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Modelling the Economic Effects of a Disruptive Event: Investigating the Implications and Effects of the Proposed Federal Single-Use Plastics Ban on Manufacturing in Ontario

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By

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ABSTRACT

During the past few decades, plastics pollution has become a global concern. Governments, in particular, are striving to find the best way to control the issues plastics have caused to the environment. The Government of Canada is seeking to phase out harmful single-use plastics by the end of 2021. The announced ban is a potentially disruptive public policy that may have consequences. A myriad of studies has been conducted on the environmental impacts of plastics, but there is a lack of literature on the evaluation of such regulations on manufacturers. This thesis aims to evaluate the economic implications of the proposed single-use plastics ban by generating a private cost-benefit analysis on manufacturers in Ontario and finds the impacts of transitioning from conventional plastics to alternative materials on companies. The model is applied to 139 single-use plastics companies in Ontario. This study assumes that manufacturers will make their decision based on the net present value of their overall benefits of material substitution. The results of the analytical model are then explained, and a series of sensitivity analyses are conducted for some parameters.

The novelty of the proposed model lies in evaluating the impacts of the ban on manufacturers from an economic point of view, covering a wide range of single-use plastics products and a one-by-one cost-benefit analysis on companies within Ontario.

DEDICATION

I dedicate this thesis to:

My parents and my brother for their endless love throughout my life,

and my friends for their support and encouragement.

ACKNOWLEDGEMENTS

I would like to sincerely express my appreciation to my supervisor, Dr. Beth-Anne Schuelke-Leech for her invaluable guidance throughout my journey and her patience. Along with her helps in my thesis, she taught me how to stay strong in difficult moments of life. Without her encouragement and support, this thesis would not have been completed.

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BBC	British Broadcasting Corporation
CAD	Canadian Dollar
CCA	Capital Cost Allowance
CCME	Canadian Council of Ministers of the Environment
CEO	Chief Executive Officer
COVID-19	Coronavirus Disease 2019
CPI	Circular economy Performance Indicator
CRA	Canada Revenue Agency
ECCC	Environment and Climate Change Canada
EPS	Expanded Polystyrene
EU	European Union
GDP	Gross Domestic Product
GHG	Green House Gas
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
NAICS	North American Industry Classification System
NPV	Net Present Value
PBP	Payback Period
PET	Polyethylene Terephthalate

PHA	Polyhydroxyalkanoates
PHB	Polyhydroxybutyrate
PLA	Polylactic Acid
PP	Polypropylene
PPE	Personal Protective Equipment
PS	Polystyrene
PVC	Polyvinyl Chloride
RIC	Resin Identification Code
ROI	Return on Investment
RRRDR	Remanufacturing, Refurbishment, Repair, and Direct Reuse
SBD	Small Business tax Deduction
UNEP	United Nations Environment Program
USD	United States Dollar
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1-1- Background and Motivation

Regardless of whether they are natural like COVID-19, or man-made such as policy shifts, disruptions can have substantial and often time-consuming consequences. Arguably, climate change is one of the largest sources of disruption that mankind has faced. Sometimes, disruptive governmental regulations and policies, such as bans or restrictions, fundamentally affect an industry or businesses in ways that are difficult for the businesses to address or absorb. The proposed single-use plastics ban by the Canadian Federal Government is an example of such policies. Single-use plastics bans have been proposed and implemented in various countries. In 2019, Prime Minister Justin Trudeau proposed a ban on single-use plastics as a part of its environmental election platform. With the re-election of the Liberals, the plastics ban became an official policy and is set to come into effect by the end of 2021. In addition to the planned Canadian federal restrictions on single-use plastics, there are local and provincial restrictions that have been passed to reduce plastics use (Freinkel, 2011; Geyer, 2020). Unquestionably, the single-use plastics ban will affect the economy, and manufacturers will have to adapt by altering their strategies accordingly.

Plastic was first invented in 1850's (American Chemistry Council; Streit-Bianchi, Cimadevila, & Trettnak, 2020). Its versatility and desirable properties made it a convenient and relatively cheap option for manufacturers (Andrady & Neal, 2009). The adverse environmental effects were not understood or considered. Consumers and manufacturers

now better understand the environmental problems that plastics can cause due to their structural permanence (i.e., it is not biodegradable) (Earth Day Network, 2018).

Plastics have provided benefits to society as well. Its lightweight characteristics relative to its strength and its flexibility in manufacturing meant that many products were converted to be made of plastics or were designed and manufactured to take advantage of plastics properties. Using plastics rather than heavier metal in components reduces the mass of automobiles, making them more fuel-efficient, resulting in reduced carbon dioxide emission. The durability of plastics containers allows food to be stored or carried, reducing food waste. Plastic pipes provide a means of transporting clean and healthy drinking water supplies (Andrady & Neal, 2009). Its relatively low cost made many products affordable, lightweight, and attractive to consumers. Plastics have become integral to our consumer society (Geyer, 2020).

Unfortunately, the very benefits that make plastics attractive as a component of many products are detrimental to the environment (Thompson, Moore, Saal, & Swan, 2009). Most plastics end up as garbage in waste management facilities and landfills. Their extraordinarily long-life means that plastics stay in the environment for generations. Once in the environment, plastics can cause problems for wildlife and humans by contaminating water sources and changing natural biological processes (Sigler, 2014). Moreover, plastics are made from petrochemicals, which cause greenhouse gases and global warming (Shen et al., 2020).

Despite these adverse impacts of plastics, there has been a heated debate over replacing plastics with alternative materials. Recent studies by Franklin Associates (2013) and

Denkstatt (2011) question the environmental benefit of reducing plastics use by using substitute materials.

In a report published by Trucost (2016), it is stated that the environmental impacts of using plastics for consumer goods are four times less than plastics alternatives. This report explains that although some materials, such as aluminum and steel, are more costly than plastics, producing a product with the same function and application requires more material on a weighted average basis. In fact, this report is claiming that it is the lightweight feature of plastics that makes them less costly than its mix of alternatives.

Every day, more than three million tons of plastics are thrown away by Canadians, with about one-third being single-use plastics products and packaging, which results in waste of almost 15 billion plastic bags annually and approximately 57 million straws daily (Environment and Climate Change Canada, 2020).

Plastics are used for packaging, construction, and automotive applications (Canadian Council of Ministers of the Environment, 2018). In Canada, 37% of plastics waste is composed of durable products such as textiles, furniture, and appliances, with the rest being non-durable products, such as single-use plastics products and packaging (CCME, 2018). Figure 1 shows the global plastics production by industrial sector in 2015.

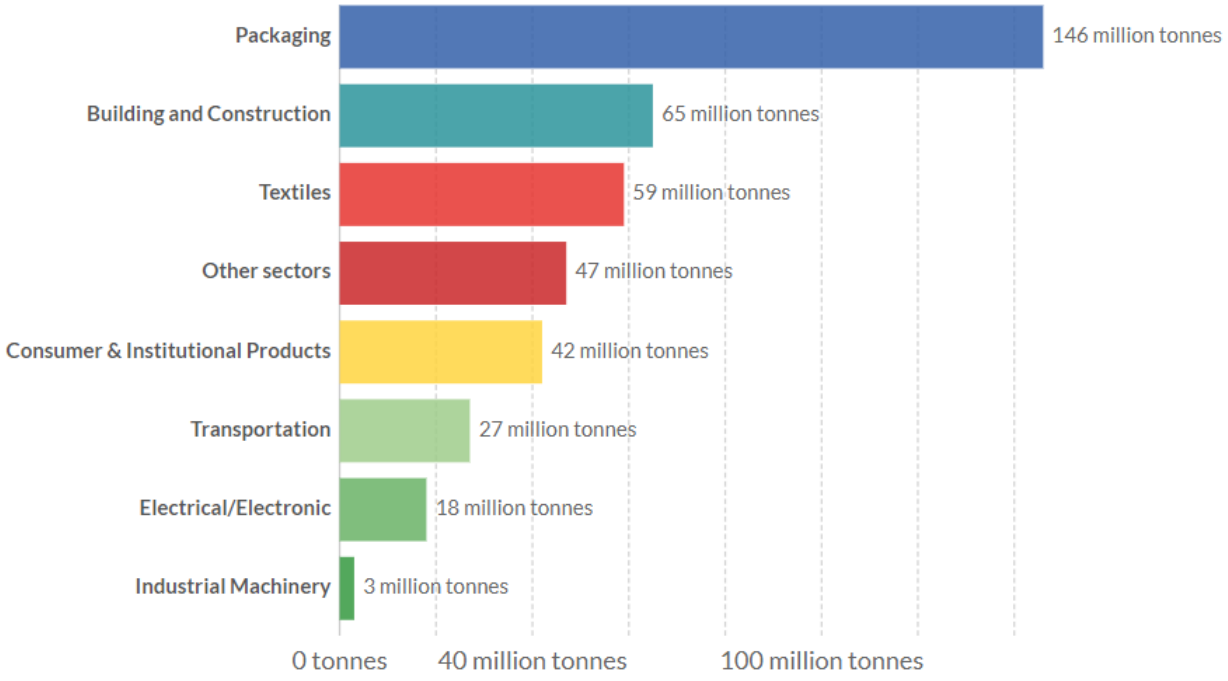

Figure 1. Primary Plastic Production by Industrial Sector, 2015[1]

1-2- Governments and Single-use Plastics

Single-use plastics (also known as disposable plastics) items are products that are intended to be thrown away or recycled immediately after they are used (UNEP, 2018). According to World Economic Forum (2016), one-fourth of the resins used to produce single-use plastics products are manufactured in China, Hong Kong, Japan, the Republic of Korea, Taiwan, followed by North America, the Middle East, and Europe.

Undeniably, single-use plastics have valuable functions, which cannot be easily replaced with other materials for their safety, health, manufacturability, and accessibility. At the same time, plastics are causing environmental problems that must be addressed.

Many governments have turned their attention to reducing plastics waste (Harris, 2018). Some of these policies have specifically focused on eliminating the use of polyethylene

[1] Source: Geyer, Jambeck, & Law, 2017

(single-use) plastics bags because of the problems they cause in recycling facilities and the wide availability of alternatives, such as paper or cloth bags (Hopewell, Dvorak, & Kosior, 2009).

Over one hundred businesses in consumer packaging have now agreed upon turning into a circular economy for plastics and make their plastic packaging reusable, recyclable and compostable and eliminate unnecessary plastic packaging by 2025, including Coca-Cola, Denon, Mars, and Nestlé (Independent Commodity Intelligence Services**,** 2019). These corporations are the world's biggest plastics polluters and responsible for 20% of the produced packaging around the world (Ellen MacArthur foundation, 2018). However, governments have also been enacting policies and legislation in order to hasten this conversion (Schnurr et al., 2018). While these companies have announced their contribution to environmental actions, they are still under public pressure for polluting the environment (Yale Environment 360, 2020).

Even seeming small policies can have an impact. The results of the study on the Toronto plastics bag levy have shown this policy has had a positive impact on consumer behavior; however, the level of influence depends on different factors including a consumer's educational level, housing situation, socio-economic status, and income. Moreover, these policies are generally more effective on people who were already using reusable bags and on people with higher socio-economic status (Rivers, Shenstone-Harris, and Young, 2017). The results of this study also indicate that these types of policies have less effect on people with lower socioeconomic status which shows the limit of such policies and the necessity of cultural and behavioral changes.

In 2018, the European Parliament voted for a ban on single-use plastics products including plastic drinking straws, stirrers, cotton buds, cutlery, plates, balloon sticks, Oxo-biodegradable food containers, and expanded polystyrene cups by 2021 (The European Parliament, 2019).

Canadian Council of Ministers of the Environment (2018) published a report explaining a Canada-wide action plan on zero plastics waste. The report claims that about 65% of the plastics that are collected to be recycled in Canada are sent to recycling facilities in Ontario and Quebec and the remaining plastics are exported overseas. Thus, plastics waste is not simply a local problem.

1-3- Problem Statement

While governments, companies, and other communities are striving to take actions against single-use plastics, some researchers believe that substituting plastics with alternatives could be more harmful for the environment. For instance, results of a study conducted by Boustead Consulting & Associates (2007) indicate that polyethylene single-use plastic bags are more advantageous and cause less harm to the environment when compared to compostable plastic bags made from Ecoflex and paper bags with a minimum 30% recycled fiber. The results show that these alternatives use more energy, oil, and water for manufacturing, and they emit more greenhouse gases. This illustrates the need for further research on the impact of such bans on the environment, economy, and society. Moreover, any ban on traditional plastics products can impact cultural norms and social equality (Ritch, Brennan, & Macleod, 2009). These impacts should be considered as well. A few examples of the impact of a poorly designed regulation are explained more in Chapter 2. They highlight the importance of a precise assessment on different aspects of plastics.

Unfortunately, studies that address the economic impacts of phasing out plastics are very limited. The literature shows that a significant number of studies investigate and assess the environmental and social aspects of a single-use plastics ban. However, the influence on plastics manufacturers and the economy has been neglected. Ontario is among the biggest plastics waste producers in Canada with 47 percent of all establishments in the country in 2009, including the largest plastics manufacturers (Statistics Canada, 2017). The importance of plastics industry in Ontario's economy and the lack of studies on economic aspects of single-use plastics ban emphasizes the significance of this study. The following chart shows the distribution of establishments within Canada by region.

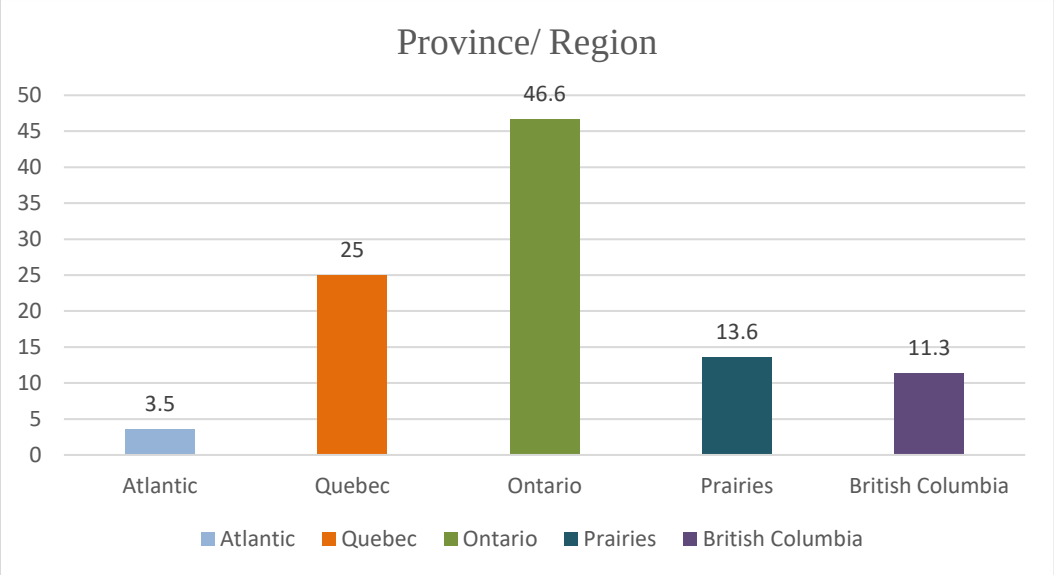

Figure 2. Regional Distribution of Establishments, 2009[2]

1-4- Research Objectives

This research aims at evaluating the economic impacts of a single-use plastics ban on plastics manufacturers in Ontario through a cost-benefit analysis on plastics substitution.

[2] Source: Statistics Canada, 2017

Paper, aluminum, glass, wood, and PLA have been selected as alternatives to petrochemical plastics and evaluated from a cost-benefit perspective. The primary data used in this study has been obtained from the primary collection and compilation of manufacturers databases.

The objectives of this study are:

1. To evaluate the implications of the ban on manufacturers in Ontario,
2. To assess the impacts of the ban on the economy,
3. To compare plastics with alternative materials from different perspectives.

This study is presented in five chapters. The current chapter provided background about different aspects of plastics and the importance of financial analyses for regulations prior to their implementation.

In chapter 2, a literature review is done with efforts to address the gaps in this field. Chapter 3 provides the steps of the methodology and explains how the proposed model is generated. Chapter 4 discusses the results of the analysis including the sensitivity analysis. Chapter 5 presents a conclusion and discussion, including some policy recommendations and suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of previous studies relevant to different aspects of plastics. Emphasis is on single-use plastics and their existing environmental and economic impacts. The literature explores how plastics bans can be a disruption to the economy and predicts possible transition paths towards the change. It also considers plastics waste management and its weaknesses, plastics in a circular economy, how governments are concerned with plastics issues, and finally, the most prevalent plastics manufacturing techniques. This literature review helps us understand where single-use plastics stand in our lives and the market and why it is still an issue despite numerous actions that have been taken so far.

2-1- Disruptions

Cambridge Advanced Learner's Dictionary defines disruption as "an interruption in the usual way that a system, process or event works"[3]. Some disruptive events are followed by economic impacts. Sometimes disruptions can be natural or man-made disasters such as earthquake, hurricane, pandemic disease, port closure, or terrorist attack (Kazimi & Mackenzie, 2016). Disruptions have occurred during the history and some of them have had detrimental impacts on humans' lives, economy, and infrastructure.

The novel Coronavirus disease is the most recent outbreak with 1,039,443 deaths by October 4, 2020 (Worldometers, 2020). It was first reported in Wuhan, China in December

[3] https://dictionary.cambridge.org/dictionary/english/disruption

2019. On 11 March 2020, the World Health Organization (WHO) officially announced the Coronavirus Disease-2019 (COVID-19) as a pandemic and asked for isolation and quarantine to prevent the spread of infection. Like some disruptions, COVID-19 not only affect normal lives of human but has had detrimental economic impacts as well.

Supply chain, production, and trade have been significantly affected by COVID-19 pandemic (Shokrani, Loukaides, Elias, & Lunt, 2020). The arising number of cases has led to shortage of medical devices. As a result of an increasing demand for personal protective equipment (PPE), governments are calling manufacturers and suppliers for quick actions. The significant shift in demand and supply during the outbreak has increased uncertainty (Okorie et al., 2020) and caused production interruption or even factory closure and decision-making issues for governors, manufacturers, and suppliers.

Along with the aforementioned disruptions, introducing breakthrough technologies or new regulations that depend upon fundamental changes can be disruptive for people, organizations, industries, etc. As claimed by Steve Goodrich, CEO of the Center of Organizational Excellence, while we sometimes consider politics and these changes as negative disruptions, they will bring a new normal after a while if they are implemented in a proper way. Therefore, the important questions are how politicians or relevant authorities implement the new policy and how affected sectors respond to the change and adapt themselves?

While many manufacturers are forced to lay off their employees, some have taken the situation as an opportunity to help society and stay in the market by using smart methods and technologies. Okorie et al. (2020) refers to benchmarking, rapid decision making,

organizational flexibility, and using digital technologies within manufacturing as effective tools to ensure pandemic and post-pandemic manufacturing capabilities.

2-1-1- Evaluating Disruptions

Fundamental changes can be disruptive at first and last for a while. Bans and prohibitions are sometimes disruptive regulations affecting the economy (Johnstone & Kivimaa, 2018). In today's competitive market, companies should consider that disruptions can occur in production too. Agility and their proper respond to disruptions are as important as on-time delivery or other factors that satisfy their customers; otherwise, it will bring about an increase in cost, delay in deliveries, and economic losses (Burggräf, Wagner, Lück, & Adlon, 2017).

Although manufacturers should adapt themselves to engage disruptive technologies, conform to new regulations, and adapt themselves to changes, they should take smart and cost-efficient strategies to deal with the disruption and stay competitive. Cauvin et al. (2009) explain that disruption management is often categorized into two strategies: reactive approached and pre-emptive approaches. The former is used when the disruption already exists. Reactive approach, sometimes, focuses on the evaluation and improvement of decisions made by decision-makers during the disruption with the aim of reducing the impacts of disruptions (Cauvin et al., 2009).

