanding of effective measure. It includes feasibility studies of the efficiency of equipment, quantity, suitable circumstances, and the timeline for target effect. Establish standard data collection and categorization of systems will improve evaluation for decision-makers. Publicity of research and data of waste management on a national and regional level will stimulate a market with a mixture of governmental and private actors. A governmental data collection of waste patterns is needed for a better and well-performed analysis.

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11. APPENDIX

APPENDIX 1: SYSTEM

Calculations behind table 6.6.2.The calculations are explained in detail in theory section: 4.4.1 & Analysis section:6.6.2. The output is explained in 6.6.1.

Independent variable	BLT		WWT	
Q		150		200
P	€	418.24	€	1,144.62
V	€	192.36	€	484.52
B	€	22,143.20	€	58,740.00
Discount factor Equity		86.96%		86.96%
S	€	102.88	€	102.88
PH-PL		0.5		0.5
A	€	192,549.57	€	510,782.61

Indicator	BLT		WWT	
Cost of Debt		1%		1%
Cost of Equity		15%		15%
WACC		10%		7%
S	€	102.88	€	102.88
PH-PL		0.5		0.5
Machine cost	€	89,000.00	€	623,000.00
Maintenance cost	€	39,160.00	€	89,000.00
Equity		68%		48%
Debt		32%		52%

	Financing			
System	**Captial cost**		**Maintenance**	
BLT	€	89,000.00	€	39,160.00
WWT	€	623,000.00	€	89,000.00

..

	S * Q				**P*Q**			
Years	**BLT**		**WWT**		**BLT**		**WWT**	
1	€	15,432.00	$	20,576.00	€	62,736.49	€	228,923.48
2	€	15,432.00	$	20,576.00	€	62,736.49	€	228,923.48
3	€	15,432.00	$	20,576.00	€	62,736.49	€	228,923.48
4	€	15,432.00	$	20,576.00	€	62,736.49	€	228,923.48
5	€	15,432.00	$	20,576.00	€	62,736.49	€	228,923.48
Total	€	77,160.00	$	102,880.00	€	313,682.43	€	1,144,617.39

Capital structure								
	I				A			
Years	BLT		WWT		BLT		WWT	
1	€	128,160.00	€	712,000.00	€	38,509.91	€	102,156.52
2	€	39,160.00	€	89,000.00	€	38,509.91	€	102,156.52
3	€	39,160.00	€	89,000.00	€	38,509.91	€	102,156.52
4	€	39,160.00	€	89,000.00	€	38,509.91	€	102,156.52
5	€	39,160.00	€	89,000.00	€	38,509.91	€	102,156.52
Total	€	284,800.00	€	1,068,000.00	€	192,549.57	€	510,782.61

	I-A				Rb			
Years	BLT		WWT		BLT		WWT	
1	€	89,650.09	€	609,843.48	€	44,286.40	€	117,480.00
2	€	650.09	€	(13,156.52)	€	44,286.40	€	117,480.00
3	€	650.09	€	(13,156.52)	€	44,286.40	€	117,480.00
4	€	650.09	€	(13,156.52)	€	44,286.40	€	117,480.00
5	€	650.09	€	(13,156.52)	€	44,286.40	€	117,480.00
Total	€	92,250.43	€	557,217.39	€	221,432.00	€	587,400.00

	BLT						WWTI					
Years	Debt		Debt increase per year		Yearly coverage		Debt		Debt increase		Yearly coverage	
1	€	89,650.09	€	17,930.02	€	17,930.02	€	609,843.48	€	121,968.70	€	121,968.70
2	€	650.09	€	162.52	€	18,092.54	€	(13,156.52)	€	(3,289.13)	€	118,679.57
3	€	650.09	€	216.70	€	18,309.23	€	(13,156.52)	€	(4,385.51)	€	114,294.06
4	€	650.09	€	325.04	€	18,634.28	€	(13,156.52)	€	(6,578.26)	€	107,715.80
5	€	650.09	€	650.09	€	19,284.37	€	(13,156.52)	€	(13,156.52)	€	94,559.28
Total					€	92,250.43					€	557,217.39

Yearly coverage				
Years	BLT		WWT	
1	€	17,930.02	€	121,968.70
2	€	18,271.84	€	119,899.25
3	€	18,671.25	€	116,712.74
4	€	19,183.01	€	111,301.60
5	€	20,024.93	€	99,258.10
Total	€	94,081.05	€	569,140.39