On the other hand, pre-emptive approaches are in fact precautions to prevent disruptions. Some studies, such as the one conducted by Heil (1995), suggest that according to case studies, pre-emptive approach is more beneficial and cost-efficient than reactive approach; however, none of disruption management strategies can ensure that no disruption will occur in the system (Burggraef, Wagner, Dannapfel, & Vierschilling, 2019).

2-1-2- Punctuated Equilibrium Model

Punctuated equilibrium model in social theory describes the phases when an organizational change or a large-scale change in public policies is made and predicts a behavioral pattern and suggests that changes will experience a burst at first but will become stable gradually (Gersick, 1991). One of the advantages of punctuated equilibrium theory is that it includes both the stability stage and the change stages (Baumgartner, True, & Jones, 2007).

Sadeppartly (2012) explains that when a public policy decision is made, the sectors to which the policy is applied may not show significant progress during the first phase. However, they will go through a transition point where changes and shifts become more visible. It is a critical phase that must be passed wisely because after this phase, changes are difficult (if not impossible) to occur. During the second phase, a steady state is reached. In this phase, the consequences of the decisions that were made during the first two phases are represented (Sadeppartly, 2012).

Single-use plastics prohibition is a crucial decision that needs to be assessed and understood comprehensively that how exactly it is going to be implemented. This thesis is mainly focused towards the viability of substitution materials from a cost perspective, but given that the proposed ban is a public policy and parts of this study also involve public policy-makers, this section helps understanding the concept better.

Based on Punctuated equilibrium theory, market transformation occurs in three periods (Phillips & Merrill, 2015). Deep structure is the first period explaining the current market and its values, strategies, how the resources are allocated, and how it is controlled. It is followed by equilibrium and revolution. During the second period, the system makes

incremental changes and reaches to a level of inertia where does not tend to change because of the existing risks and uncertainties in new ideas that may result in big losses (Gersick, 1991). Revolutionary period is the most important component of punctuated equilibrium theory. A common definition of revolutionary periods based on six theories is defined by Gersick (1991) as “relatively brief periods when a system's deep structure comes apart, leaving it in a kind of irregularity until the period ends, with the "choices" around which a new deep structure form. Revolutionary outcomes, based on interactions of systems' historical resources with current events, are not predictable: they may or may not leave a system better off. Revolutions vary in magnitude.”

Figure 3 shows the periods of punctuated equilibrium model based on Gersick (1988).

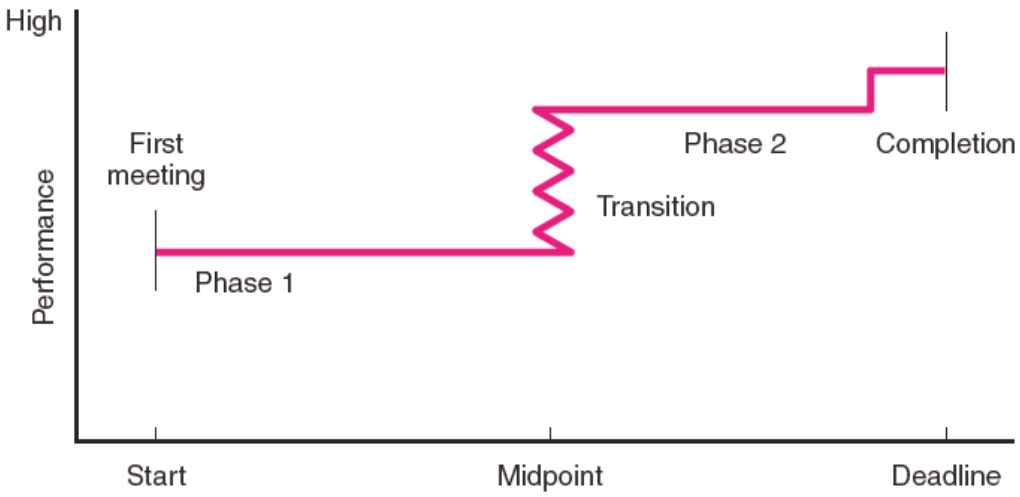

Figure 3. Punctuated Equilibrium Model Based on Gersick (1988)

Moving toward single-use plastics ban is very likely to have disruptive potentials for plastics industry. It may also have other consequences such as job losses or factory closure. If policymakers focus on taking it to a market reform and more efficiency in a steady state,

they can reduce the negative impacts of the disruption (Pereira, Specht, Silva, & Madlener, 2018).

2-2- Municipal Solid Waste Management

2-2-1- Definition and Implementation

Due to an increase in population and consequently, the consumption rate (Cherubini et al., 2009; Laurent et al., 2014), we have been surrounded by waste generated by human activities in the past few years. Therefore, waste management has become more crucial than always. Mismanagement of waste would lead to contamination of the environment and serious impacts on public health (Andreoni et al., 2015).

Solid Waste Association of North America defines *waste* as a discarded substance after its primary use which typically lacks economic value but may have secondary intrinsic value and can be applied to solid waste, wastewater, hazardous waste, and electronic waste. Although definitions may vary depending on local, provincial, and national laws, solid waste refers to any discarded material in shape of solid, semisolid, liquid or contained gaseous that are generated by residential habitation, industrial operations, and community activities (Liu & Liptak, 1999). Any of these wastes other than hazardous waste is known as municipal solid waste. The act of collecting, transporting, treating (processing), reusing, and disposing of solid waste in an environmentally and economically viable and feasible manner is called solid waste management (Ontario, 2020).

Waste management is a huge challenge for governments in that it requires space and does not disappear by itself. Waste accumulation requires space and leads to the spread of flies and microbial pathogens and cause public health issues (Christensen, 2010).

For handling waste management properly, it is important to focus on waste management hierarchy with a set of strategies that allows efficient use of resources (United States Environmental Protection Agency, 2017). The European Commission's Waste Framework Directive 2008/98/EC (WFD2008) defines the waste hierarchy as the priority order of operations to be followed in the management of waste: prevention, preparing for reuse, recycling, other recovery (including energy recovery), and disposal. In 2015, the Circular Economy Strategy from European Commission defended the role of waste management based on a waste hierarchy as the way to lead to the best overall environmental outcome and to get valuable materials back into the economy (EU Commission, 2015).

The United Nations Environment Program (UNEP) (2015) defines the waste management hierarchy as follow:

1- Prevention: in waste management hierarchy, prevention is on the top of the list, meaning to avoid the generation of waste including recyclables in the first step. From a consumer behavior viewpoint, it can be achieved through buying less harmful products that have the least amount of material used for packaging and instead of discarding items, trying to reuse or repair them if possible (UNEP, 2015).

2- Minimization: by designing a product properly, waste can be minimized. Specially for packaging material and toxic contents (Banerjee and Srivastava, 2009) that normally utilize a lot of material, a suitable design can minimize the waste. Focusing on environmental aspects during the design phase is an encouraging tool to minimize or prevent waste (European Union, 2010)

3- Reuse: Reusing a product can be either reusing it directly or repairing it by remanufacturing, refurbishing and part disassembly depending on the product and its design (European Union, 2015; CCME, 2018). Reuse is not a new strategy. It has been used since the past decades; however, at that time, reuse was an option used in poverty and the product was a low-quality one, but now, it demonstrates environmental concerns of governments and organizations and is a sign of smart management. Although by incineration and recycling a small portion of energy can be recovered, reuse techniques reduces the disposal expenses and saves more energy (Ellen Macarthur, 2019).

4- Recycling: Recycling is a set of activities including collecting, sorting, processing, and transforming discarded materials to raw materials to produce new products (United States Environmental Protection Agency, 2017)

5- Energy Recovery: the process of waste-to-energy including combustion, anaerobic digestion, and gasification through which non-recyclable waste material is converted into usable energies is called energy recovery. Approximately ten percent of the whole volume of the waste is turned into ash after recovery which is sent to landfills (United States Environmental Protection Agency, 2017).

6- Controlled deposit: Landfill is the most prevalent method of controlled deposit of waste. Landfill is "disposing of waste in a site used for the controlled deposit of solid waste onto or into land" (Ellen Macarthur Foundation, 2013, p.25). Disposal is the least preferred option in waste management hierarchy for its environmental consequences, particularly for those who live near landfills it can have negative effects on their health (Gertsakis & Lewis, 2003).

2-2-2- Plastics Waste Management

As shown in the following chart, plastics production and consumption have increased dramatically over time due to the unique features it has. Although plastics are getting attention for their environmental impacts, imagining the world without plastics is somehow impossible. Plastics pollution is of the biggest concerns for the environment and human health and plastics waste is a global challenge to tackle (Landrigan et al., 2018), so they end up being landfilled or incinerated. Particularly for single-use plastics that are one of the most concerning parts of plastics problems, it is of great importance for governments to provide a good waste management system because with the current consumption and waste management pattern, the Earth will end up with approximately 12 billion tons of plastics waste by 2050 (Geyer, Jambeck, & Law, 2017).

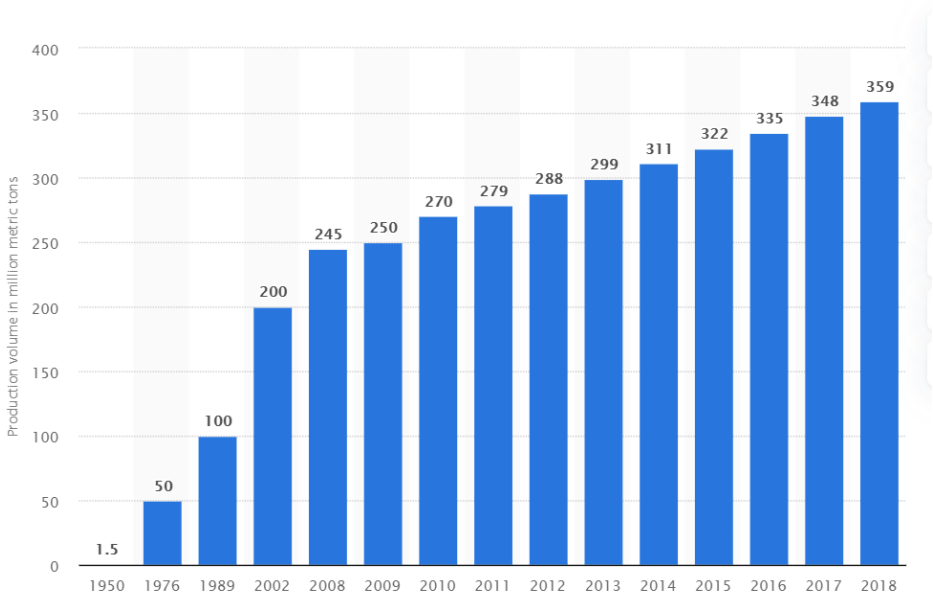

Figure 4. Global Production of Plastics from 1950 to 2018 (in million metric tons)[4]

[4] Source: Statista, 2020

There are many health hazards associated with handling of contaminated plastics waste; however, different factors contribute to an inappropriate plastics waste management such as extensive collection and transportation cost and health hazards associated with collecting, sorting, and handling contaminated plastics waste (Singh & Devi, 2019).

While governments are seeking to go towards sustainability because of the lack of infrastructure and poor awareness of recyclability of some single-use plastics products such as plastic bags, recycling them is currently low (Boustead Consulting & Associate).
In 2014 only about 30% of plastics waste was recycled in Europe (PlasticsEurope, 2016). In the same year, Canada was able to recycle only 9% of plastics waste. From the remaining amount, 86% was landfilled, 4% incinerated with energy recovery, and the rest was leaked into seas and the environment (Franklin Association, 2018). Lack of infrastructure and poor awareness of recyclability of plastic bags are important reasons for inadequate plastic bag recycling (Boustead Consulting & Associate).

Depending on the type of plastics, the recovery option may vary but a combination of strategies and techniques need to be applied in order for an integrated waste stream. While some thermoplastics like PE, PET, and PP can easily be sorted, recycled, used as fuel, and transformed into high value-added materials (Wang, et al. 2019), recycling some types of plastics and products is challenging if not impossible (Rebeiz & Craft, 1995).

Although remanufacturing, refurbishment, repair, and direct reuse (RRRDR) is on the top in waste management hierarchy, it is the least used in Canada (ECCC, 2019). According to the Environment and Climate Change Canada (2019), one of the limitations of this option is that some products are not designed repairable and it is often cheaper to dispose of a

plastics product and buy new a one than to repair them. Even though direct recycling requires low operating cost and technology, it is not easy to produce a high-quality product out of recycled materials unless virgin materials are added, but this is not a cost-effective solution and increases the manufacturing costs (Silveira, Cella, Tanabe, & Bertuol 2018). One of the most prevalent value recovery options to manage plastics waste is incineration with energy recovery (also known as waste to energy recovery) (Iacovidou, Velenturf, & Purnell, 2019). One of the advantages to plastics incineration is that plastics, including thermosets and mixed plastics, are accepted by all kinds of waste-to-energy facilities, but incineration releases hazardous substances such as polycyclic aromatic hydrocarbons, dioxins, and furans (Wang et al., 2019).

Poor labeling system is an important reason for insufficient uptake of recycling; therefore, some countries, states, and provinces like the United States and Europe are using the labeling system known as resin identification code (RIC) for the seven most prevalent types of plastics (American Chemistry Council, 2017). It is a consistent system that lets the consumers know if the product is recyclable or not so as to improve the consistency in plastics manufacturing and reprocessing of recycled palstics (Sustainable Palstics Coalition, 2017). Table 1 describes RIC with some of their applications. China is using five different post-consumer paths with 150 identification codes in conjunction with the same RIC Europe and America are using (Hunt et al., 2015).

Table 1. Resin Identification Codes for Plastic Packaging[5]

Code	Material Characteristics	Application

[5] Source: American Chemistry Council

	Clear, tough, gas and moisture barrier, shatter resistant.	Plastic drinking bottles, food trays, textile, peanut jar, ovenable film.
	Solvent resistant, high tensile strength, stiff.	Shampoo and detergent bottles, grocery bags, wire and cable covering, reusable shipping containers.
	Chemical resistant, clarity, good processing performance, grease, and oil resistant.	Clamshells, blister packaging, shrink wraps, pipes, sliding, windows, flooring, wire insulation.
	Flexible, transparent, tough, acid resistant.	Household garbage bags, stretch films, shrink wraps, container lids, squeezable bottles, wire, and cable covering, toys.
	Good chemical resistant, high melting point, optical clarity, low moisture vapor transmission.	Take-out containers, bottle caps and closures, medicine bottles, automotive and carpeting.
	Low melting point, moisture barrier for short shelf-life products, stiff, low thermal conductive.	Meat trays, food packaging, rigid packaging (e.g., yogurt), loose fill, disc cases, agricultural trays, cable spools, coat hangers, toys.
	Other plastics (e.g., nylon, polylactic acid, acrylic, etc.)	Varies depending on the resin.

RIC is used for both thermoset and thermoplastic polymers. The majority of single-use plastic applications have been highlighted in Table 1 are thermoplastics that can be remelted, reprocessed and used again by the application of heat (Mallick, 2010). The table is indicating that different types of thermoplastics are used for producing disposable plastics products and therefore, the ban on single-use plastics can mean banning all these types of plastics.

Being aware of plastics environmental impacts, Ontario is taking actions to manage this issue by reducing plastics wastes. Ontario Blue Box Program is an updated version of the original recycling program that requires municipalities to collect and sort standard materials including some plastics products (Ministry of the Environment, Conservation and Parks). One of the consequences of this regulation was a 61.3-precent material recovery. Another new policy is the ban on collecting plastic bags from recycling bins in Windsor-Essex with the aim of reducing plastic bag consumption. The authorities of Windsor-Essex region announced that as of June 2020, plastic bags will not be collected and recycled anymore (Windsor Star, 2020). While Ontario has made moves towards plastics waste management, it still requires further conscious actions in waste management to cut down plastics' environmental consequences.

2-3- Circular Economy

In the 20th century, industrial economy was based on a "take-make-dispose" plan, a one-way production and consumption pattern in which raw material is taken from resources, the product is manufactured, sold, used, and then discarded as waste at the end of its lifecycle (Ellen MacArthur Foundation). As the global human population grows (Roser, Ritchie, & Ortiz-Ospina, 2013), consumption level of natural resources increases, and a linear economy is not suited to supply the demand. Therefore, a new approach is required to minimize the consumption of natural resources and energy while meeting the demand. For maintaining a competitive advantage and improvement in resource performance, businesses and organizations are striving to switch from linear economy to circular economy.

The concept of circular economy has a wide scope of implementation and is applicable in a wide variety of industries (Korhonen, Honkasalo, & Seppälä, 2018). Also, many studies have been conducted on this topic. More than 100 published articles in 2016, while this number was only 30 in 2014 (Geissdoerfer et al., 2017); plastics industry is not an exception.

Many organizations and companies, such as The American Chemistry Council, are investing in finding solutions to keep plastics away from the environment and oceans while keeping them still in use by making new products out of recycling or remaking post-use plastics into raw materials. Depending on the material, there are different technologies and programs for value recovery (American Chemistry Council, 2018).

In a report conducted by Deloitte and Cheminfo Services Inc. (2019), remanufacturing, refurbishment, repair, and direct reuse (RRRDR) and mechanical recycling are considered the most preferred techniques for plastics value recovery. This method is the most preferred, yet the least used option in Canada because there are limitations to these techniques (CCME, 2018). The report claims that mechanical recycling is the most prevalent recovery option that is being used by the existing 10-11 facilities within Canada. The main type of plastics that is recycled in these facilities are from packaging and are mostly PET, LDPE, HDPE, and PP. Mechanical recycling includes reprocessing waste materials into secondary material while the structure of the material stays intact.

Of mechanical recycling drawbacks is its high operating costs and low profitability and it is not possible to mix different polymers when they are melted, even if they are as similar as polyethylene and polypropylene (Hubo & Ragaert 1970). A study in Nova Scotia shows that although there is enough available information on product resin codes and their

recycling methods on products with plastic films, there needs to be more policies to mandate manufacturers to educate their customers on proper ways of recycling and the importance of it (Ashtab & Whyte, 2019).

It is necessary to accurately calculate the actual output of the recycling process in a way that the quality of the output product is not changed. This way, we can evaluate the waste management system performance and ensure that the calculated recycling rate is not more than what it really is so that the mixed-plastics stream and impurities do not alter the rate and the goal of the circular economy. In a study conducted by Eygen, Laner, and Fellner (2018), the material flow analysis of plastic packaging in Austria shows that approximately half of the collected polymer packaging belongs to LDPE, 20% to PET, and 14% to PP.

To decrease the environmental problems of the disposal of plastics waste and measuring the performance of the circular economy of thermoplastic waste treatment, developing an indicator can be a valuable addition to circular economy (Hopewell, Dvorak, & Kosior, 2009). The authors offer that a proper circular economy performance indicator (CPI) in this case could be a quality factor divided into four levels: 1) closed-loop recycling for high quality material to be completely substituted with the virgin material, 2) semi closed-loop recycling by adding extra virgin material to lower quality products, 3) open-loop recycling for low quality material, and 4) incineration used when the plastic is of very low material. In addition to defining quality as a CPI, *designing for recycling* would improve the compatibility between polymers (Huysman, Schaepmeester, Ragaert, Dewulf, & Meester, 2017).

A research in the United Kingdom was conducted to understand the viewpoint of stakeholders of the UK food packaging supply chain towards transitioning from a linear

economy to a circular economy. The study illustrates current and future challenges of this transformation faced by stakeholders. Industries are concerned that there is no financial benefit at first and it might take some time to reach a satisfactory rate of return or the initial cost of implementation might not meet expected added value (Clark, Trimingham, & Storer, 2019).

2-4- Plastics Production Process

This section discusses the most common processes of producing plastics products: blow molding, stretch blow molding, and thermoforming. Blow molding can be divided into three main processes including extrusion blow molding, stretch blow molding, and injection blow molding (Kazmer, 2011).

2-4-1- Extrusion Blow Molding

Extrusion blow molding is typically used for producing HDPE (Belcher, 2002). In extrusion blow molding, raw plastics material enters a top-mounted hopper into a barrel of extruder and then heated, melted, and formed into continuous profile. There is a rotating screw with which resin comes in contact and forced through a die (Cantor, 2011). A tube of film is made by the air that blows through the center of the die and cooled and then it is flattened after passing through nip rolls and this is where two flat film sheets are produced (Franklin Associate, 2018, p. 102). Extrusion blow molding can be divided into two parts: single-screw extruder and twin-screw extruder. The former is the primary form of extruder which is still popular for its ease of production and low-cost equipment. Twin-extruder is still evolving and is used for polymer powder extrusion for high-capacity applications such as polyester films (Belcher, 2017).

2-4-2- Injection Blow Molding

Injection blow molding is the most prevalent method for producing thermoforming products used to produce wide variety of products (Mallick, 2010). In the injection molding process, molten plastic is injected into a mold cavity where the air is blown though the core rod and forms the products by air pressure. In the next step, as the molten plastic comes to contact with the cooled wall of the mold, it solidifies and ejects as a finished part (Franklin Associate, 2018).

2-4-3- Stretch Blow Molding

Stretch blow molding is mostly used to produce high quality and high clarity PET soft drink bottles (Franklin Associate, 2018), in which the plastics, like other processes, is melted and injected into a mold. When the formed preform is pre heated, it is inflated and stretched by using high pressure air. Finally, the mold cools up and forms to the shape of the mold and is forced out of the two halves mold (Shrivastava, 2018). One of the advantages of this technique is that the production rate is much higher compared to other techniques and the barrier properties increase since the bottles and containers made by stretch molding are pulled both in hoop and axial direction which leads to a better- quality product (PET All Mfg, 2018).

2-4-4- Thermoforming

Thermoforming technique includes a set of sheet-forming processes, mostly used for polymers such as ABS, LDPE, HDPE, PET, PVC, PP, PS, and Cellulose (Cheremisinoff, 2001). Thermoforming is a low-temperature, low-pressure process that starts with heating a sheet of plastic to the point where it is malleable and then it is stretched (Ashter, 2014). When it gets to the point where it can maintain the shape of the desired mold, it is removed

to trim the excessive plastic from the product (Drobny, 2014). Thermoforming market encompasses disposable products such as rigid packaging. On the other hand, sheets with a thickness between 1.5 and 3 mm are too costly to produce disposable products with and too fragile to be used for industrial applications (Throne, 2017). Thermoforming is useful for bio-based plastics such as PLA and PBS as well (Barletta & Puopolo, 2020), depending on whether their price and performance characteristics are beneficial compared to traditional plastics or not (Throne, 2017). Another reason that makes thermoforming more beneficial than injection molding for some products is that thermoforming requires less expensive equipment tooling and can make larger surface area parts with shorter lead time. However, one of the disadvantages is that it generates more scrap and regrind (Cheremisinoff, 2001).

2-5- Single-use Plastics Production Process

Plastics production can be divided into three subcategories: manufacturers of plastics processing machines and auxiliary equipment, manufacturers of molds and extrusion dies, and manufacturers of raw materials. There are 357 mold maker and 72 machinery subsector establishments in Ontario, that constitutes 75% and 71% of all subsector establishments in Canada, respectively (Statistics Canada, 2012). In this section, manufacturing processes of some single-use plastics products are explained to have a better understanding of the processes and how products are produced[6].

[6] Production processes are learned through YouTube (https://www.youtube.com/) videos and https://www.thomasnet.com/ .

2-5-1- Plastic Bottles

In the process of plastic bottle production, pellets and flakes of (recycled) PET are combined by an automatic mixer and dropped into an injection machine where a thick liquid plastic is made. The machine then shoots the molten plastic into a mold to shape the preforms and they are hardened in a cooling machine. A different molding machine transforms the preforms into single-use bottles and then they are reheated, blown into, and cooled. When the leakage and strength tests are done they are transferred by a conveyor belt to the branding station where prints logos or sticks labels on the bottles and then sent for packaging.

2-5-2- Plastic Bags

Plastic bags are often made of HDPE or LDPE resins (Prakasam & Largeteau, 2017). These pellets are mixed into a homogeneous liquid in an extruder where a long thin PE film is produced. When the film cools down and is cut into a desired width, it is rolled up and transported into the printing station where alcohol-based ink is printed on the rolling PE film. A sealer bonds the edges of the bag and put the bags on two spindles. Then, a punch gives the bags the desired handle hole before the sides is sealed. For producing zipper bags, a zipper strip is produced separately and then it is cut, heated, and stuck on the bags.

2-5-3- Plastic Cups

The most prevalent production process of plastic cups is vacuum forming (Throne, 2017). Like any other plastics product production, the pellets should first be mixed and melted. In the first process of plastic cup production, an automated machine loads and mixes pellets into an extruder where the pellets are heated, melted, and shaped into a hard plastic sheet in a die. The sheet passes into an oven and heats in it and then enters the thermoforming

machine which pushes and vacuums the plastic sheet into mold cavities. This way, long rows of cups are made. A trimmer, then cuts off the extra parts from the cups. The left-over plastic is re-melted to be used for new sheets. A conveyor belt transfers the cups to a part where rolls the lip of the cups for safety reasons. The manufacturing process of the lid is the same as the cup. Semi-rigid containers are produced with the same process.

2-5-4- Plastic Cutlery

Cutlery can be made of polystyrene or polypropylene which is a lighter, more flexible, and less expensive type of plastics (WebstaurantStore, 2020). The molds that make cutlery is made of two halves: a right-side-up cavity and an upside-down cavity. The molten plastic is injected into a mold and a cooling system solidifies the form in approximately ten seconds. The cutleries then drop off the mold and are transferred for packaging by a conveyor belt. They are packed either individually or in batches based on the demand.

2-5-5- Straws

Straws have probably the simplest manufacturing process and do not require complicated machines and processing techniques. First, the pellets and colorant chemical are combined in a mixer. When the pellets are melted, an extruder forces the plastics into a circle shape die. The long rounded plastic is cooled and hardened as it passes to the next step which is cutting. A slitter cuts the long straw into individual straws with desired length and then the wrapper machine packs them. If the product to be produced is a flexible straw, a machine compresses the corrugation to preserve the flexible straw. Plastic coffee stirrer sticks are produced the same way as straws.

2-5-6- Flexible Packaging

Flexible packaging is made of flexible materials that allows the package to be formed easily when filled with the product and makes the product visible, resistant to puncture, sealable, and peelable (Ashter, 2014).

Depending on the packaged product, flexible packaging may consist of one to four layers: surface, bulk, barrier, and sealant, but it is mainly distinguished as wraps (stretch-wrap, shrink wrap, twist memory films), bags, sacks, and pouches (McKeen, 2013), sometimes come in metalized film and lamination (Izdebska, 2016, a). Plastics such as PE, PP, PET, PVC, PA, and PS, along with biodegradable plastics like PLA, cellulose, and starch-based plastics are suitable for producing films with printing purpose (Izadebska, 2016, b).

The production process and the machines of winding and unwinding flexible packaging are simple. When the pellets are mixed and melted, they are formed into plastic films by an extruder machine and then rolled on a cylindrical core. The rolls will be unwound for their eventual use.

Lamination process is the combination of two webs of films together (Marsh and Bugusu 2007), either with the same or different materials. The materials used in flexible packaging is often two plastic films or a plastic film with a paper or foil web. The sheets or webs are laminated mainly in three ways: hot-roll lamination, extrusion lamination, flame lamination and adhesive lamination (Ashter, 2014). For laminated sheets, the plastic film and a sheet of aluminum or paper (depending on the application) are laminated in a heat seal coating process by proper adhesive and laminating machine. Then the sheets are sent for printing. There are two techniques for printing: rotogravure printing and flexography printing. In rotogravure printing, one color of the ink at a time is transferred through a

cylinder with an engraved pattern of multicolor dots. Rotogravure can produce high quality package printing compared to flexographic and is suitable for magazines, gift wraps, shopping bags, etc.

Flexography printing works with a partially or entirely print media covered plate cylinder that carries ink for an image. The plates are wrapped around cylinders. The solvent-based inks used for printing depends on the characteristics of the material used. It can be nitrocellulose (NC), polyamide (PA), polyvinyl butyral (PVB), polyvinyl chloride (PVC), acrylic, or polyurethane (PU) (Izadebska, 2016, c). The next process is slitting the sheet. It is the process of cutting webs into narrow rolls that are the actual products and quality that customers see. Depending on the material, slitting options may vary. Since the cost of waste is high, it is crucially important to choose a slitting technique that makes the least amount of waste (Dunn, 2015).

2-5-7- Stretch Film

Stretch film is used to secures a product on an item. They are made of LDPE and commonly used to wrap food on a food tray or boxes on pallets for transportation (Biron, 2016).

Blown stretch film is a vertical process that involves extrusion of the thermoplastic through a circular die. When the film cools down gradually, it is rolled and cut into the desired width. Cast stretch film, however, is a horizontal process and the thermoplastic flows into a flat die and then onto a chilled roll where it solidifies and can be cut.

2-5-8- Blister Packaging

The simplest type of blister packaging is the one made of a vacuumed plastic sealed on a paperboard or aluminum sheet. Blister packaging backing might consist of paperboard for

smaller consumer goods or aluminum for pharmaceuticals. They secure the product, extend its shelf life, and protect it from humidity, contamination, and other external factors (Papania, Zehrung, & Jarrahian, 2018). A more complicated type of blister packaging is used for pharmaceutical products and consists of the forming film, lidding, and heat-seal coating.

The lidding builds the final structure of the packaging. The material should be compatible with the heat-seal coating process and printable. The materials used for pharmaceutical blister packaging can be paper/foil, or paper/plastics/foil. Heat-seal coating is the bond between the thermoformed plastics parts and the lidding which the physical quality of the final packaging depends on. The coating is applied on the printed roll and can be either solvent- or water- based (Pilchik, 2000).

2-5-9- Expanded Polystyrene Containers

Expanded polystyrene (often confused with Styrofoam, a trademarked brand for EPS) is mostly used in packaging with the aim of insulation and product protection. However, they are also used to produce foam cups, plates, trays, and lids with a little difference in production process (Niaounakis, 2020).

Expanded polystyrene packaging is made of tiny pellets that are expanded in a steam chamber. The heat causes gas in the pellets to escape and that is how the air can enter the pellets. This way, the pellets will inflate about 40 times their original size. When pellets are expanded in a foam expanding machine, they are dropped in a block molding machine. The volume of the pellets dropped in the machine varies depending on how dense the final product should be. The denser the product, the more amount of pellet is required. When

the pellets are steamed together, the block is made and then cut with a foam cutting machine with copper and Nickle wire.

2-6- Alternative Products Production Process

2-6-1- Aluminum Can

A proper alternative material for plastic drinking bottles would be aluminum due to its lightweight and recyclability.

The aluminum sheet rolls into a press that punches it and from the sheet into cup-shape pieces. The cup gets taller and thinner when pushed through an iron ring. This process goes on until the desired thickness and height is achieved. Then a trimmer trims the edge and gives a clear look to the edge. Then, the cans move to a washer by a conveyor belt and both inside and outside of the can is washed. The inside layer of the can gets a coating to prevent the drink to get an irony taste. Once the cans are dried, designed shapes and colors are printed on the can. After the printing process, a necking sleeve die rolls the edge of the cups and then, they are packed to be shipped to beverage factories.

The lids are assembled after the cans are filled with the drink. A lid dispenser spreads the lids on the cans and then fixes them.

2-6-2- Glass Jars

Glass is a transparent material made of silica sand, limestone, and soda ash (Glass Alliance Europe), sometimes combined by recycled glass. The materials are blended and delivered to a furnace through a hopper. The molten material pours out of the furnace when it reaches the consistency of honey and then a blade cuts the glass as they are guided into a forming machine and come out as parisons. The parisons are then delivered into molds and a blow

molding machine blows air into the mold and the glass stretches towards the walls of the mold cavity and gets the shape of the final bottle. The bottles then pass through flame to prevent cracks due to quick cool down. The bottles cool down gradually and then sent for packaging.

2-6-3- Paper Straw

The process of producing paper straw starts with adjusting three paper strips of reels on the machine. One of the reels is an inner feeder, and the other two are middle and outer feeder. The papers are guided through an adhesive applicator, get twisted together, and form a long tube of paper. Then, a cutter cuts the tube into desired length. The diameter and length of the straws are adjustable and can be set differently for different usages. In the next step, the straws are delivered to a drier to make sure that the glue has dried, and then sent for packaging.

2-6-4- Paper Bags

Since most paper carry bags are made from kraft paper, they are considered as sustainable substitutes for plastic bags. The production of these bags does not require complex processes and machinery. Recycled paper rolls can be produced either by paper bag manufacturers or recycling companies. The rolls are first printed and rewound. For bags with paper handles, a thin strip of paper and a sting are twisted together and then cut by a cutter blade. The handles are then stuck on a piece of paper by adhesive and the sheet moves to the folding station where a metal guide folds the bottoms and sides. The bottoms of the bags are then opened and roller with coated glue rolls it and seal it. Lastly, they are checked for quality and delivered for transportation.

2-6-5- Bioplastics

The huge number of studies on advantages of biodegradable polymers imply that biodegradable polymers have become among the top solutions for plastics issues among governments and industries. They are obtained from renewable resources, degrade as a result of the action of microorganisms, undergo decomposition into carbon dioxide, methane, water, inorganic compound, or biomass, and finally absorbed through the organism cell walls (Kumar, Yaakob, & Siddaramaiah, 2011).

To use other materials as alternatives for conventional plastics, two important factors should be considered: the cost of these materials, and the cost of processing them. This study evaluates mechanical properties, manufacturing process, and prices of PLA, PHAs, and starch as feasible alternatives to conventional polymers.

PHAs:

Polyhydroxyalkanoate (PHAs) are biodegradable polymers produced in nature by microorganisms. Polyhydroxybutyrate (PHB), a copolymer of PHAs, is often compared with polypropylene because of its physical and mechanical characteristics such as good resistance to moisture or gas barrier properties and broadly used for tissue engineering, packaging, and lamination coating (Gomes et al., 2013). The manufacturing process and equipment used for manufacturing PHB food packaging is not very different than that for PP packaging yet, because of the difference in some characteristics and structure of the polymers, the condition of manufacturing should be different and specifically adjusted to the characteristic of the polymers. Bucci et al. (2005) evaluated PHB food packaging by mechanical and dimensional tests and compared it with PP in the same format and the same manufacturing process. The results of the study show that the injection molding process of

PHB encountered some difficulties has a longer cycle time (Bucci, Tavares, & amp; Sell, 2005). In addition to the mentioned issue, the production cost of PHB is about 5-10 times greater than petrochemical plastics (Kim, 2000).

PVA:

polyvinyl alcohol (PVA) is a petroleum-derived biodegradable polymer that can be used in biomedical application if the aging effect is controlled by physical entanglement (Sadasivuni, Ponnamma, Kim, Cabibihan,, & Al-Maadeed, 2017). However, PVA is not a quite environmentally friendly substitute for conventional plastics because of the greenhouse gases it emits during the production. Besides, it is very dependent on the price of crude oil (Auras, Harte, & Selke, 2004).

PLA:

Polylactic acid (PLA) is the most abundant used biodegradable polymer derived from renewable resources such as corn starch or sugar cane. It is widely used in single-use plastics products particularly wrapping films, food containers, and beverage bottles (Gross, 2002). Its thermal and mechanical properties make it a suitable alternative for PET and PS (Corneillie & Smet, 2015). PLA films and bags are produced by blow molding process and have shown satisfactory mechanical properties that are similar to PE. PLA foam extrusion has also become of interest as a substitute for EPS due to its their insulation, heat resistance, flame retardancy, and other mechanical properties. They are used for producing food trays, cups, containers, and insulation for packaging goods such as electronics for instance (Hagen, 2012).

Despite its good permeability, PLA is brittle and has a low melting point which limits its use for low temperature applications (Murariu, Ferreira, Alexandre, & Dubois, 2008). Thermoforming and blow molding of PLA is similar to processing methods of conventional plastics, but their processing condition is very critical as a small deviation might lead to deterioration of the material properties (Soulestin, Prashantha, Lacrampe, & Krawczak, 2011). The features of polylactic acid have made it suitable to be used as alternative to petrochemical plastics in this study. However, while this thesis predicts that PLA is a viable alternative, it is worth mentioning that this may not be viewed entirely viable by all manufacturers. PLA and other biodegradable plastics have not completely been embraced by all industries, mainly for financial matters. Therefore, finding a substitute material may not be as easy as it seems. Giant companies, such as Coca-Cola or Pepsi have not yet been able to find a material that is as cost-effective as plastics; hence even bioplastics may not solve the problem of plastics pollution entirely in a near future (Yale Environment 360, 2020).

2-7- Policies and Regulations

Existing reports and studies show that several governments have passed laws on plastics. While some of them have been successful, there is evidence that shows some of these laws have had negative impacts or made no difference after implementation. The impacts of some of these laws are mentioned in this section. This section explains some policies on plastics around the world.

European Union:

In 2017, the European Council, European Parliament and European Commission agreed upon increasing packaging recycling from 65% by 2025 to 70% by 2030 (UNEP, 2018). New legislations are set by the EU Commission to recycle a minimum of 50% of all plastics packaging waste by 2025 and to ban the top ten single-use plastics products found on EU beaches by 2021 (Attenborough, 2018). The European parliament has voted for banning single-use plastics products including plastic drinking straws, stirrers, cotton buds, cutlery, plates and sticks for balloons as of 2021 (European Commission, 2019).

Ireland:

PlasTax is the tax on plastic bags set by the government of Ireland in 2002. The outcome of the introduced law after one year was a decrease in plastic bag usage per person from 328 to 21 per year and also more than 90% drop in plastic bag usage (Convery, McDonnell, and Ferreira, 2007). Within four years, the levy was raised to €0.22 because a regulatory impact assessment indicated that the usage of plastic bags increased to 31 bags per person and to keep annual plastic bag usage to a maximum of 21 bags per person, a law was legislated to increase the levy once a year to at last €0.70 per bag. It is considered as the most successful tax in Europe (McLaughlin, Megan, 2016).

Rwanda:

The ban on manufacturing and selling single-use plastics that was announced in 2008 by the government of Rwanda was not prosperous due to improper and insufficient consulting and poor investment is recycling. The outcome of their mismanagement was smuggling plastic bags to Rwanda from other countries at first, but plastics bags started replacing by paper bags (UNEP, 2018).

Kenya:

One of the most severe bans was announced by the government of Kenya which was to ban plastic bags usage, importation, and production. Under the announced law, those who had been sentenced for an offence would carry a penalty of a four-year jail or fines up to $38,000 (Clapp & Swanston, 2009).

South Africa:

Dikgang, Leiman, and Visser (2012) studied the impacts of the regulations on single-use plastic bags with less than 30-micron thickness in South Africa. and a levy was set on retailers in 2003. After a levy on retailers was set in 2003, a non-profit company used a percentage of the levy to start activities for creating sustainable jobs in plastics recycling industry. The new law, at first, put some pressure on poor segment consumers who used cheap plastic bags for shopping; however, after a while, consumers changed their perspective and started to think of plastic bag fees as a part of their shopping and the consumption of plastic bags returned to its previous level.

China:

Not being effectively and adequately enforced, Chinese government eventually had to lift the ban on single-use plastics tableware including cutlery, serving dishes, and glassware in 2013 (China File, 2013.). However, the politicians set a levy on plastic bags thicker than 25 microns and completely banned those thinner than 25 microns in 2008 except knot bags used for handling fresh food and instead, encouraged consumers to use durable cloth bags and shopping baskets (Xanthos and Walker, 2017). The outcome of the new law was a significant drop in plastic bag usage. Nonetheless, plastic bags are still being used in rural areas (data released in 2016 by the National Development and Reform Commission, China's economic planning agency) for not having proper enforcement (Zhu, 2011).