Subsidy				
Years	BLT		WWT	
1	€	32,023.64	€	99,672.18
2	€	32,023.64	€	99,672.18
3	€	32,023.64	€	99,672.18
4	€	32,023.64	€	99,672.18
5	€	32,023.64	€	99,672.18
Total	€	160,118.19	€	498,360.90

Profit								
	Breakeven V				NPV for E			
Years	BLT		WWT		BLT		WW	
1	€	(478.13)	€	(2,439.37)	€	5,023.03	€	13,324.76
2	€	116.28	€	659.18	€	4,367.85	€	11,586.75
3	€	117.73	€	637.25	€	3,798.13	€	10,075.44
4	€	119.89	€	604.36	€	3,302.73	€	8,761.25
5	€	124.23	€	538.58	€	2,871.93	€	7,618.48
Total	€	-	€	-	€	19,363.68	€	51,366.68

APPENDIX 2: SENSITIVITY ANALYSIS

The analysis is done by the use of formula:

$$\frac{\Delta Y}{\Delta X} * \frac{X}{Y}$$

The variables used are the same as in the section above. For further detail see explanation of that section.
The output is explained in detail in analysis section 6.6.2

	Δ X		X	
Indicators	BLT	WW	BLT	WW
Q (1%)	1.5	2	150	200
Rd (1%)	0.01	0.01	1%	1%
Re (+1%)	0.01	0.01	15%	15%
P_H-P_L (1%)	0.005	0.005	0.5	0.5
CC (1%)	890	6230	89000	623000
OC (1%)	391.6	890	39160	89000
S (1%)	1.0288	1.0288	102.88	102.88
N (1 year)	1	1	5	5
B	221.432	587.4	22143.2	58740

Y						
System	I	A	I-A	P	NPV	V
BLT	286630.611	192549.565	94081.0458	420.684061	19363.6802	192.362667
WW	1079922.996	510782.609	569140.387	1156.54039	51366.6758	484.52

ΔY						
BLT						
Indicators	**I**	**A**	**I-A**	**P**	**NPV**	**V**
Q (1%)	0	0	0	0	1420.99122	-0.1235036
Rd (+1%)	1867.185813	0	1867.18581	2.48958108	0	0
Re (1%)	16.71017676	-1659.91	1676.62022	2.23549363	637.240967	0
P_H-P_L (1%)	19.19188618	-1906.4313	1925.62322	-0.3556971	-191.71961	-2.9231947
CC (1%)	906.4207081	154.782609	751.638099	1.23951747	15.5656593	0.23733333
OC (1%)	1959.885402	1770.71304	189.172359	2.96732315	178.071143	2.71509333
S (1%)	0	0	0	0	0	-1.0288
N (1 year)	39633.47138	38509.913	0	-19.658501	2497.33472	0
B (1%)	-19.38380504	1925.49565	221.432	0.35925406	193.636802	2.95242667

WWT						
Indicators	**I**	**A**	**I-A**	**P**	**NPV**	**V**
Q (1%)	0	0	0	0	3667.39945	-0.3957851
Rd (+1%)	12167.08157	318233.043	12167.0816	12.1670816	0	0
Re (1%)	44.32763932	-4403.2984	4447.62599	4.44762599	1690.43022	0
P_H-P_L (1%)	50.91095209	-5057.2536	5108.1645	-0.7076771	-508.58095	-5.8158416
CC (1%)	6344.944957	1083.47826	5261.4667	6.5074667	108.959615	1.246
OC (1%)	4454.285005	4024.34783	429.937179	5.05793718	404.707142	4.628
S (1%)	0	0	0	0	0	-1.0288
N (1 year)	91865.67459	102156.522	-10290.847	-103.43244	6624.76252	0
B (1%)	-51.42006161	5107.82609	587.4	0.71475385	513.666758	5.874

BLT Sensitivity						
Indicators	**I**	**A**	**I-A**	**P**	**NPV**	**V**
Q (1%)	0%	0%	0%	0%	734%	-6%
Rd (+1%)	1%	0%	2%	1%	0%	0%
Re (1%)	0%	-13%	27%	8%	49%	0%
PH-PL (1%)	1%	-99%	205%	-8%	-99%	-152%
CC (1%)	32%	8%	80%	29%	8%	12%
OC (1%)	68%	92%	20%	71%	92%	141%
S (1%)	0%	0%	0%	0%	0%	-53%
N (1 year)	69%	100%	0%	-23%	64%	0%
B (1%)	-1%	100%	24%	9%	100%	153%