In 2008, China set a nationwide regulation in which retailers were required to charge for plastic bags with the aim of reducing plastic bag litter. The impact of this regulation differs among regions but generally, based on the collected data before and after the implementation, plastic bag usage dropped about 50% (He, 2012).

Over 300 million tons of plastics are produced of which 20% is produced in China (Wang et al., 2019). China, as the largest importer of waste plastics, resulted far-reaching impact on the global production and consumption of virgin plastics and plastics solid waste management when importing plastics wastes was banned in 2018 (UNEP, 2018).

The United States:

Many states and municipal governments in the United States have instituted single-use plastics bans or other policies to try to reduce plastics waste. For instance, Proposition 67, also called the California Plastic Bag Ban Veto Referendum, was a referendum passed to voters to either approve or reject California Senate Bill 270 (SB270) which prohibited certain type of stores to provide customers with single-use plastic bags and charges customers $0.10 for reusable plastic bags or recyclable paper bags. Exceptions were compostable bags that have certification logo, paper bags with 40% post-consumer recycled content, and reusable and washable bags that can be used at least 125 times before they are thrown away (State of California Department of Justice, 2016). However, there were arguments to Proposition 67. Opposing organizations argued that the imposed $0.10 fee on plastic bags is a hidden tax taken from customers and given back to retailers and not kept by the government. In fact, they expected the money to be spent on environmental projects. They also claimed that single-used plastic bags are 100% recyclable and banning

them would affect manufacturers and people who are working in plastics manufacturing industry and lead to a substantial job loss (Mahoney & Seaward, 2016).

Shortly after when single-use polystyrene containers were banned in New York city in 2015, recycling firms and plastics producers sued the city claiming that polystyrene is recyclable, but then ban was lifted by the New York Supreme Court the same month (Babin, 2017). Then, the New York City Department of Sanitation conducted a study to see whether this material is recyclable or not and the results of the report showed that it is not environmentally and economically feasible to recycle them, hence the ban was back again in 2017 (UNEP, 2018).

Costa Rica:

Costa Rica is planning to ban some single-use plastics products such as containers, straws, cutlery, bottles, and bags by 2021 and instead, use biodegradable alternatives. This was announced on 2017 and to implement this strategy, some local governments and private sectors are supporting it, as well as the United Nations Development Program (UNDP, 2017).

Thailand:

In 2009, Bangkok's local authorities started a campaign with chain supermarkets and some stores to give a 1-percent discount for every THB100 purchase in case they bring their own cloth bags within 45 days (UNEP, 2018). In addition, in order to reduce plastics leakage to the environment, Thailand is setting a nationwide full ban on single-use plastic bags starting in 2021 (McKinsey, 2020).

Canada:

The CCME Zero Plastic Waste Strategy was approved by the environment minister of Canada in November 2018. The principle of this Canada-wide strategy is to phase out plastics from the environment. In this report, it is stated that plastics are mainly used for packaging, construction, and automotive and in Canada. 37% of plastics waste is composed of durable products such as textile, furniture, and appliances, and the rest belongs to non-durable products such as single-use plastics products and packaging. About 65% of plastics are collected to be recycled in the existing recycling facilities which are mainly located in Ontario and Quebec, and the rest is imported overseas. Despite having enough capacity for recycling clean and easily recyclable plastics products, it is still challenging for Canada to recycle products such as electronic devices, vehicle, or polystyrene products. Therefore, a Zero Plastic Waste Strategy will be defined and then developed by governors, manufacturers, retailers, consumers, and waste management stakeholders (CCME, 2018).

Likewise, Canada is taking actions towards sustainability. The Federal Government of Canada is working with different sectors, from industries and organizations to Canadians. Some of these actions are briefly discussed in this section:

- **Microbeads Toiletry Regulation, 2017:** Microbeads are plastics particles less than 5 millimeter, widely used in toiletries. The Government of Canada released the Microbeads in Toiletry Regulation in June 2017 including a prohibition on using microbeads in toiletry products such as toothpaste and skin cleansers. The reason for this ban was because microbeads that were washed down household drains ended up in the ocean (ECCC, 2020).
- **Ocean Plastics Charter, 2018:** Canada, France, Germany, Italy, the United Kingdom, and the European Union signed the Charter and committed to switch

from a linear to a reduce-reuse-recycle (circular economy) system for plastics and take sustainable actions towards marine plastics by working with industries and international organizations (ECCC, 2020).

- **Canada-Wide Strategy on Zero Plastics Waste, 2018:** Commits to implement a circular economy principle on plastics and keep all plastics away from the environment. The strategy was planned in two phases: Phase I deals with the design of plastics products, plastics waste management, and recycling capacity. The second phase focuses on consumer awareness to take responsibility for the plastics waste they produce, and commitment to reducing plastics waste. The first phase was approved in June 2019 and the second phase will be released in 2020 (CCME, 2018).
- **Single-use Plastics Ban, 2019:** The Government of Canada announced that certain harmful single-use plastics products will be banned as of 2021 and manufacturers are single-use plastics products or the ones the sell items with plastics packaging will be responsible for the plastics waste they produce (ECCC, 2019). This study focuses on analyzing the economic impacts of this ban announced by the Federal Government on plastics manufacturers in Ontario.

The following table summarizes the policies discussed in this section.

Table 2. Policies on Single-Use Plastics

Country/ Region	Year	Policy	Impact
Ireland	2002	A €0.15 levy on plastic bags which was increased to €0.22.	Plastic bag consumption dropped by more than 90% within a year.

Rwanda	2008	Ban on production, consumption, importation, and sale of PE bags.	First, plastics bag was smuggled to Rwanda, but it was replaced by paper bags over time.
Kenya	2017	Ban on production, consumption, importation, and sale of plastic carrier bags and up to $38,000 or four-year jail for offenders.	NA
South Africa	2003	Ban on plastic bags and levy on retailer.	The consumption of plastic bags dropped at first but started increasing again due to insufficient enforcement.
China	2008	Ban on non-biodegradable plastic bags and levy on consumer for thicker ones.	The consumption of plastics bags decreased up to 80%in supermarkets, but it was not enforced enough in food markets and small retailers.
Costa Rica	2021	Will ban all kinds of single-use plastics	NA
Thailand	2009	Discount for customers who bring their own cloth bags to stores.	NA

By conducting a literature review, it is realized that available studies on this topic often do not consider:

- The actual supply and demand of alternative products,
- The impact of producing bioplastics on agriculture,
- The impact of policies and regulations on plastics manufacturers,
- Specificities of all single-use plastics products (i.e., healthcare and medical devices)

CHAPTER 3

DATA AND METHODOLOGY

3-1- Introduction

After conducting a literature review to have an outline of where plastics stand in market and why single-use plastics ban can be a public policy disruption -particularly in the province of Ontario- a database of plastics manufacturers was created. The database includes the name of the companies, along with their approximate annual revenue, the number of employees working at the company, their locations, and the products they produce. Single-use plastics products of the companies are categorized based on North American Industry Classification System (NAICS). After identifying the manufacturing process of selected products, a cost-benefit model is generated. In this study:

- A mutually exclusive cost-benefit analysis is used,
- Ontario is selected as the case study,
- Data has been derived from available resources,
- The results of the applied model will demonstrate how the proposed ban affects single-use plastics manufacturers in Ontario.

3-2- Case Study

Ontario single-use plastics manufacturers have been selected as the main case study of this research, because in addition to the fact that Ontario contributes to an enormous portion of plastics waste generation in Canada (Statistics Canada, 2017), the province has stepped into plastics waste reduction alongside the Federal Government. During the past few years,

the province of Ontario has set waste policies and regulations stressing on environmental outcomes. Some of the recent and ongoing environmental movements are explained in this section.

- ***2015: Update of Waste Diversion Act, 2002***

In 2002, the Province of Ontario proposed the Waste Derivation Program with the aim of reducing, reusing, and recycling waste. In 2015, they proposed a new version of the program since only 15 percent of waste stream was recovered in the province under the current program. The goal of this action was to increase market value, decrease waste, and promote the collection and recycling system to an efficient system by switching into a circular economy (Ministry of the Environment, Conservation and Parks).

- ***2016: Waste-Free Ontario Strategy***

The Waste-Free Ontario strategy is aimed at achieving a waste-free Ontario by 2050 and making a transition into a circular economy. It is focusing on reducing the amount of waste sent to landfills by preventing waste production in the first place, rather than conventional recycling or waste management strategies. The Government of Ontario states that it supports innovation in recycling and believes that by taking this action, more jobs will be created, recycling costs will decrease, and it will provide consumers with a more convenient recycling system (Ontario, 2016).

- ***2018: Made-in-Ontario Environment Plan***

This plan offers solutions to enhance water, air, and land quality and supports Ontarian families and communities with GHG, waste, and litter reduction. The Government of

Ontario supports Ontarians to preserve the environment and help decreasing GHG emission (Ontario, 2018).

- ***2020: Ban on Single-Use Plastic Bag Recycling***

The Windsor-Essex solid waste authorities announced that as of June 1, 2020, no plastic bag (even recyclable ones) will be collected from their recycling containers. This is because even though some plastic bags have recycling symbols, they are not always recyclable. Moreover, plastic bags get wrapped around recycling machines and cause downtime at recycling facilities. They will officially implement the policy with the purpose of this ban is to reduce litter by cutting down the number of plastic bags used by consumers at the time of purchase (Essex-Windsor Solid Waste Authority, 2020).

- ***Plastic Bag Take-Back Program***

York region has started the Plastic Bag Take-Back program as a way to reduce plastics bags that are sent into landfills. People can stuff their plastics bags in one bag and drop them off at stores with Take Back bins. The information on participating stores in each region can be found on the website (The Regional Municipality of York, 2018). Some other municipalities such as Peel region has started similar recycling programs for plastics bags too. This region announced that only up to two extra garbage bags will be collected as of January 2, 2021 (The Regional Municipality of Peel, 2020).

Despite these actions taken by Ontario's government, there are still criticisms by environmentalists stating that the incumbent government is not paying enough attention to environmental issues (Xing, 2019).

Ontario is one of the important manufacturing centers not only in Canada, but in the United States too, because it is the third to have the most employees in North America, after California and Texas (Ontario, 2019). According to Statistics Canada, nearly half of the establishments are in Ontario (Statistics Canada, 2017). The following pie chart demonstrates the distribution of manufacturers in Canada.

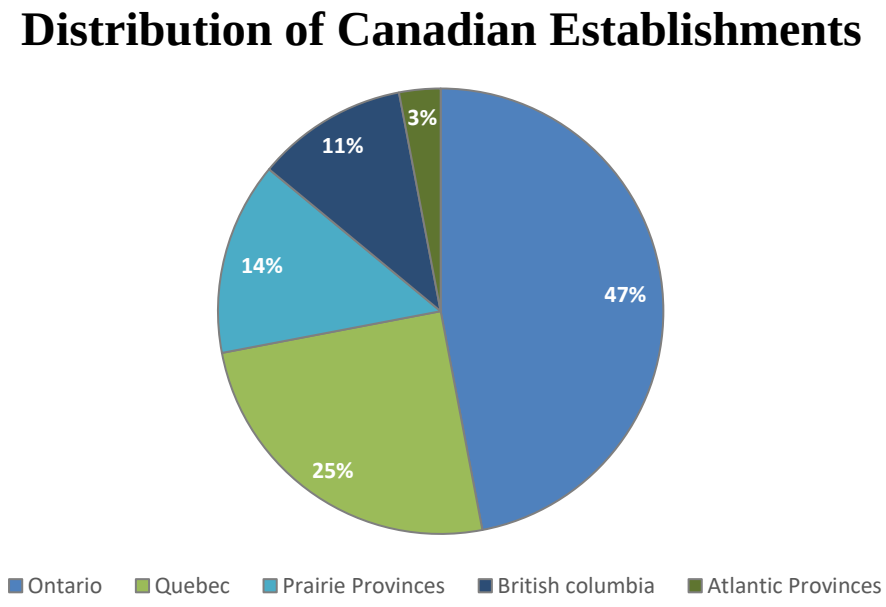

Figure 5. Distribution of Canadian Establishments[7]

Another reason that makes Ontario a suitable option as a proper case study is that a substantial percentage of dominant Canadian plastics firms that are owned by the United States and European multinational firms are located in Ontario (Statistics Canada, 2017).

Based on the plastics manufacturing database of Ontario created for this study, a substantial portion of plastics manufacturers in Ontario are located in the southwest of the province and their distribution is much denser in GTA. Figure 6 shows the distribution of the single-

[7] Source: Statistics Canada, 2017

use plastics manufacturers found in Ontario based on the database of Ontario plastics manufacturers of this study. The red pins belong to single-use plastics manufacturers and the blue ones show other plastics producers. The distribution of manufacturers is important for calculating shipping costs, which will be explained later in this chapter.

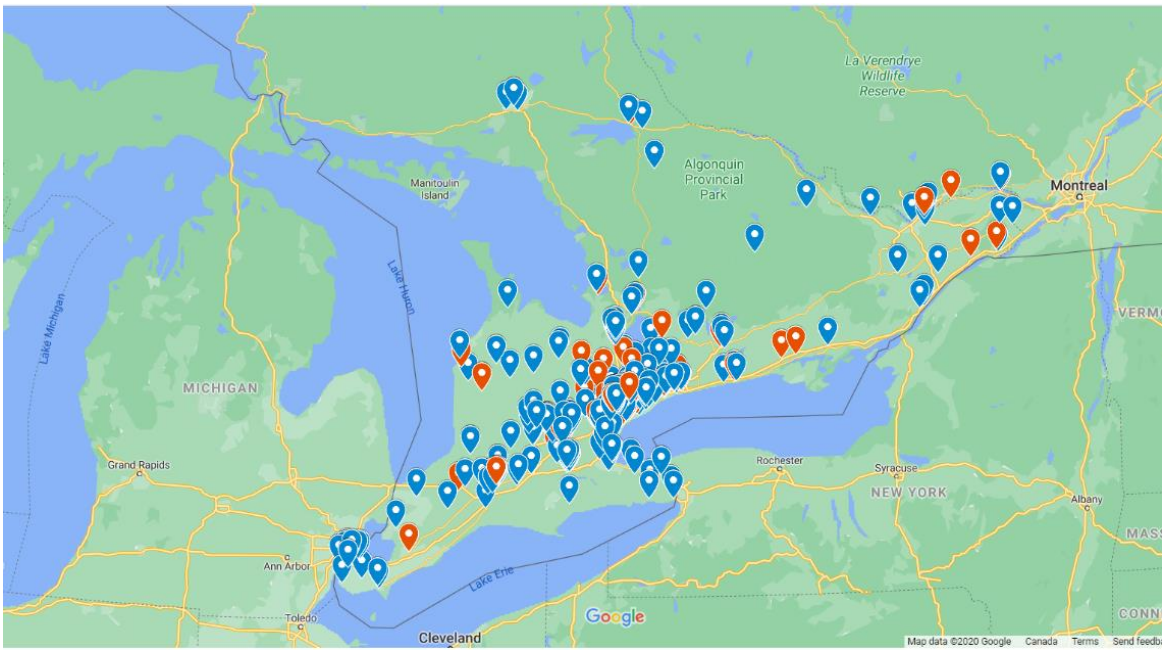

Figure 6. Plastics Manufacturers Distribution in Ontario[8]

3-3- Data

According to Statistics Canada, there are 1,160 establishments in Ontario working in plastics industry, among which 333 are non-employer/intermediate establishments and 827 are employer establishments[9].This data is related to 2019. Given that the regional distribution of the Canadian plastics products industry has not changed substantially over

[8] Source: Google Maps
[9] Source: Statistics Canada, special tabulation, unpublished data, unclassified excluded, 2019

the past 10 years (Statistics Canada, 2017), this study assumes that the number of establishments will remain the same during the period considered in the model.

In this thesis, plastics companies are categorized as micro, small, medium, and large establishments based on their employment size range according to the Government of Canada categorization. An employer establishment is defined as a small establishment, whether a corporate or an incorporate business, where the total number of employees are one or more regular workers excluding contract workers, company pensioners, working owners, outside directors of incorporated companies, and commission workers with no pension fund or unemployment insurance (Government of Canada, 2017).

A non-employer or intermediate establishment refers to incorporated businesses with no or an intermediate number of employees and annual revenue of $\$30{,}000.00^{+}$ (Government of Canada, 2017). Canadian Industry Statistics categorizes businesses by their employment size range as follow (Government of Canada, 2019):

- 1-4 employees: Micro
- 5-99 employees: Small
- 100-499 employees: Medium
- 500^{+} employees: Large

In this study, required data for the CBA model was basically obtained through web searching. Most information was found from the website of companies. The procedure of building the dataset started from gathering the name of available plastics manufacturers

from three business directories: Companylisting[10], Ctidirectory[11], and Canadian Plastic[12]. After finding online available plastics companies in Ontario, their locations and products were found by searching through the website of each company, one by one. Then, companies were classified into "single-use plastics" producers and "other plastics" producers based on the products they produce. In this study, companies that are partially involved with single-use plastics are also considered as single-use plastics producers. In the next step of creating the dataset, the annual revenue and number of employees working at each company were found using The Dun & Bradstreet[13], Zoominfo[14], FRASERS[15], and Manta[16] online resources.

Among 1,160 plastics manufacturers in Ontario (Statistics Canada, 2019), 607 companies were found from the above-mentioned directories, with 139 of them producing single-use plastics-related products and the rest producing other products in plastics industry. As it was mentioned, in this research, those businesses that are partially involved with single-use plastics are also considered in the model. This is due to the fact that regardless of the level of the impact, they will also be affected by the ban and need strategies to adapt themselves to the change.

The collected data shows cumulative annual revenue of the found plastics manufacturers is approximately 4.8 billion dollars in and it is 1.06 billion dollars for single-use plastics

[10] http://www.companylisting.ca/
[11] https://www.ctidirectory.com/
[12] https://www.canplastics.com/
[13] https://www.dnb.com/
[14] https://www.zoominfo.com/
[15] http://www.frasers.com/
[16] https://www.manta.com/

industry. The data also shows that over 32,000 people are working in plastics industry and near 6,800 of them belong to single-use plastics producers.

3-4- Single-use Plastics Products

The law of banning single-use plastics items voted by the European Parliament in 2019 includes plastic cutlery (knives, forks, spoons, and chopsticks), plastic plates, stirrers, balloon sticks, straws, food and beverage containers, cotton bud sticks, and beverage cups, along with Oxo-biodegradable plastics (European Commission, 2019).

The list of items to be banned in Canada was unveiled by the Environment and Climate Change Minister, Jonathan Wilkinson in October 2020. The ban encompasses grocery checkout bags, straws, stir sticks, six-pack rings, cutlery, and food takeout containers made from hard-to-recycle plastics.

One of the questions to be answered is whether other single-use plastics, especially plastic medical devices will be banned in the future or not, and if they will, what are they going to be substituted by. The importance of plastic medical devices is because plastics are attractive for hospitals and clinics because they are cost effective, durable, and easily sterilized (National Geographic, 2019) and there are concerns that substituting single-use plastics medical devices with reusable ones might lead to problems such as spread of infections.

The products chosen in the analysis of this study are classified based on North American Industry Classification System (NAICS) 2017 version. The North American Industry Classification System is a collaborative method used by statistical agencies of Canada, Mexico, and the United States for classifying industries (Statistics Canada, 2020). This

classification makes data analysis more straightforward. NAICS has a hierarchical coding system: the first two numbers of a six-digit NAICS code represent the sector, the third number designates the subsector, the fourth number is related to the industry group, the fifth one designates the industry, and the last digit is regarding national details (US Census Bureau, 2020).

The products primarily fall under the category of *Plastics Product Manufacturing* (#3261) or *Chemical and Allied Products Merchant Wholesalers* (#4241) (US Census Bureau, 2020). The system shows the number of related sectors and subsectors and helps to better understand which (sub)sectors are likely to be more sensitive to the ban. Table 3 and 4 shows the NAICS 2017 codes for the selected products in the aforementioned categories.

Table 3. NAICS Category (#3261)[17]

3261 (Plastics Product Manufacturing)
326111 (Plastic bag and pouch manufacturing) • *bags, plastics film, single wall or multiwall* • *Food storage bags, plastics film, single wall or multiwall* • *Frozen food bags, plastics film, single wall or multiwall* • *Grocery bags, plastics film, single wall or multiwall* • *Merchandise bags, plastics film, single wall or multiwall* • *Trash bags, plastics film, single wall or multiwall*
326112 (Plastics Packaging Film and Sheet -including laminated- manufacturing) • *Film, plastics, packaging* • *Flexible packaging, plastics film* • *Packaging film, plastics, single-web or multiweb*
326140 (Polystyrene foam product manufacturing) • *Cups, polystyrene foam* • *Dinnerware, polystyrene foam* • *Food containers, polystyrene foam* • *Polystyrene foam packaging*

[17] Source: North American Industry Classification System

326150 (Urethane and other foam product -except polystyrene- manufacturing • *Foam plastics products (except polystyrene) (e.g., packaging, food containers)*
326160 (Plastic bottle manufacturing) • *Bottles, plastics*
326199 (All other plastics product manufacturing) • *Plastics bottle caps and lids* • *Plastics cups (except foam)* • *Plastics dinnerware (except foam)* • *Plastics gloves*

Table 4. NAICS Category (#4241)[18]

4241 Paper and Paper Product Merchant Wholesalers
42130 (Industrial and Personal Service Paper Merchant Wholesalers) • *Closures, paper, and disposable plastics* • *Disposable plastics products (e.g., boxes, cups, cutlery, straws, dishes, sanitary food containers)* • *Eating utensils, disposable plastics* • *Foam plastic trays* • *Knives, disposable plastics* • *Plastics bags* • *Plastics foam products, disposable (except packaging, packing)* • *Shipping supplies, paper, and disposable plastics*

The selected single-use plastics items in this study are beyond the unveiled list of products to be banned in Canada. The study evaluates the effects of a potential more strict ban by considering a few other products in the evaluation. Selected products in this study are as follows:

Poly bag, retail bag, zipper bag, laminated pouch, mail bag, shrink film, garbage bag, wicket bag, snack web, stretch film, roll stock, flexible food packaging, cup, dinnerware,

[18] Source: Based on North American Industry Classification System

cutlery, straw, stirrer stick, EPS container, bottle, jar, tray, blister packaging, clamshell packaging, semi-rigid container, PP container, caps, and closures.

This study first selects products that are going to be banned by the end of 2021 and products that are likely to be banned in the future and then finds a viable alternative material for each product to figure out the level of the impact of the ban as a disruptive policy on economy. The following flowchart shows the process of the methodology in this study. The steps of the methodology and the process of generating the cost-benefit model are then explained in more details.

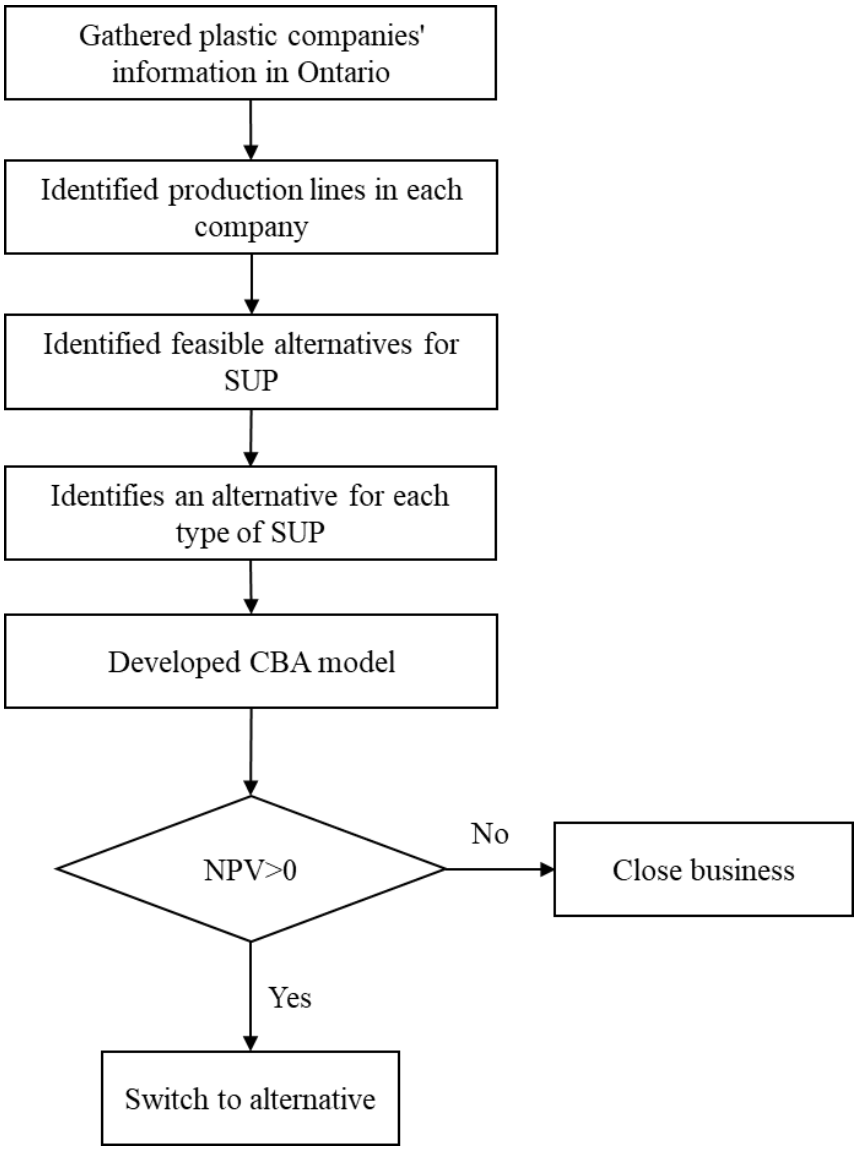

Figure 7. Methodology Process Flowchart

Depending on the objectives of the decision-maker, different factors can be used to select an alternative material, such as function, viability, availability, cost, etc. This section defines and briefly discusses these criteria and explains which ones are more crucial in this thesis.

Functionality and physical structure of the alternative product are required by the consumer and determines what the product is for and how it works (Albert & Thirupathi, 2009). In fact, the alternative material should have the specifications to perform the same functionality of the same product made from petrochemical plastics.

Second, the alternative material needs to be processable, feasible, and have a reasonable lifetime. Product viability means that a product has features to be used by customers who will provide feedbacks on the product. Münch et al. (2013, p1) explain that it is "an artefact that may be incomplete in functionality or quality but displays characteristics that allows determining its customer value". Therefore, we can say that there is an overlap between function and viability.

It is an important factor to know if there is enough resource to respond to the existing demand or not, and if the resource is available, is it accessible or not. Sometimes, availability can be periodic, which may change the demand (Grubor & Milicevic, 2015). Therefore, it is of great importance for the manufacturer and market to take this factor into account.

Finally, like in any other project, the factor of cost is one of the most important and influential factors that determines whether the company is capable of continuing the business or not. Companies can use different cost estimation techniques to minimize their costs while maintaining the quality at a desired or acceptable level (Huang, Newnes, & Parry, 2012).

There are other criteria that can be considered for making decision about selecting an alternative, but the main focus of the thesis is on assigning an alternative material to each SUPs based on function and cost.

Some of the single-use plastics products are easy to find a replacement for, either from manufacturing perspective or consumers perspective. On the other hand, some plastics products are difficult to be substituted with materials other than plastics. For instance, stretch films and sheets are not easy (if not impossible) to be substituted with other materials. There might be exceptions, but in general, using other materials for these products changes their function. Namely, it might be possible to use other items to cover or wrap foods instead of stretch films, but this is not always a feasible option. Therefore, this study considers the most feasible alternative for products.

Table 5 shows a summary of production process of single-use plastics products with machines used for each process. The last two columns on the left show the types of plastics that are currently been used and one alternative material that has been dedicated to the product.

Table 5. Production Process and Materials

Plastics Product	Process	Machine	Alternative Material
Beverage Bottles	Pellets are blended	Mixer/Blender	Aluminum
	Pellets are melted, mold shapes the preforms	Extrusion molding machine	
	Preforms cools down	Cooling machine	
	Air blows into the preforms	Injection molding machine	
	Caps are assembled on bottles	Capping machine	
	Labels are printed	Printing machine	
	Labels are sealed around bottles	Labeling machine	
	Bottles are sent for packaging	Wrapping machine	
Bags*	Pellets are blended	Mixer/Blender	Paper
	A long film is blown from the extruder	Extrusion molding machine	
	The film is rolled up	Winder/Unwinder	
	Labels are printed	Printing machine	
	The film is cut into desired sizes	Slitter/cutter	
	Sides of the film is bonded	Sealing machine	
		Belt making machine	

* Including retail bag, wicket bag, poly bag, garbage bag, T-shirt bag, zipper bag, and flexible (food) packaging.

	Zipper is made and sealed on the bags		
Cups/Jars	Pellets are formed into hard sheets Long rows of cups are vacuumed Extra plastics are deflashed Lip of the cups are rolled Labels are sealed around bottles Labels are printed	Extrusion molding machine Vacuum forming machine Slitter/cutter Plastics Forming machine Labeling machine Printing machine	Glass
Cutlery	Pellets are blended Pellets are melted and injected into cavity Products are sent for packaging	Mixer/Blender Injection molding machine Wrapping machine	Wood
Straws/ Stirrer Sticks	Pellets are blended The mold is forced out into a die The tube is cut into desired length Straws are sent for packaging	Mixer/Blender Extrusion molding machine Slitter/cutter Wrapping machine	Paper (straw) Wood(stirrer)
EPS Containers	EPS pellets are heated EPS pellets are expanded EPS blocks are made EPS blocks are cut EPS sheets are vacuumed Extra plastics are deflashed	Steam chamber Foam expanding machine Foam mold making machine Slitter/cutter machine Vacuum forming machine Slitter/cutter	PLA
Sheets**	Pellets are blended A long film is blown from the extruder The film is rolled up The film is cut into desired sizes	Mixer/Blender Extrusion molding machine Winder/Unwinder Slitter/cutter	PLA
(Laminated) Pouch	Pellets are blended A long film is blown from the extruder The film is rolled up Labels are printed Sheets are laminated on the film The film is cut into desired sizes	Mixer/Blender Extrusion molding machine Winder/Unwinder Printing machine Laminating machine Slitter/cutter	Paper
Stretch Film	Pellets are blended and heated Thermoplastic is extruded through a die The film rolls up The rolls of stretch film are cut	Film blowing Film blowing machine Winder/Unwinder Slitter/cutter	PLA
Blister packaging, clamshell	Pellets are formed into hard sheets Long rows of containers are vacuumed	Extrusion molding machine Vacuum forming machine Slitter/cutter	PLA

** Including pallet cover sheet, shrink film, bubble wrap, and roll stock.

Packaging; Tale-out Container	Extra plastics are deflashed Products are delivered for packaging	Conveyor belt

3-5- Cost-Benefit Analysis

Public projects are known as projects operated and financially supported by the government, such as road repair or construction (Kassel, 2017). For public project decision making, cost-benefit (also benefit-cost) analysis is widely used as a key analytical tool.

In fact, the most use of cost-benefit analysis is for economic choices that involve investment projects in order to figure whether investment is beneficial or not (Prest & Turvey, 2014). It is an economic tool that allows sectors to weigh different projects when there are mutually exclusive alternatives and maximizes the benefits of the investment (Pelot, 2016). In conjunction with evaluating projects, we can use CBA for proposed regulations and policies too (Prest & Turvey, 2014). The proposed ban is a public policy that can have social, environmental, and economic consequences but given that the main focus of this study is economic costs for manufacturers and environmental costs are excluded from the model, we can actually say that this thesis is a private cost-benefit analysis that evaluates the aggregation of the costs and benefits of individual companies.

Some countries such as Canada, the United States and Australia, as well as the European Commission have established guides to the use of cost-benefit analysis. In 1999, the Government of Canada set a policy that all the regulatory proposals are required to employ cost-benefit analysis as a key tool that represents a convincing case with potential positive impacts on the environment, economy, businesses, and society compared to alternatives,

in a way that the benefits are maximized over the costs, compared to non-regulatory alternatives (Government of Canada, 1999).

In April 2007, the policy was modified to both regulatory and non-regulatory options. *The Cabinet Directive on Streamlining Regulation* requires departments and agencies to demonstrate a case, whether regulatory or non-regulatory, that maximizes the value to the society, that is "the net economic, environmental, and social benefits to Canadians, business, and government over time." (Treasury Board of Canada Secretariat, 2007).

There are sets of rules and steps for cost-benefit analysis implementation. The framework of the cost-benefit analysis in this study are summarized as follows:

Step1: Define the problem and objectives of the project,

Step2: Identify benefit and costs,

Step3: Generate the CBA model,

Step4: Perform the sensitivity analysis.

3-5-1- Problem Definition

According to the Environment and Climate Change Canada, in 2016, less than ten percent of the plastics consumed in Canada were recycled, while 86% were landfilled, 4% incinerated with energy recovery, and 1% leaked into the environment. Packaging contributes to approximately half of the generated plastics waste (ECCC, 2019). In June 2019, the Prime Minister, Justin Trudeau, announced that the Federal Government of Canada will take further actions to reduce plastics wastes by banning harmful single-use plastics products as early as 2021. Major disruptions such as these kinds of policies encompass risk and uncertainty, hence their long-term effect should be acknowledged.

Failure to such bans and regulations has economic and environmental consequences. In fact, a policy is assumed a failure when the costs of it exceed its benefits (McConnell, 2016). To prevent the costs and loss of valuable resources, it is important to note that these policies require scientific assessments and infrastructure work prior to their implementation. The announcement of single-use plastics ban by the government of Canada was not clear enough and did not suggest how the government is planning to execute the ban. No alternative plan has been proposed yet. Banning all single-use plastics would require manufacturers to adjust production to comply with the ban. This study considers two possible options that manufacturers have if they are unable to sell their products that are considered single-use plastics. The first option is to cease production of single-use plastics if they are unable to adapt themselves to the new situation. In this case, the manufacturers simply lose this portion of their business and shutdown these operations. The second option is to alter the materials that they are using so that the output of production is no longer within the category of single-use plastics. In this case, manufacturers would use materials such as bioplastics, glass, wood, aluminum, or other appropriate materials instead of petrochemical plastics.

3-5-2- Objectives for the Project

Some environmentalists and politicians are still blaming the Government of Ontario for plastic pollutions and complain that the authorities are not taking adequate actions (Xing, 2019). Green Party Leader, Mike Schreiner, complains that the incumbent Government of Ontario is not caring enough about the environment and its future. This is where Ontario is one of the important manufacturing centers in North America (Ontario, 2019).

The proposed single-use plastics ban by the Federal Government of Canada is a potentially disruptive public policy that will most likely affect manufacturers. This research is in fact a public project that evaluates possible impacts of the ban on plastics manufacturers in Ontario by generating a model, using cost-benefit analysis as a tool. While the impact of the ban on consumers is out of the scope of this study, it is worth mentioning that the ban will definitely affect consumers as well. Consumers will have to deal with changing their consumption behavior. Although reusable grocery bags or refillable cups, for instance, are being currently used, consumers still have the option of using single-use plastics products. But once the ban takes into effect, the transition to reusable items will be mandatory. It is a crucial to prepare consumers for the ban and predict their behavior before taking the ban into action.

3-5-3- Evaluation Methods

This study uses net present value and payback period methods for evaluation. Net present value (NPV) is a method broadly used in capital budgeting for determining the present value of cashflows (inflows and outflows) of a project (Hanafizadeh & Latif, 2011). It identifies which project is more profitable by translating the investment into today's dollar, using the following formula:

Equation 1. Net present value (Khan & Jain, 2000)

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^n}$$

Where,

R_t = cashflow of the period *t*,

i = discount rate,

n = number of periods.

In the current study, it is considered that a non-negative total NPV means that substituting plastics with alternative materials that are non-petrochemical plastics is profitable for the manufacturer. Contrarily, if the total net present value is negative, the next step is to analyze the consequences of material substitution by calculating the payback period. Payback period (PBP) method determines the amount of time required for an investment to reach to the break-even point. In other word, it predicts how fast the invested cash will be recovered (Reniers, 2016). In this study, a three-year payback period is the acceptable period for the company to switch to alternative materials and keep producing. If the payback period is more than three years, the manufacturer will have to cease production.

The logic for choosing a three-year payback period in this cost-benefit model is that in an unstable economic situation, it is more likely that manufacturers incline to have a more conservative approach to their investment. Currently, plastics manufacturers must deal with two disruptive events simultaneously. On one hand the COVID-19 pandemic has led to a substantial increase in personal protective equipment and other single-use plastics consumption and the government is calling on manufacturers to assist by boosting production of COVID-19 related items, but on the other hand, the Environment Minister has announced that the ban will take into effect by the end of 2021 (Flanagan, 2020). Decision making in an uncertain condition, where such conflicts exist, is more challenging and require a more conservative approach.

In this study, the cost-benefit model analyzes the outcomes of single-use plastics ban by evaluating net present value of benefits and changes in costs in three years. By subtracting the NPV of total benefits of the company from the NPV of costs attributed to material substitution, we can figure out whether material substitution is a profitable strategy for the company or not. It should be noted that in this study, the operating costs of production are in fact the changes occurred in costs of producing products with alternative materials. The flowchart bellow demonstrates the steps of costs and benefits calculations.

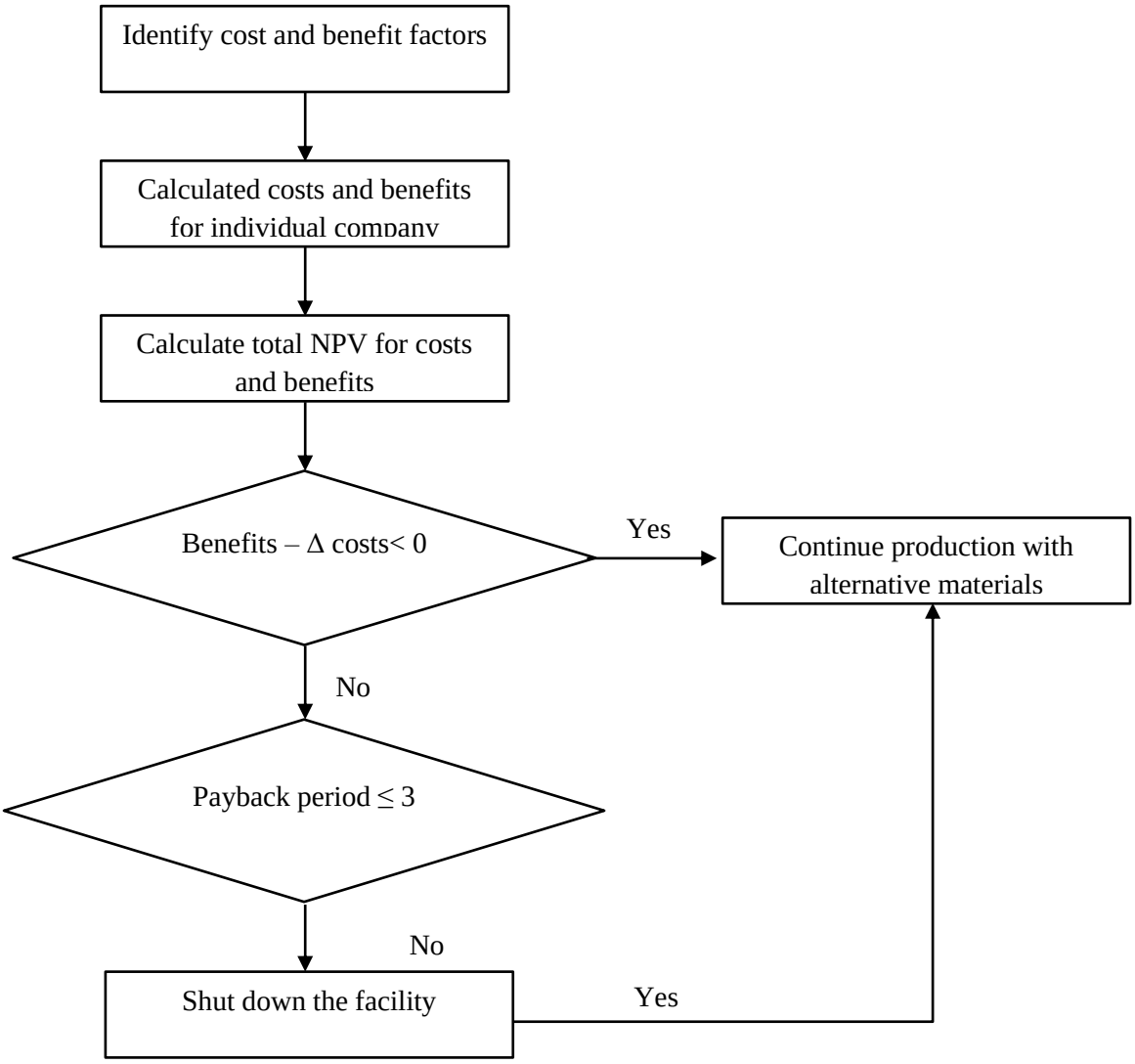

Figure 8. CBA Process Flowchart

3-5-4- Sponsor's Benefits and Costs

In public sector decision-making, the sponsor is the organization or segment who owns, funds, and performs the project (Pelot, 2016). In this case, the sponsors are the Government of Canada and the Canadian Council of Ministers of the Environment (ECCC, 2019). Although no new report has been announced yet, the expenditures of the implementation of the ban and the benefits gained must have already been determined by the government. Existing reports and studies on this topic are Canada-wide, not in provincial scope, but this study aims to analyze the impacts of the ban on manufacturers in Ontario. Because of the limitation in available data, the costs and benefits of the government are not calculated in this study, but they are mentioned in this section based on existing reports.