WWT Sensitivity						
Indicators	**I**	**A**	**I-A**	**P**	**NPV**	**V**
Q (1%)	0%	0%	0%	0%	714%	-8%
Rd (+1%)	1%	62%	2%	1%	0%	0%
Re (1%)	0%	-13%	12%	6%	49%	0%
PH-PL(1%)	0%	-99%	90%	-6%	-99%	-120%
CC (1%)	59%	21%	92%	56%	21%	26%
OC (1%)	41%	79%	8%	44%	79%	96%
S (1%)	0%	0%	0%	0%	0%	-21%
N (1 year)	43%	100%	-9%	-45%	64%	0%
B (1%)	0%	100%	10%	6%	100%	121%

APPENDIX 3: TYPE OF PLASTIC IN BRASILIA

Table below show nine products of plastic that is likely to be found as mismanaged waste. The total weight results in 128354 kg (128.354 tons). Second table show the price of the four main plastic types based on the price given by (Kunststof, 2017) and the recycling market. The total price result in 501 per kg (pounds) by (Kunststof, 2017) and 116 per kg (euro) from recycling market, the price difference contains 437 per kg (pounds).

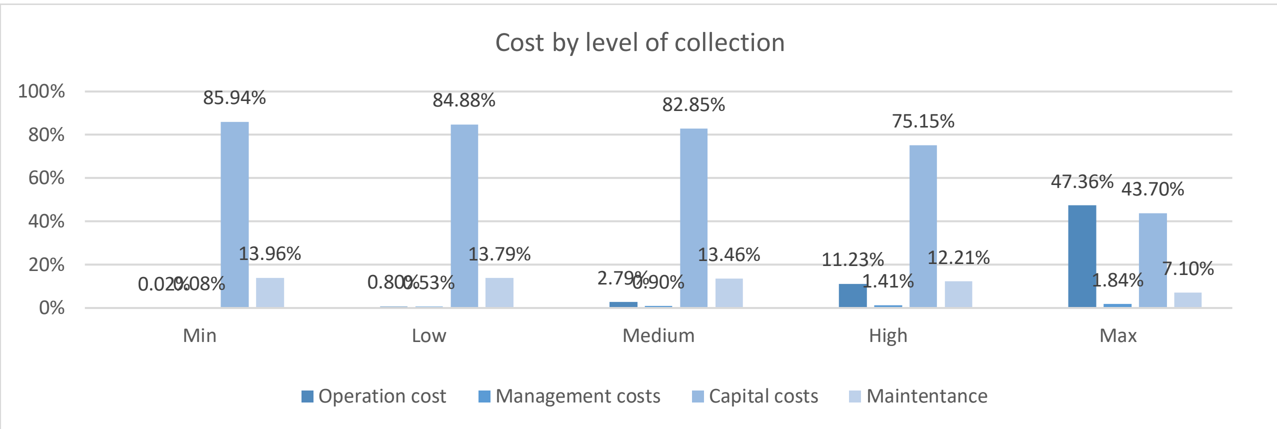
Estimation type				
Type	**Product**	**Pieces**	**Kg/Piece**	**Weight (kg)**
PE	Food wrapper	4844224	0.003	14532.672
PE	Grocery bag	847997	0.0055	4663.9835
PE	Other bag	610760	0.01	6107.6
PE	Container	1543825	0.03	46314.75
PP	Cap	1683600	0.003	5050.8
PP	Straw	1047414	0.001	1047.414
PP	Lid	712899	0.01	7128.99
PET	Bottle	1951340	0.015	29270.1
PS	foam	949154	0.015	14237.31
Total				**128353.6195**

Estimation price						
	Kunststoff			Recycling markets		
Type	**Weight**	**Price**	**Weighted price**	**Cents/pound**	**€/tonne**	**Weighted price**
PET	0.228042654	620	141.3864453	9	198.416198	45.24735628
PE	0.55798197	420	234.3524275	4	88.1849768	49.20562711
PP	0.103052832	565	58.22485014	5	110.231221	11.35963951
PS	0.110922544	600	66.55352637	4	88.1849768	9.781701966
Average price			500.5172493			102.88

APPENDIX 5: COMPARISON ESTIMATION

<u>5.1. Cost by level of collection Peer 1</u>

Based on the cost of BLT and collection based on minimum 24 tons to maximum 900 tons, this table show that capital costs are higher compared to operations, management and maintenance. It also shows that capital cost will be reduced and while the tons collection increase.