The benefits of setting a ban on single-use plastics can be divided into environmental and economic benefits. For the government, one of the benefits is the avoided annual costs of plastics ban, such as recycling, and saving the opportunity of the money received from recovering plastics that is currently been missed (ECCC, 2019). This report states that in 2017, 4,281 kilotons of thermoplastic resins were produced within Canada which valued CAD 8.2 billion. Polyethylene contributed to over 80% with about 3,700 kt followed by polyvinyl chloride with 210 kt, and polyethylene terephthalate with 144 kt.

According to ECCC (2019), the total amount of plastics waste generated in Canada in 2017 was about 3.3 million tons. Packaging, with 1,543 kt of plastics entering waste stream, contributes to nearly half of the total plastics waste, followed by other plastics (19 precent), automotive (9.4 percent), textile (7.2 percent), electric and electronic equipment (6.5 percent), construction (5 percent), home appliances (4 percent), and agriculture (0.1 percent). The study categorizes "other plastics" as plastics used in medical, dental, and

personal care, toys, household furniture, sporting goods, mattresses, industrial machinery, and chemical products and resins. The following figure shows the portion of plastics waste in 2016 generated by each sector.

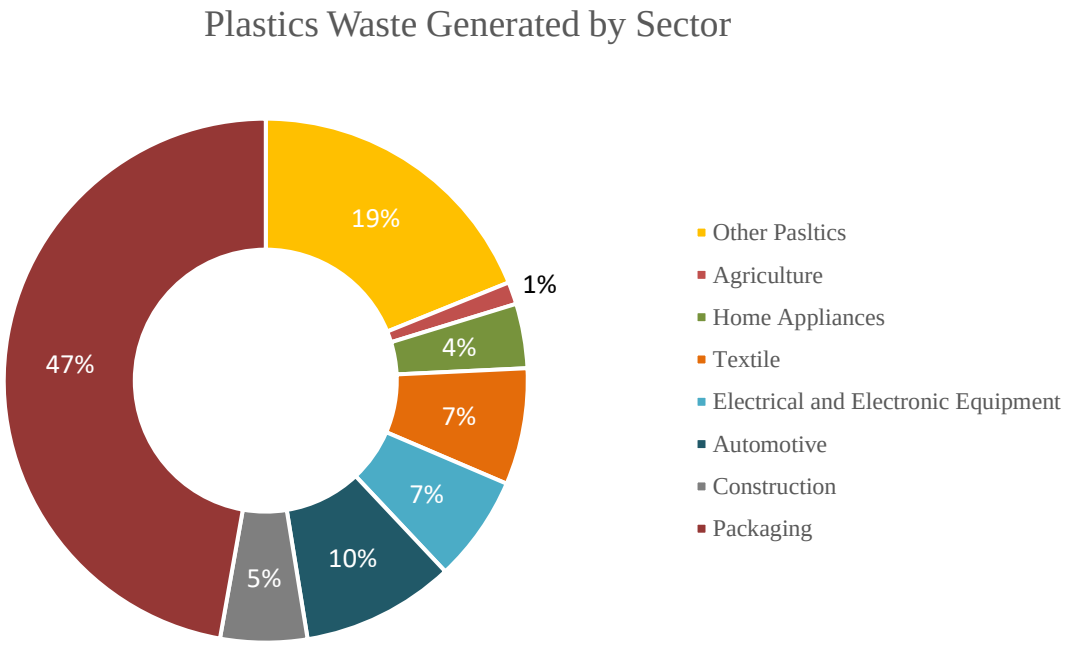

Figure 9. Plastics Waste Produced in Canada by Sector, 2016[19]

One key point to consider in substituting plastics with other materials is that plastics consume less material compared to an alternative material; hence although the environmental cost per metric ton of plastics are more than that of alternative materials, more material is required for the production of a product with the same application (Trucost, 2016). In the study conducted by Trucost (2016), the results show that producing

[19] Source: Economic Study of the Canadian Plastic Industry, Market and Waste: Summary Report to Environment and Climate Change Canada, March 2019

a product with alternative materials such as aluminum, paper, or glass, consumes four times more material to produce a product with the same function.

Table 6 compares the contribution of plastics and alternative materials to the environmental cost (Trucost, 2016).

Table 6. Environmental Impact of Plastics and Alternative Materials

Environmental issue	**Plastic**	**Average Mix of Alternatives**
Green house emission	51%	34%
Land and water pollutant	22%	40%
Air pollutant	12%	13%
External waste management	11%	11%
Damage to the ocean	3%	2%

3-5-5- Users' Benefits and Costs

In a cost-benefit analysis, users are those who benefit from the project. Benefits of a project can be direct or indirect and are favorable outcomes that the user is willing to achieve (Pelot, 2016). In every project, there are also costs (disbenefits) which are unfavorable outcomes to the users. Therefore, the total benefit of the user should be calculated as follow:

$$\textbf{Total User's Benefit} = \boldsymbol{User's\ Benefits - User's\ Disbenefits}$$

The benefits or costs might be directly attributed to the project, while some of them could be applied indirectly. They are also known as primary and secondary benefits or costs and are often challenging to be identified and quantified. This study only takes direct

parameters into consideration, but it is important to identify both to achieve a more efficient analysis for future studies.

The steps of the cost-benefit analysis conducted in this study are explained below.

First, the data of revenue and the products of each company is collected. Knowing the manufacturing process steps of selected products allows us to know what machines, equipment, and materials are used for production. As mentioned before, there are two possible scenarios: if the company is able to proceed with an alternative material, it will continue production with new machines and equipment suitable for the new material. It is assumed that machines are imported to Canada, mainly from the United States. Therefore, along with the cost of purchasing machines, manufacturers will have to bear rigging and moving costs and applicable tax and duty. These parameters constitute the capital costs of substitution. Other costs such as maintenance, salary, and utility are considered operating costs and is assumed to remain the same for both plastics and its alternative production.

3-5-5-1- Benefits

In the case of cost-benefit analysis of banning single-use plastics, the benefits really accrue to society, rather than to manufacturers themselves. In a competitive marketplace, the assumption is that manufacturers are currently using the methodologies and materials that produce the greatest returns. Benefits to the manufacturers may include a push to adapt innovative methodologies and materials that they would not otherwise investigate in order to remain in the marketplace. However, the fundamental assumption is that the benefits are for sustainability for society and a reduction in the cost of waste. If manufacturers adapt themselves to the ban by using alternative methods and materials, the benefit is that they would be able to stay in the market, keep producing, and getting revenue. However, it is

also possible that the manufacturers are unable to substitute plastics with alternative materials either because the costs exceed the benefits even if an alternative source of raw materials and a production method is available, or because there is no viable material to substitute with plastics.

Three factors contribute to benefit for manufacturers: annual revenue, capital cost allowance, and tax return. These factors are explained in this section.

- **Revenue**

Three business directories were used to collect information about total annual revenue of firms. As it was mentioned, the directories used to find plastics manufacturing in Ontario are Manta, ZoomInfo, CompanyListing, and FRASERS. Assuming that the annual revenue of firms is linear and distributed proportionately among their production lines, the allocated revenue to single-use plastics products is calculated. The amount of allocated revenue to single-use plastics production lines are used in cost-benefit. For this purpose, the annual revenue of each vendor is distributed to the existing production lines in their plant facility. For example, one of the plastics manufacturers is producing single-use water bottles and detergent bottles with an annual revenue of 7,000,000.00 Canadian dollars. Based on this assumption, the revenue allocated to each production line equals to 3,500,000.00 Canadian dollars. Since detergent bottles are normally not disposed of right after they are used once, they are not considered as single-use goods. Therefore, the amount of revenue allocated to single-use plastics products in this company is 3,500,000.00 Canadian dollars. The same calculation is done for all single-use plastics producers on the dataset to understand what portion of the costs and revenue belong to single-use plastics.

In this study, the cost-benefit model analyzes the impact of the ban for three years, starting from 2020 (n=0). Available data on manufacturers' annual revenue belong to 2017, 2018, and 2019. Therefore, it is assumed that the growth rate for revenues equals to zero at first and the amount of revenues found for firms are used as the revenue for 2020. Then, for the sensitivity analysis, different growth rates are applied to revenues.

- **Capital Cost Allowance**

Capital Cost Allowance (CCA) is a percentage of a depreciable property for the period that the property becomes obsolete in business activities and is deducted from Canadian income tax. Once the asset becomes available for use, companies can claim the depreciated asset annually to be deducted from their taxes (Pelot, 2016).

Canada Revenue Agency (CRA) classifies capital cost allowance rates of a variety of assets into 19 distinct classes (also known as asset pools). Machinery and equipment used in a business belong to the class 8 with a rate of 20% (Canada Revenue Agency, 2020). CCA is calculated regardless of the date that the asset is purchased, therefore, the "half-year convention" or "50% rule" is set up to align the costs and revenue better. The rule allows 50% of the relevant rate to be used for the base year, which is when the asset is purchased (Canada Revenue Agency, 2020). Based on half-year rule, the applied CCA rate for the year in which alternative machines are purchased equals to 10%. For the next three years, however, the normal fixed CCA of 20% is applied.

For calculating the NPV of Capital Cost Allowance achieved from alternative machines and equipment depreciation, the total amount of purchasing price for production lines of

each company is calculated. The value of the total NPV for Capital Cost Allowance of all three years is added to the total benefit.

- **Corporation Income Tax**

Eligible Canadian corporations can claim a corporation income tax return for every tax year (Canada Revenue Agency, 2020). According to the Canada Revenue Agency (CRA), the general federal and provincial (Ontario) rates are 15% and 11.5%, respectively. Small businesses can also claim the small business tax deduction (SBD), but the rates vary for small businesses. The federal rate for small businesses is 9% and the provincial rate is 3.2%. Therefore, the combined federal and provincial rates are 12.2% for small corporations and 26.5% for other corporations (CRA, 2019).

The tax year starts at the end of the base year, meaning that corporations will not benefit from corporation income tax in the base year. Based on the annual revenue of 139found single-use plastics manufacturers in Ontario, the corporation tax is calculated for the first, second, and third year. If the annual revenue of a firm is less equal to $500,000.00, the applicable combined tax rate equals to 12.2%. If it is greater than $500,000.00, 26.5% is applied to calculate the annual corporation income tax and the NPV for taxes is calculated. The summation of tax benefit values in today's dollar gives the total NPV of tax benefits of manufacturers for the intended period. It should be noted that the tax rates are determined based on the single-use plastics allocated revenue, not the total revenue of the firm.

3-5-5-2- Costs

For staying in the market manufacturers may have to bear the bulk of the costs for this ban. The incremental costs are the costs of the action they take in a way that they will be allowed

to keep producing and selling their products. These costs are the capital investment and the annual operating costs of replacing their material with a safe and affordable alternative. If the manufacturer is forced to shut down, manufacturing jobs are lost and there is a cost to the economy due to the job loss.

Once the ban takes into effect, changes will occur to jobs. Whether it is job loss or only job transition, it has costs for manufacturers, society, and the government. Simply put, if a single-use plastics manufacturer substitutes the production line with an alternative material, they will need to hire professional experts in the field, train general labors, and lay off employees with irrelevant field of expertise. While the training cost exists in this case, it does not contribute to a substantial portion of the whole cost; therefore, is excluded from the model. On the other hand, if the manufacturer is forced to shut down, manufacturing jobs will be lost which is a cost to the economy. Along with unemployment insurance imposed to the government, studies show that lay off and downsizing has hidden impacts on the society, such as health problems, sleeping difficulties, or feelings of depersonalization (Grunberg, Moore, & Greenberg, 2006).

The total sponsor's cost is calculated by combining these elements:

$$\boldsymbol{Total\ Sponsor's Cost = Capital\ Cost + Operating\ Cost - Revenue}$$

Figure 10 demonstrates the benefit and costs imposed to single-use manufacturers that would substitute plastics with an alternative material.

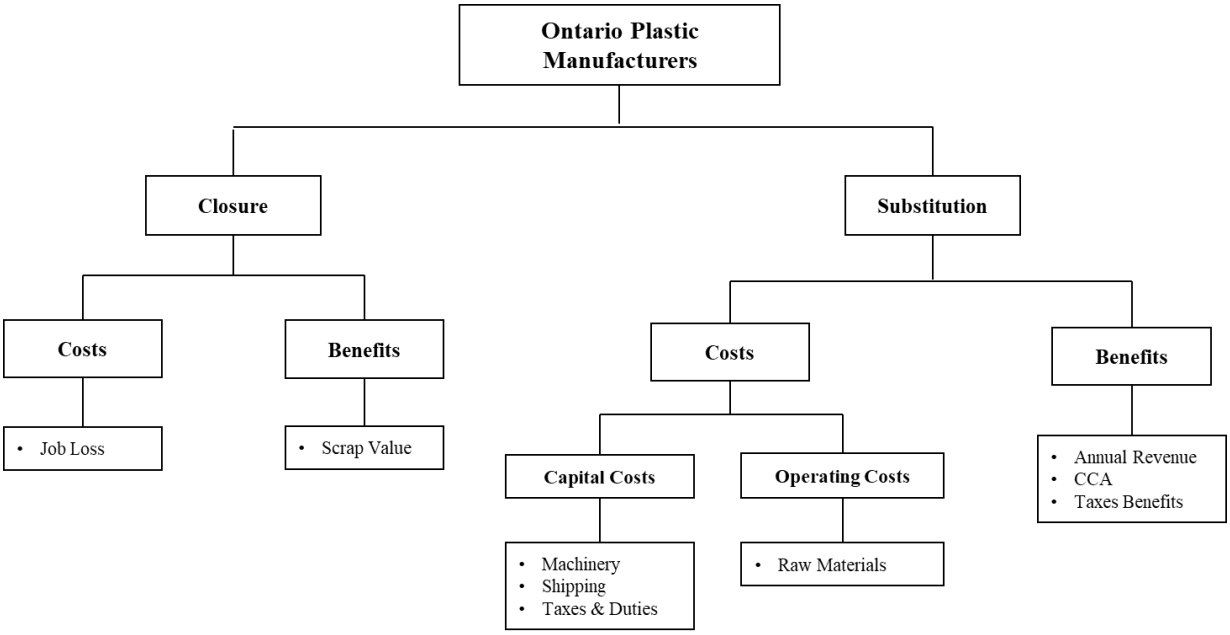

Figure 10. Cost and Benefit Factors

- **Capital Costs**

Capital costs are one-time expenditures that the company will use for more than a year (Majaski, 2020), such as building, land, machines, equipment, etc. The major capital costs in this study include the cost of purchasing and shipping machines and the duty that must be paid for importing them into Canada. The total capital cost of each production line equals the summation of purchasing prices, applicable duty, and shipping cost of all the machines needed to produce a product.

$$Production\ Line\ Capital\ Cost = \sum_{n=1}^{i} (Price\ of\ Machinry + Shipping\ cost + Duty)$$

Where, *i* is the number of machines in production process of the product.

Machines and Equipment

Changing machinery and equipment constitute a great portion of costs that manufacturers should bear in case of substitution. In addition to the purchasing price of the machine, there are other costs as well, such as moving.

Based on the list of machines used for each step of production (both for plastics and alternative materials) in previous section, the cost for buying machinery was calculated. The prices of machines were obtained online, from three manufacturing equipment dealers[20],[21],[22] that mainly sell used machines. For calculating machinery costs, this study uses those dealers that sell machines from Ohio, the United States. According to Statistics Canada (2019), Ohio has been the main exporter of industrial machinery to Canada since 2015 and it is amongst the top ten largest exporters of machinery (The United States Census Bureau, 2017). Besides, given that the case study of this thesis is single-use plastic manufacturers in Ontario, to minimize shipping costs and travel time, it was realized that purchasing needed manufacturing machinery from Ohio decreases the capital cost for manufacturers that will substitute their materials.

A range of prices were found for each machine for a more realistic assumption for machinery purchasing prices. The middle price of machines is used for the original analysis at first. Then, the sensitivity analysis shows how the results might change if the capital costs increase or decrease.

By understanding the production process of products, it was found out that the production process for petrochemical plastics and PLA are very similar and machinery can be used

[20] https://www.machinio.com/
[21] https://www.resale.info/
[22] https://www.kitmondo.com/

interchangeably. Consequently, for those products that will be substituted by PLA, the machines and equipment will remain the same.

Since the dealers often sell used machines, in order to estimate the purchasing price of new machines, the prices of a few new machines were compared with the price of the same new machines. Based on this comparison, it was found that new machines cost approximately three times more than used machines. as a result, a factor of three was selected to estimate the price of new machines. In other words, the prices offered by the dealers were multiplied by three and the value was used as the purchasing price of a new machine.

Moving and Shipping

The machines sold by used dealerships mentioned in previous section are made and located in the United States. It is assumed that machines are purchased from the United States and imported to Canada. The shipping and moving costs are added to the price of the machine as a part of the total capital cost. An American Crane and Hauling Service company[23] is selected as a sample for estimating heavy machine transportation price. The company offers a price range for heavy machine moving and rigging in North America. The prices are calculated hourly and the range varies based on the weight of the machine. Based on the assumption that machines are shipped from Ohio, and since the dataset shows that the majority of manufacturers in Ontario are located in Greater Toronto Area (GTA), the cost of shipping is calculated based on the distance from Ohio to GTA. Figure 11 shows the distribution of plastics manufacturers in Ontario.

[23] https://duffycrane.com/

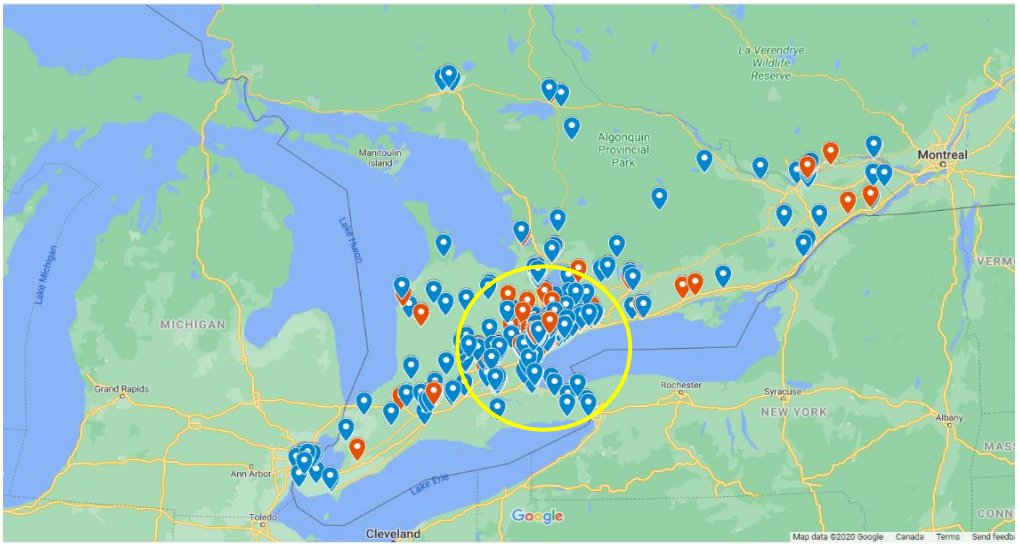

Figure 10. Plastics manufacturing density in Greater Toronto Area[24]

The map shows that a great number of plastics manufacturers are in southwest of the province. As shown in figure 9, of 139 single-use plastics companies, 110 are located in the Great Toronto Area, and 29 are outside this region. Because the majority of single-use plastics companies are located in GTA, this study uses the distance of Ohio to GTA to calculate the shipping costs.

[24] Source: Google Map

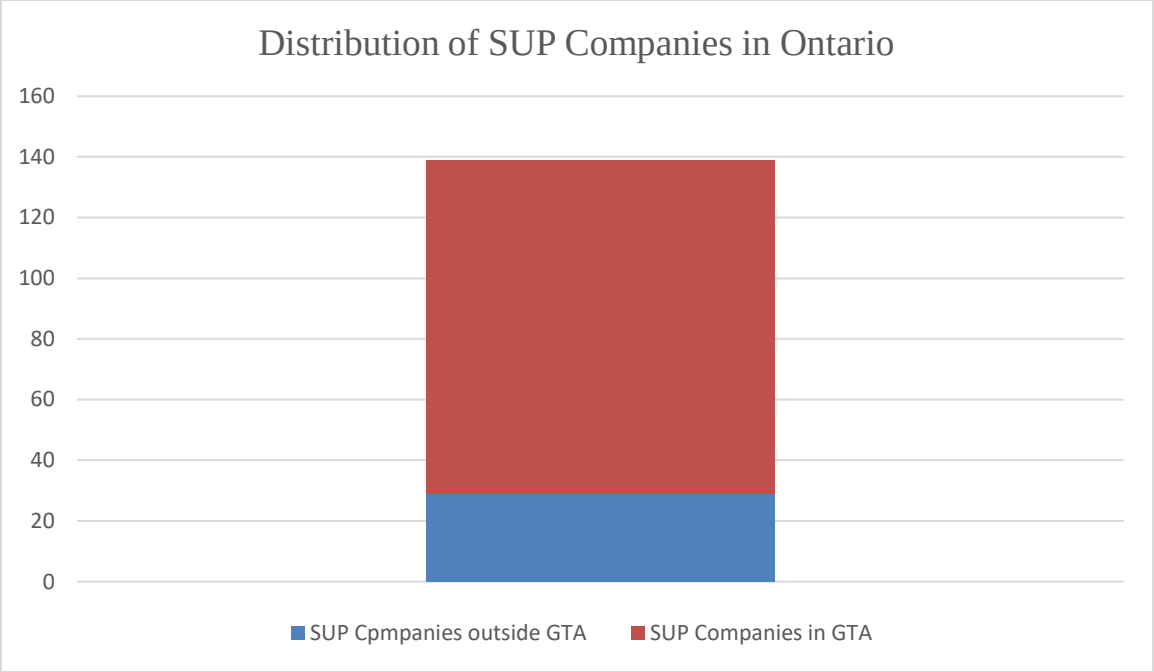

Figure 11. Distribution of SUP Companies in Ontario

As measured by Google Map, the distance from Ohio to GTA is approximately 700 kilometers. With an average speed of 100 km/h, it takes 7 hours to ship the machine from Columbus (capital of Ohio) to GTA. This speed is in fact the rounded average of the maximum speed limits of the States the trailer passes to reach to its destination which consist of Ohio, Pennsylvania, New York, and Ontario. The maximum speed for trailers in Ohio is 55 miles per hour and in New York, Pennsylvania (Insurance Institute for Highway Safety, 2020), and Ontario is 65 miles per hour (Ontario, 2020).

For the total shipping cost calculation, the proper price rate for each machine is multiplied by the number of hours needed for the machine to be arrived at its destination.

$$Moving\ Cost\ (CAD) = Price\ Rate\ (CAD/h) * 7\ (h)$$

The following table shows the price list offered by the crane and hauling service company.

Table 7. Machinery Shipping Price Range

Truck, Tractors, and Trailers	
Description	**Rate per hour**
18 Ft. Van w/ Lift gate	$ 80.00
Tractor & Flatbed	$ 85.00
Tractor & Dovetail	$ 95.00
Tractor Step deck	$ 95.00
Tractor Low bed to 50 ton	$ 95.00
Tractor Low bed to 60 ton	$ 115.00
Tractor Low bed to 75 ton	$ 140.00
Tractor Low bed 90-ton standard	$ 170.00
90-ton Perimeter Deck	$ 180.00
Loads over 75+ ton	$ 210.00

The weight of the machines does not exceed from 50 tons hence the appropriate price rate is 95 USD/ hour. The used exchange rate for converting United States dollar to Canadian dollar is 1.3063 (Bank of Canada[25]). Therefore, the shipping rate per hour equals to:

$$Price\ Rate\ (CAD)\ per\ hour = 95 * 1.3036$$

$$Price\ Rate\ (CAD)\ per\ hour \approx 125$$

[25] The annual average exchange rates are published by 12:30 ET on the last business day of the year. Exchange rates are expressed as 1 unit of the foreign currency converted into Canadian dollars.

According to the company, the prices include tax, insurance, and personnel, yet there is a 2% fuel surcharge added on the final invoice. Therefore, an approximate total shipping cost is calculated as follows:

$$Total\ Shipping\ Cost\ (CAD) = Moving\ Cost\ (1 + 0.02)$$

$$Total\ Shipping\ Cost\ (CAD) = 125 * 7 * 1.02$$

$$Total\ Shipping\ Cost\ (CAD) = \ 892.5$$

Tax and Duty

Many products imported to Canada are subject to duty and tax (Canada Border Services Agency, 2019). Depending on the type of goods, country of origin, value of goods, and other factors, the amount of applied duty and tax may vary. It should be noted that country of origin does not only mean where the good is imported from. For some products, the country where they are made and assembled are also important factors to consider. It was already mentioned that it is assumed that machines are originated in and shipped from the United States. This study calculates the tax and duty of the imported machines by reading through Canada Border Service Agency and using a Canada-USA import duty estimator[26]. It estimates the duty based on the value of goods. The duty for importing machinery is a one-time cost, paid as a part of total capital cost.

- **Operating Costs**

[26] https://quotes.borderbuddy.com/

Contrary to capital costs, operating costs are ongoing costs related to the operation of the business, including salary, material, rent, maintenance, utility, etc. (Murphy, 2020). Operating costs associated with production in this study are explained in this section.

Raw Material

The single-use plastics products assessed in this study are made from a variety of plastic types, including PET, HDPE, PVC, LDPE, PP, and PS.

In order to detect the material cost, the net weight of products is used to estimate the amount of material needed to produce an item. Moreover, the capacity and availability of the machines determine how many pieces of each item is produced every year. The information of product net weight along with the capacity of machines, help finding material cost of production.

$$Uptime\ \% = \frac{Operating\ Time}{Planned\ Production\ Time}$$

$$Planned\ Production\ Time = Shift\ Time\ - Breaks$$

$$Operating\ Time = Planned\ Production\ Time - Down\ Time$$

Given that in a year with 252 business days, a manufacturer operates an eight-hour shift a day, with total break time of one hour per shift, the planned production (available) time will be 1,764 hours per year. Assuming that 15 minutes per shift is dedicated to down time, then the annual operating time is 1,701 hours. Therefore, the uptime will be 96%.

The material used as the alternative to plastics is selected based on its functionality, viability, availability, and cost of the material. Accordingly, aluminum, wood, paper, polylactic acid, and glass are selected as alternatives for petrochemical plastics. In this study, only the main raw materials which have the greatest impact on costs are taken into account. For instance, the main material used for producing paper bags is kraft paper, yet the amount of glue is too low and is not included in the material cost in the model.

While it is expected that the ban would lead to more innovation in products that make them become more user-friendly, environmentally friendly, and cost efficient, but in this study, single-use plastics items will be replaced by the best existing option and no innovation and novelty is assumed for alternative products. For instance, the alternative product for plastic grocery bags is paper bags that are already being produced and exist in the market. Substitute materials for products are as follow:

- Paper for plastic grocery bags, zipper bag, pouch, wicket bags, poly bags, roll stocks, and straws.
- Wood for plastic cutlery and stirrers.
- Aluminum for cold beverage bottles.
- Glass for plastic jars and containers.
- Polylactic acid for other plastic garbage bags, flexible frozen food packaging, stretch films, shrink wrap, bubble wrap, containers, blister packaging, and clamshell packaging.

The amount of material requirement for production is empirical data collected through weighing the average size of each product. The material cost of each product is calculated by multiplying the net weight of an average size product to the price of the raw material. Then, by multiplying this number to the production capacity, the annual material cost of production for each item is calculated. The prices of raw materials are obtained from some suppliers or manufacturers offering raw material.

Table7 compares the net weight of an average size product when it is made of plastics to that of an alternative material (the weights of products substituted by biodegradable plastics remains the same, therefore, are not included in table 8).

Table 8. Plastics and alternative material weight comparison

Product	Alternative Material	Plastics Mass (gr)	Alternative Mass (gr)
Beverage bottle	Aluminum	11	14
Retail bag	Kraft paper	3	10
Cutlery	Wood	1.5	2
Caps and closure	Aluminum	3	4.5
Straw	Paper	0.9	1.2
Stick stirrer	Wood	0.8	1.3
Poly mailer bag	PLA-coated paper (25% plastic, 75% kraft paper)	8	13
Pouch	PLA-coated paper (25% plastic, 75% kraft paper)	10	13
Zipper bag	PLA-coated paper (25% plastic, 75% kraft paper)	8	13
Poly bag/ wicket	Kraft paper	3	11

Snack web	PLA-coated paper (25% plastic, 75% kraft paper)	1.9	0.8
Jar	Glass	11	35

Salary

One of the aforementioned assumptions of this study is that the operating costs of the model is in fact the changes in cost by altering plastics to other materials. Therefore, some costs will remain the same for both production with plastics and production with alternative material. Salary of staff is a cost that remains the same before and after substitution.

However, if the material substitution is not profitable for a company and also investment recovery is more than three years, the facility should call a halt to production which will have consequences. One of the negative impacts of facility closure is employment loss. The impacts of job loss and unemployment is on the government to bear, yet this study estimates the number of lost jobs and discusses its possible impacts.

In every manufacturing facility, employees are working in different positions such as operator, designer, plant operator, project engineer, etc. While some of these positions are necessary in all manufacturing, it is not easy to determine all job positions and the number of workforces. Different factors contribute to the number of employees working in a company, namely, the annual revenue or the number of production lines of a manufacturer. Because of this limitation, in order to calculate the average number of employees working in single-use plastics segment, the same steps for SUP revenue allocation in the previous section have been applied to the total employees working at the company. The implications of the ban on employees will be discussed in Chapters 4 and 5.

3-6- Critical Assumptions for the Analysis

To accomplish the objectives of the study, assumptions have been made. The summary of these assumptions are as follows:

- The parameters of benefits and costs associated with material substitution are considered as having the greatest impact on the results of the model. The costs of changing machines and materials contribute to the majority of the total costs of manufacturers.
- Canadian dollar is used as the currency for this study. The prices, revenues, costs, etc., in this study are basically for the period of 2017 to 2019, hence the exchange rate used to convert other currencies (US dollar and Euro) is the average exchange rate of the years 2017, 2018, and 2019. According to the Bank of Canada[27], the Average Exchange Rates for the relevant period are 1.44936 for converting CAD to EUR, and 1.3063 for converting CAD to USD.
- According to Statistics Canada (2019) and The United States Census Bureau (2017), Ohio has been the main exporter of industrial machinery over the past few years. Manufacturers will try to minimize shipping costs by choosing suppliers that provide the most convenient and cost-effective delivery. The existence of a used equipment supplier in Ohio provides a means for evaluating equipment and delivery costs. Thus, Ohio is used as the origin for machinery for this thesis.
- As has been mentioned, alternative materials are selected and assigned to each plastics product based on their function, viability, availability, and cost. Therefore,

[27] https://www.bankofcanada.ca/rates/exchange/annual-average-exchange-rates/

this study does not take any possible shortage of materials into account. Only one alternative is considered in this thesis.

- Industrial machine and equipment dealers used in this study often offer used machinery. After comparing the prices of some used machines to the prices of new machines, a factor of three times the used price is used to estimate the price of new machines. Thus, the prices for the equipment used in the model are the price of corresponding used equipment.
- Given that single-use plastics medical devices are not included on the list of products to be banned in Canada and given that they are critical elements in healthcare that require meticulous studies by experts, single-use plastics medical devices are excluded from the model.
- As the goal of this thesis is to analyze the impacts of the ban on "single-use plastics" products, all the parameters of costs and benefits are specific to SUP products. For those companies that also have production lines other than SUP, the costs and benefits are distributed evenly to each production line. For the annual revenue of firms, it is assumed that revenues are linear and distributed proportionately among each production lines.
- The same assumption and calculation as the previous one have been made to employees of firms, namely that they are evenly distributed across product lines.
- The aim of this thesis is to model and evaluate the implications of the proposed single-use plastics ban on Ontario plastics manufacturing, hence the social impacts of the ban on employment are not directly included in the calculations of the CBA

model of this study. However, possible consequences of the lost jobs due to the implementation of the single-use plastics ban are discussed in Chapter 4 and 5.

- In this study, it is assumed that companies purchase semi-finished materials from suppliers rather than processing raw material themselves. For instance, they purchase semi-finished aluminum sheets and form the sheets into beverage cans.
- The model does not take into account the benefits or costs to the suppliers of raw materials. The evaluations are conducted on single-use plastics manufacturers in plastics industry. Therefore, effects of the ban on other industries can be excluded from the model.
- It is assumed that all the materials, including resins, semi-finished goods, and raw materials, are provided by suppliers within Canada. Canada is a leading producer of the materials that can be used as alternatives to single-use plastics, including:
    - ✓ Paper and Wood alternatives: In 2013, Canada was the leading forest product trading country followed by Sweden and Finland (Natural Resources Canada, 2020). Pulp and paper product manufacturing and solid wood product manufacturing are both subsectors of this industry. With 3% of Canada's GDP, the Canadian pulp and paper sector plays an important role in the Canadian economy (Natural Resources Canada, 2006).
    - ✓ Aluminum: Canada is the world's fourth largest producer of primary aluminum after China, Russia, and India, with 4.9% of the total primary aluminum production in the world (Natural Resources Canada, 2018).

- ✓ Plastic Resins: According to Statistics Canada, in 2010, about 90 percent of domestically consumed resins are produced inside the country (Statistics Canada, 2011).
- ✓ Glass: Statistics provided by Trade Data Online show that while the total glass and glass products export of Canada valued only 588.9 million dollars in 2019, the value of importing glass and glass products was 2.8 billion dollars in the same year (Statistics Canada, 2020). Although a great portion of glass and glass products are imported to Canada, this study assumes that manufacturers supply this material from Canadian glass manufacturers. This assumption does not affect the results of the analysis since glass does not contribute to a great portion of alternative material and the number of companies that manufacture those plastic products that will be substituted by glass are substantially low.

- The environmental benefits of a single-use plastics ban are not explicitly included in the model. They are considered externalities that benefit society, but do not directly benefit the company or factor into their economic decisions.

CHAPTER 4

RESULTS AND DISCUSSION

This section presents the results of the model of the single-use plastics ban and the cost-benefit analysis. As presented in the methodology section, 139 single-use plastics manufacturers in Ontario were found in online business resources. In this chapter, the alternative materials are briefly compared to conventional plastics based on the findings of this study and the literature. Then, the overall results of the CBA model are discussed, and individual evaluation is conducted for a small sample of the most affected companies. A series of sensitivity analyses are presented to show how the results may change if any of the variables changes, and then the results of the sensitivity analyses are discussed. In the end, possible implications of the ban are proposed, and the scope of the study is discussed.

4-1- Material Comparison

Alternative materials for each product are selected based on functionality and cost. Although innovation in product design would make production more cost efficient, in this study, no novelty is considered for alternative products.

This section compares plastics products with their alternatives from a financial perspective. While some environmental characteristics of materials are mentioned and discussed briefly, the environmental costs and benefits are not considered in the CBA model. Table 8 shows the annual material cost of each product per production line based on their net weight and the capacity of the machines. As it was mentioned in Chapter3, after finding the prices of plastics resins and alternative materials from available resources, the cost of material for each product was calculated based on the average net weight of each product

times the cost of suitable material. Then, according to the annual production capacity of machinery that was found in the detail features of machine, the number of goods produced by the company was calculated and multiplied by the material cost of a unit of product. Table 9 shows the results of the cost of material calculation for each product.

Table 9. Material Cost Comparison

Original Product	Plastics Material Cost	Alternative Material Cost
Beverage bottle	$ 198,426.15	$ 256,000.50
Retail bag	$ 57,595.36	$ 119,001.96
Cutlery	$ 51,123.93	$ 106,312.50
Caps and closure	$ 61,348.72	$ 82,285.88
Straw	$ 22,085.54	$ 36,450.00
Stick stirrer	$ 19,631.59	$ 36,450.00
Poly mailer bag	$ 76,793.81	$ 157,533.21
Pouch	$ 159,987.11	$ 157,533.21
Zipper bag	$ 127,989.69	$ 157,533.21
Poly bag/ wicket	$ 57,595.36	$ 119,001.96
Snack web	$ 42,556.57	$ 96,943.51
Jar	$ 198,426.15	$ 1,019,239.20
Take-out container	$ 104,701.81	$ 109,700.38
Film	$ 39,996.78	$ 53,564.64
EPS container	$ 62,651.09	$ 109,700.38
Flexible food packaging	$ 159,987.11	$ 171,406.84

Blister packaging	$ 76,279.37	$ 85,703.42
Clamshell packaging	$ 72,154.96	$ 85,703.42

The numbers in table 8 indicate that except for pouches, plastics are less costly options for the rest of products. One reason for the cost efficiency of plastics is that based on the weights of the products, plastics are lighter and consume less material compared to alternative materials assigned to them. Although plastics can end up in landfill and harm the environment due to their light weight, manufacturers might prefer lightweight plastics for their cost-efficiency.

4-1-1- Plastics Versus Paper

The Danish Environmental Protection Agency published a report in 2018 that shows Low Density Polyethylene plastic bags have the lowest environmental impacts when used once (not being reused). Based on this report, while plastic bags take a substantial amount of time to decompose, paper bags decompose more easily and quickly; however, the durability of plastic bags provides an opportunity to reuse them more frequently and the number of times a bag can be reused is a critical factor from a circular economy perspective. Based on the Danish report, plastic bags should be used 37 times, whereas paper bags should be reused 43 times before they are discarded (The Danish Environmental Protection Agency, 2018).

Assuming that paper bag producers purchase bulk kraft paper rolls rather than producing paper from scratch, based on the prices of material and machinery found from

aforementioned resources and the calculations of the model, the capital cost of paper bag production is less than that for producing plastic bags.