5.2. Cost of system Peer 2

Cost of water wheel trash interceptor (WWT) at minimum to maximum tons of collection (24-900 tons). Breakeven illustrate the system is price sensitivity of tons collected, going from low collection at price $38.77 per kg to max collection at $2.33 per kg.

Water wheel Trash Interceptor	Minimum	Low operation	Medium	High operation	Maximum
Plastic bottles	14142	56567	84850	157130	530314
Polystyrene containers	18398	73591	110386	204419	689914
Cigarettes butts	5130000	20520000	30780000	57000000	192375000
Glass bottles	300	1201	1801	3336	11259
Grocery bags	7328	29311	43967	81420	274793
chips bags	11720	46879	70318	130219	439489
Sports balls	85	338	508	940	3173
Total tons of trash	**24**	**100**	**150**	**278**	**900**
Tons of trash per month	2	8	13	23	75
Operation cost	$207.85	$7,500.00	$26,937.43	$119,540.00	$866,880.00
Managements costs	$707.11	$5,000.00	$8,660.25	$15,000.00	$33,600.00
Capital costs	$800,000.00	$800,000.00	$800,000.00	$800,000.00	$800,000.00
Maintenance	$130,000.00	$130,000.00	$130,000.00	$130,000.00	$130,000.00
Total expenditure per year	**$930,914.95**	**$942,500.00**	**$965,597.68**	**$1,064,540.00**	**$1,830,480.00**
Fixed costs					
Capital cost per ton	$33,333.33	$8,000.00	$5,333.33	$2,877.70	$888.89
Maintenance per ton	$5,416.67	$1,300.00	$866.67	$467.63	$144.44
Total fixed costs per ton	**$38,750.00**	**$9,300.00**	**$6,200.00**	**$3,345.32**	**$1,033.33**
Variable cost per unit					
Operation cost of trash collection per ton	$8.66	$75.00	$179.58	$430.00	$963.20
Managing costs	$7.07	$50.00	$86.60	$150.00	$336.00
Total variable cost per ton	$15.73	**$125.00**	**$266.19**	**$580.00**	$1,299.20
Breakeven price per ton	**$38,765.73**	**$9,425.00**	**$6,466.19**	**$3,925.32**	**$2,332.53**
Breakeven price US $ per kg	**$38.77**	**$9.43**	**$6.47**	**$3.93**	**$2.33**

5.3. Overview of companies and projects (peer 1 and 2)

Peer 1

Peer 1 is Water Wheel Trash Interceptor based on the first year of operation. Capital costs include direct costs of purchased equipment and construction materials, equipment and material installation, health and safety equipment. O&M (operation and maintenance) include electrical costs, labor costs for maintenance, maintenance materials, administration, insurance, licences, equipment replacement costs, trench maintenance and analytical costs.

System of collection	**Peer 1**
Water Wheel Trash Interceptor	2014
Area of impact: Baltimore Inner Harbor, Maryland	**Year 1**
Expenditures	
Capital costs	$800,000.00
Maintenance	$130,000.00
Operation cost of trash collection per ton	$430.00
Management	$15,000.00
1-year collection effect	
Plastic bottles	$157,130.00
Polystyrene containers	$204,419.00
Cigarettes butts	$57,000,000.00
Glass bottles	$3,336.00
Grocery bags	$81,420.00
chips bags	$130,219.00
Sports balls	$940.00
Total tons of trash	$278.00
Total operation costs	$119,540.00
Total costs (1 year)	$1,064,540.00

Source: (Ferguson Foundation, 2020)

Peer 2

Following table show the expenditures, characteristics of system, level of collection and types of waste mostly collected from Water Wheel Trash Interceptor program in Anacostia.

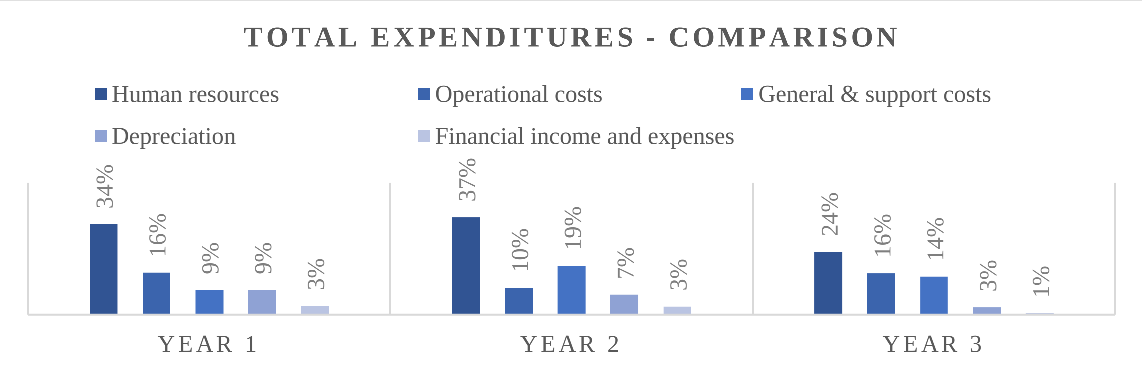
The effect of system is the period of operation from 2009-2014 and the types of collection contain six months period of 2011.

Project 1: Anacostia River Trash Trap Program		**Peer 2**	
Funding by government per unit			$0.05
Investment cost			$5-600,000
Expenditures per year		**Low estimate**	**High estimate**
Designing, building, installing (vary of site conditions)		$50,000	$100,000
Maintenance costs		$28,000	$44,000
Total cost of high level of collection (1 year)		$78,000	$144,000
Operation costs		$100,000	
Designing, building, installing (vary of site conditions)		$6,000	$10,000
Maintenance costs		$27,000	$30,000
Total cost of low level of collection (1 year)		$33,000	$40,000
Characteristics of system		**Small size**	**Large size**
Weight (Kg)		275	500
Depth (mm.)		200-250	200-250
Flowrate (cubic m/s)		2.5-3	2.5-3
Maintenance p/kg waste		$10	$8
Hours maintenance h/m		15	10
Hours maintenance h/y		180	120
2009-2014			
Effect of collection system		**Ton/year**	**Kg/year**
Pound of trash in total		1.89	1890
Volunteer work removed		9.83	9833
Total tons of trash in period		11.7	11,723
Mar 2011 - Aug 2011	**%**	**Ton/year**	**Kg/year**
Plastic bottles	29%	0.74	735.295
Plastic Grocery Bags	1%	0.03	25.355
Plastics	1%	0.03	25.355
Styrofoam	3%	0.08	76.065
Recreational balls	1%	0.03	25.355
Glass bottles	5%	254	253550
Organic debris	60%	1.52	1521.3
Weight	5071	2.54	2,536

Source: (Ferguson Foundation, 2020)

5.4. Cost Distribution of Project

Table below show distribution of costs in comparison of the 3 years of operation of peer 1 and 2 (Ocean Cleanup and Edmonton). Operations and human resources tend to be highest cost first 3 years. Table added to explain where funding will be necessary.



Source: numbers from (Edmonton, 2017) (Ocean Cleanup, 2018)

APPENDIX 5: PRICES

<u>6.1. Virgin prices and recycled prices</u>

EU (2017)						
Type	**Virgin Price/kg ($) (EU)**		**Virgin ($) /ton**		**Virgin (€) /ton**	
PMMA	$	2.75	$	3,787.18	€	3,500.00
PC	$	1.79	$	3,300.25	€	3,050.00
tpPVC	$	1.31	$	1,306.80		
PE	$	1.50	$	1,114.51	€	1,030.00
PVC	$	3.87	$	1,033.36	€	955.00
ABS	$	3.13	$	1,947.69	€	1,800.00
PET	$	1.11	$	1,114.51		
PS	$	3.97	$	1,455.36	€	1,345.00
PA	$	1.32	$	1,317.60		
PP	$	2.38	$	1,363.38	€	1,260.00
LDPE	$	1.42	$	1,417.49	€	1,310.00
HDPE	$	1.34	$	1,336.33	€	1,235.00

Source: (Kunststofenrubber, 2020)

Explanation:

Price List (EU)				
Type	**Recycled (€)/ton**		**Recycled ($)/ton**	
LDPE	€	580.00	$	627.59
HDPE	€	577.50	$	624.88
PP	€	700.00	$	757.44
PVC	€	200.00	$	216.41
PS	€	925.00	$	1,000.90
ABS	€	800.00	$	865.64
PET	€	510.00	$	551.85
PC	€	1,850.00	$	2,001.79
PMMA	€	1,100.00	$	1,190.26

Explanation:

Type	**Virgin (Brazil**		**Recycled (Brazil)**	
Abb.	**Price/kg ($)**	**Price/Ton. ($)**	**Price/kg ($)**	**Price/ton ($)**
PVC		$ -	$ 0.10	$ 98.53
PP	$ 1.52	$ 1,520	$ 0.17	$ 174.32
Pet		$ -	$ 0.21	$ 214.11
Pead	$ 3.36	$ 3,361	$ 0.49	$ 492.63
Pebd		$ -	$ 0.15	$ 149.68

APPENDIX 6: EXTRACTION METHODS

Table shows all found methods for extracting plastic and other waste for rivers, oceans and other waterways. Some of them are for large scale operations, others for small scale operations. Not all methods or concepts are patented, and some have been patented after the period of research.

Extraction methods	
Name	**Add. Functions of solution**
Bandalong	Litter Trap (BLT)
Bandalong	Boom System
Bubble Barrier	
Clear Rivers Litter Trap	
Clearwater	Waterwheel (WWT)
Clearwater	Trash Cages
CTU-system	
E. Borg Cleaning Cuttlefish	
E. Borg Ocean Cleaning Syst.	
Mare x-ray	
Marine Litter Device	
Nash Run Trash Trap	
Ocean Cleanup Passive Syst.	
Ocean Cleanup Interceptor	
Ocean Phoenix	
River Cleaning Noria	
River Clean-up	
Sea Defence Solutions	
Seabin	
Seavax	
Shore Liner	
Storm X	
Waste aid	
Waste free ocean	
Waste Shark	
Zero Plastic Rivers	
City Trash Skimmer Boat	
Cleantech Infra	
Dual Vane Trap	
Plastic Fischer Trash Booms	
Plastic Whale	
Enerquip Trash Rack cl. mach.	
Huber Coars Screen Trashmax	
Jash Fine Bar Screen Mat	
Vulcan Industries Stair Screen	
Ecosol Modular Trash Rack	

6.1. Explanation of variables

Choice of variables in corporation with Jordi Oolthuis in the evaluation of 30 systems. Following will be a specific explanation for each variable that is explained in theory chapter 4.2. and analysis, section 6.2. All variables not be situation depending on variables in comparison analysis.

Extraction variable	Explanation
Water surface	Score based on quantity collected on surface
Underwater	Score based on quantity collected under water
Macroplastic	Score based on quantity collected bigger than one centimetre.
Microplastic	Score based on quantity collected smaller than one centimetre.
Big rivers	Exceed width of 25 meters and depth on several meters Score 1: >5m Score 2:5-15m Score 3:15-35 Score 4:35-70m Score 5:<70
Small rivers	Smaller width of 25 meters and depth on several meters. Score 1: >20-25m Sore 2:15-20m, Score 3-5:1<15m. And higher score if possibility to readjustment
River life	Effect on river life. Score 1: Block all river life Score 2: High danger getting trapped Score 3: Low danger getting trapped Score 4: River life safe, danger can occur Score 5: No effect on river life
Maintenance	Hours of maintenance and maintenance intensity. Score 1: Very low level of hours, score 2: Low level of labor-intense work Score 3: Some labor intense work score 4: Short time, non-labor intense score 5: Maintenance by hand 5: Labor-intense work
Maintenance costs	Maintenance costs required per year. Score 1: 10.000 $ Score 2: 10-25.000 $ Score 3: 25-50.000 Score 4:50-100.000$ Score 5: <100.000$
Investment costs	Investment cost per year. Score 1: >25000$, Score 2: 25-100.000$ Score 3: 100-400.00$ Score 4:400-1000.000$ Score 5: <1000.000
Capacity	Capacity of quantity collected, maintenance, applicability for small and large rivers. Score 1: Full time maintenance, suitable for small, small scale Score 2: Small scale, daily maintenance Score 3: Small-scale, weekly maintenance or big scale with maintenance every other day Score 4: Small scale maintenance every two months, big scale once a month Score 5: almost no maintenance required

6.2. Score of variables

Effectiveness	Situation	Exploitation
Water surface: -%	Big rivers: -/5	Maintenance: -/5
Under water: -%	Small rivers: -/5	Investment: -/5
Macro: -%	River life: -/5	Costs:-/5
Micro: -%	Navigability: -/5	Capacity: -/5