4-1-2- Plastics Versus Glass

Although there are methods to improve the energy efficiency of glass production (Worrell, Galitsky, Masanet, & Graus, 2008), glass manufacturing is still known as one of the most energy intensive industries. The melting furnace alone contributes to 75% of the total energy needed for the entire glass production (Redko, Redko, & Dipippo, 2020). The melting process occurs through fuel combustion which is very energy intensive. Besides, the energy costs, melting, and refining processes of glass manufacturing are complex (Redko, Redko, & Dipippo, 2020). Thus, based on the calculations of the CBA model, both the material and the capital cost of producing glass jars as an alternative to plastic bottles is very costly. Moreover, Table 7 in Chapter 3 shows that glass jars are at least three times the mass of plastic bottles and require more raw material. According to the database of single-use plastics manufacturers in Ontario, there are three companies producing plastics jars (Companies #50, #52, #53). Based on the assumption that plastics jars are replaced by glass jars, these companies will need to convert their plastics jar production lines into glass and bear the high costs of establishing new glass manufacturing lines. The results of the CBA model in this study show that although the NPV of their total benefit drops if they switch to producing glass jars, they can still make profit out of substitution.

4-1-3- Plastics Versus Aluminum

Aluminum is being used as a popular material for beverage packaging. The weight to strength property of aluminum (i.e., it is relatively lightweight in relationship to its volume and strength) and its high recyclability make aluminum attractive to producers (Gautam,

Pandey, & Agrawal, 2018). However, aluminum is a non-renewable resource, as producing aluminum requires bauxite, which must be obtained through strip mining (Guo, Wang, & Gao, 2018). According to the International Council of Bottled Water Associations (2008), 820 million liters of bottled water were produced in Canada in 2000. By replacing all plastic bottles with aluminum cans, the demand for alumina would increase and it might not be possible for them to meet the demand in long-term.

This study assumes that manufacturers buy aluminum sheets from aluminum suppliers and form them into desired shapes. Therefore, the explicit costs of mining, refining, and ingot casting are exempted from the model. Rather these costs are incorporated through the price of the aluminum. Based on this assumption, the primary calculations of costs and benefits show that the production costs (machinery and material) of aluminum cans are higher than that for plastic beverage bottles.

4-1-4- Plastics Versus Bioplastics

The literature on bioplastics show that there are still uncertainties about whether bioplastics are better options for petrochemical plastics or not. Depending on what type of biodegradable plastics we are considering for substitution, the benefits and drawbacks may vary. Some environmental scientists argue the biodegradability atmosphere of bioplastics and believe that the special environmental condition bioplastics require is an issue that affects the sustainability of bioplastics (Jabeen, Majid, & Nayik, 2015). Therefore, the sustainability of bioplastics remains an open-ended subject.

However, from an economical point of view, the result of the cost-benefit model in this study show that PLA is a better solution to petrochemical plastics. One of the most important benefits of using PLA is that manufacturers will not have to make substantial

changes in their production lines. The process and machines used for producing single-use plastics products are often similar. Although PLA resins are more expensive than other types of conventional plastics (Lemos Machado Abreu, Gonçalves de Moura, Vasconcelos de Sá, & Vera Alves Machado, 2017), manufacturers will not have to bear the capital cost (machinery) of substitution.

4-1-5- Plastics Versus Wood

Wood is the preferred materials for cutlery and utensils in this study. Wooden cutlery can be made of bamboo, birch, maple, etc., which are all compostable and renewable resources (Rarhod, Hwang, Nahid Thohid, & Uifalusi, 2015). However, making wooden cutlery instead of plastics causes deforestation and can be harmful for the environment and also, they are brittle and may contain splinter that can be harmful (Chen, Ko, & Wei, 2011). Based on the database of Ontario SUPs manufacturers, there are 10 companies producing plastics cutlery and 2 companies producing stick stirs that should be substituted by wood. Plastics machinery should be replaced by wood processing machines. Although the material is more expensive than plastics (Chen, Ko, & Wei, 2011), the prices of machines found in this study show that the capital cost (machinery) is unlikely to be a huge burden for manufacturers.

4-2- Summary

The following table summarizes the main machinery required for production along with advantages and disadvantages of alternative materials from various perspectives based on the literature and findings of this study.

Table 10. Advantages and Disadvantages of Alternative Materials and Machinery Used for Alternative Production

Material	Advantages	Drawbacks	Machinery
Paper	Biodegradable, easy to print, good mechanical strength (Raheem, 2013), lightweight.	High energy consumption, use non-renewable resource (Bystrom & Lonnstedt, 1997), contribute to deforestation (Rarhod, Hwang, Nahid Thohid, & Uifalusi, 2015)	Flexographic printing machine, Paper bag forming machine, Slitter, Paper-plastic laminating machine (for PLA-coated paper bags)
Glass	Strong, versatile, easily molded, recyclable (GharPedia)	Energy intensive, complex manufacturing process (Redko, Redko, & Dipippo, 2020), expensive machinery and equipment, expensive material, brittle	Furnace, Mixer and processor, Feeder, Blow molding machine, Annealing lehr, Lubricant coating machine
Aluminum	Lightweight, recyclable, (Gautam, Pandey, & Agrawal, 2018),	Non-renewable (Guo, Wang, & Gao, 2018), complex mining and refining process (American chemistry Society, 2001).	Aluminum extrusion press, cutting machines, Punching machine, Aluminum sheet printing machine, Washing/Drying Machine, Necking sleeve die, Screw capping machine, Cap punching machine
Bioplastics (PLA)	Degradable, lightweight, renewable resource (Lemos Machado Abreu, Gonçalves de Moura, Vasconcelos de Sá, & Vera Alves Machado, 2017), recyclable and compostable (Maiza, Benaniba, Quintard, & Massardier-Nageotte, 2015)	Release toxins if not recycled properly (Laxmana Reddy, Sanjeevani Reddy, & Anusha Gupta, 2013), low gas-barrier properties, costly, brittle (Lemos Machado Abreu, Gonçalves de Moura, Vasconcelos de Sá, & Vera Alves Machado, 2017)	Similar to petrochemical plastics machines
Wood	Eco-friendly, renewable resource, compostable (Rarhod, Hwang, Nahid Thohid, & Uifalusi, 2015)	Brittle, costly, contains splinter (Chen, Ko, & Wei, 2011), contribute to deforestation (Rarhod, Hwang, Nahid Thohid, & Uifalusi, 2015)	Veneer cross cutter, Wood hot press, Vertical plywood veneer dryer, Sanding and Polishing Machine, Engraving Machine

Some plastics products are not a big challenge to find a replacement for. While switching plastics bags with paper or cloth bags may not be a big of deal both for manufacturers and

for consumers, it is difficult to find a replacement for some products in a short-term. In essence, there might be a risk in substituting plastics water bottles with materials such as aluminum. There is a need for technology innovation in aluminum beverage cans to reduce the potential risks of this particular material. However, since the supply and environmental consequences are considered externalities to the CBA of this thesis, it will not affect the results.

4-3- Cost-Benefit Analysis of SUP Ban for Ontario Manufacturers

A cost-benefit analysis has been conducted to evaluate the implications of the proposed single-use plastics ban on manufacturers in Ontario. For this purpose, a database of 139 single-use plastics manufacturers in Ontario was created, as described in the methodology section. This section describes the costs and benefits of single-use plastics by alternative materials and major parameters of costs and benefits related to material substitution. By calculating the NPV of total costs and benefits over the next three years, the overall benefit of each manufacturer was calculated. Based on the results of the model, the overall benefit for 132 manufacturers was positive, which means material substitution will be theoretically financially feasible. These companies have the opportunity to keep producing, getting revenue, and staying in the market even after the ban takes into effect. However, their net profits may decrease because of the imposed costs of purchasing new machinery or because alternative materials are more expensive than plastics. The following table contains information about 139 found single-use plastics manufacturers in Ontario including their production lines, number of employees allocated to SUPs lines, and the annual revenue generated by single-use plastics production lines.

Table 11. 139 Ontario Single-Use Plastics Manufacturers

Number	Production Lines	SUP Allocated Revenue	SUP Staff
1	Signs, costume plastic fabrication, poly bag, zipper bag	$350,000.00	3
2	Polybag, zipper bag, wicket, roll stock, laminated pouch	$2,300,000.00	17
3	Retail Bags, polymailers, stretch film, zipper bag, label	$28,000,000.00	160
4	Flexible Food Packaging, clamshell packaging, meat PE tray, corrugated box	$5,833,333.33	30
5	Laminated pouch, roll stock, flexible fruit packaging, wicket, polybag, snack web, carton box	$4,285,714.29	39
6	Polybag, roll stock	$500,000.00	2
7	Jute bag, plastic retail bag	$1,500,000.00	4
8	Garbage Bags	$10,000,000.00	75
9	Flexible food packaging, shrink wrap, garbage bag	$8,000,000.00	30
10	garbage bag, grocery bags, wicket bag, flexible food packaging, Paper bag	$3,600,000.00	20
11	retail bags, garbage bag	$23,000,000.00	200
12	garbage Bags, roll stock	$1,300,000.00	5
13	Flexible food packaging, garbage bag, retail bag, industrial sheet	$5,250,000.00	60
14	garbage bags, retail bags, paper bag, carton box, label, tissue, gift wrap	$114,285.71	1
15	Poly bag, roll stock	$2,500,000.00	24
16	Garbage bags	$8,000,000.00	44
17	stretch film, flexible food packaging, snack web, shrink film, zipper bag	$3,000,000.00	75
18	Shrink film, candy twist wrap, bag	$225,000.00	2
19	Paper roll, plastic roll stock	$3,750,000.00	4
20	Garbage bags	$500,000.00	15
21	garbage bags, Poly bag, roll stock	$1,200,000.00	10
22	poly bags, roll stock, poly gloves	$2,000,000.00	15
23	poly bags, roll stock	$17,000,000.00	80
24	garbage bag	$1,200,000.00	10
25	shrink film, stretch film, industrial sheet	$1,800,000.00	20
26	PE gown, shoe cover, non-woven cover, hard head protection, Latex gloves	$5,333,333.33	12
27	Garbage Bags, stretch film	$7,000,000.00	52
28	Paper bag, plastic bags, zipper bag	$200,000.00	1
29	Plastic bag, shrink film, laminated pouch	$3,700,000.00	57
30	Poly bags, zipper bag, film, garbage bag, industrial sheet	$4,800,000.00	33
31	Retail bags	$500,000.00	4
32	Zipper bag, retail bag, wicket, pallet cover	$6,000,000.00	44
33	Stretch Films, Shrink Films, Strapping, tape, conveyor belt, Industrial sheet, pallet wrapping machine	$866,666.67	7
34	Plastic Film, Laminated snack Packaging	$1,500,000.00	15
35	snack web, clamshell packaging, flexible packaging, bubble wrap	$7,000,000.00	50
36	Shrink film, poly bag, label	$1,040,000.00	17
37	Plastic Films and Sheets	$200,000.00	2
38	Plastic Films and Sheets	$1,750,000.00	45

39	Stretch film	$23,000,000.00	200
40	Laminated Pouches	$60,000,000.00	175
41	Plastic Films and Sheets	$3,500,000.00	52
42	Industrial sheet, stretch film	$8,750,000.00	62
43	Laminated pouch, mailing bag, flexible food packaging, paper bag	$9,000,000.00	48
44	shrink wrap, flexible food packaging, meat PS tray, roll stock, Industrial sheet	$14,000,000.00	50
45	Pharmaceutical bag, semi-rigid PE packaging, industrial sheet	$5,000,000.00	20
46	Plastic rigid plate, wicket	$166,666.67	3
47	Stretch film, shrink films	$1,200,000.00	10
48	Packaging for automotive, household, marine, agricultural and recreational markets	$2,000,000.00	63
49	Foam takeout container, foam tray, foam plate	$2,300,000.00	20
50	Jars, containers, Bottles	$3,300,000.00	25
51	Beverage bottle, detergent bottle	$3,750,000.00	15
52	Jars, containers, Bottles	$1,300,000.00	10
53	Jars, containers, Bottles	$3,000,000.00	50
54	Carton box, Plastic food Packaging	$3,100,000.00	17
55	Flexible food Packaging, cutlery, and PP Containers	$3,200,000.00	10
56	Clamshell food container, cup, cutlery, straw, stirrer stick, paper cup, face shield, latex gloves	$37,142,857.14	281
57	Caps and Closures	$16,000,000.00	40
58	Molded Products, Clamshell Packaging	$250,000.00	6
59	PP takeout container	$15,900,000.00	100
60	PS+PET+Paper (Cups, Containers, Cutlery, lid, dinnerware)	$7,000,000.00	50
61	PP takeout container, foam dinnerware, clamshell container, Carton box, paper cup	$22,500,000.00	60
62	PE Biscuit trays	$2,300,000.00	20
63	Bottle Caps, injection molding	$1,500,000.00	13
64	Caps and Closures	$1,500,000.00	50
65	PS food Containers, PET clamshell container, cutlery	$17,000,000.00	400
66	Caps and Closures	$5,000,000.00	25
67	Clamshell food Containers, cutlery	$17,000,000.00	45
68	Semi-rigid PP Food containers, lids	$75,000,000.00	750
69	Clamshell food Containers, blister packaging, bottle, detergent bottle, reusable food container	$1,500,000.00	11
70	Clamshell Food Container	$1,200,000.00	3
71	Clamshell Packaging and Trays	$1,200,000.00	11
72	Rigid gift boxes, clamshell packaging	$1,000,000.00	13
73	Blister Packaging, Clamshells, Display Trays	$933,333.33	5
74	Display, blister and clamshell packaging	$1,533,333.33	13
75	Blister packaging, face shield, carton packaging	$6,666,666.67	15
76	laminated pouch, bottle sleeve, wicket bag, flower sleeve	$11,000,000.00	101
77	Roll stock, flexible Packaging	$12,000,000.00	89
78	Beverage bottle, laminated pouch, snack web, flexible food packaging, detergent bottle, carton box, industrial film and wrap	$8,571,428.57	71
79	Roll stock, pouch, poly bags	$7,500,000.00	25
80	Plastic Bags, stretch film, flexible food packaging	$17,000,000.00	250

81	flexible food packaging, blister and clamshell, industrial cover, carton box	$10,200,000.00	80
82	Bags, Flexible Packaging, wicket bag, stretch film, industrial cover, boat cover	$1,000,000.00	12
83	Laminated Pouches, Bags, flexible packaging	$8,700,000.00	75
84	Stretch film, garbage bag, shrink film, meat PS tray, flexible packaging, tape, paper bag, latex gloves, protective coverall, tissue, detergent bottle	$10,833,333.33	36
85	Bubble wrap, industrial film, corrugated box	$333,333.33	7
86	pet food packaging, flexible food packaging, candy twist wrap	$10,000,000.00	85
87	Zipper bag, Pouch, laminated packaging film, roll stock, flexible food packaging	$600,000.00	3
88	grocery bag, zipper bag, flexible packaging, poly bag, garbage bag, carton box, paper bag	$1,285,714.29	4
89	Bags, flexible packaging, Films and Sheets	$35,000,000.00	50
90	Zipper bag, flexible packaging, shrink wrap, pouch, poly bag, wicket, carton box, label	$2,333,333.33	19
91	frozen food bag, zipper bag, roll stock	$270,000.00	1
92	Paper packaging, pouch, flexible food packaging, wicket, snack web	$8,000,000.00	48
93	Zipper bag, Grocery Bags, flexible food packaging, wicket, laminated snack pack	$3,000,000.00	12
94	flexible packaging bag, paper bag, woven bag, burlap	$1,000,000.00	18
95	Laminated pouch, retail bag, flexible food bag, zipper bag, industrial cover	$560,000.00	6
96	Roll stock, stretch film, bag, laminated pouch	$16,000,000.00	120
97	Flexible food bags, biohazard bag, carton box, industrial sheet	$8,500,000.00	90
98	Stretch film, Shrink wrap, autoclave bag, Pallet cover, woven bulk bag	$1,800,000.00	3
99	retail bag, roll stock, garbage bag, shrink wrap, stretch wrap, construction bag, pallet cover	$257,142.86	9
100	Poly bag, laminated pouches, roll stock	$5,000,000.00	46
101	Medical Healthcare Packaging Films, Food Flexible Packaging, Tags and Labels	$23,333,333.33	33
102	Flexible food Packaging, snack web	$3,000,000.00	19
103	Laminated snack pack, roll stock, paper packaging	$3,866,666.67	13
104	Foam food container, PS cup, bubble wrap, cutlery, poly bag, snack web, flexible food packaging, label, tissue, paper cup, corrugated box, foam sheet	$20,181,818.18	20
105	PS cup, PS dinnerware, straw, poly bag, stretch film, sheet, stirrer stick, garbage bag, hearing protection, label, carton box, napkin, paper bag	$2,450,000.00	10
106	Poly bags, zipper bag, garbage bag, cutlery, foam plate, foam cup, stretch wrap, bubble wrap, hearing protection, tape, protective coverall, tissue, wipe	$2,916,666.67	19
107	roll stock, poly bag, zipper bag, laminated pouch, gift box, carton box	$800,000.00	10
108	Pouches, flexible food packaging, Bottles, Laminated snack pack, Garden Bags, paper bag, Industrial sheet	$7,428,571.43	86
109	Poly bag, shrink film, garbage bag, laminated pouch, pallet cover	$12,000,000.00	90
110	Bubble bag, zipper bag, PP food container, stretch film face mask, latex gloves	$4,000,000.00	22
111	Stretch film, clamshell food container	$6,500,000.00	33
112	blister packaging, clamshell packaging, snack web, flexible food packaging, roll stock, semi-rigid PP packaging, laminated pouch	$28,000,000.00	179

113	laminated pouch, snack web, flexible food packaging, shrink wrap, blister packaging, carton packaging	$5,000,000.00	24
114	Blister packaging, semi-rigid PP packaging, snack web, roll stock, food packaging, carton box	$20,000,000.00	104
115	PE Gloves, garbage bag, flexible food packaging, zipper bag, PP food container, cutlery, clamshell Food Containers, Paper Bags, carton box, Poly Bags, Tissue paper, jewelry box, garment bag	$45,769,230.77	146
116	Shrink wrap, clamshell packaging, retail bag, gift box, display	$1,800,000.00	15
117	Bubble Sheets, mailer bag, Roll Packs, Plastic Packaging, paper wrap, Foam sheet	$7,333,333.33	71
118	stretch film, shrink film, bubble wrap, Tape, first aid box, corrugated packaging, foam sheet	$16,071,428.57	26
119	Bubble wrap, laminated snack rolls, clamshell food container, corrugated box, foam sheet	$9,000,000.00	33
120	blister packaging, bottle, cap, laminated pouch, Carton packaging, label	$46,666,666.67	233
121	Flexible food packaging, Containers	$1,000,000.00	30
122	shrink wrap, blister and clamshell, corrugated packaging	$3,435,000.00	9
123	Shrink wrap, blister packaging, bag, clamshell food packaging, carton box, label	$2,000,000.00	18
124	Flexible Candy and Confectionary Packaging, confectionary packaging, carton box, plastic gift box, tag	$200,000.00	3
125	Blister packaging, shrink wrap, insulation foam	$6,000,000.00	30
126	blister packaging, shrink wrap, display	$4,000,000.00	17
127	Blister packaging, laminated pouch, tape, sheet, snack web	$21,600,000.00	40
128	bubble wrap, poly bag, laminated pouch, stretch wrap, shrink wrap, garbage bag, pallet cover, Carton box, kraft paper, tape, foam sheet	$2,181,818.18	13
129	flexible packaging	$500,000.00	3
130	PE Gloves, flexible Packaging, Stretch Wrap	$4,500,000.00	33
131	Clamshell packaging, blister packaging, laminated pouch, gasket and washer, injection molding, foam sheet	$3,750,000.00	21
132	Clamshell packaging, shrink wrap, corrugated box	$2,000,000.00	5
133	Glass and plastic beverage bottles, Closures and Caps	$4,666,666.67	23
134	Cutlery, Straws, bottle, caps, PP container	$1,000,000.00	10
135	blister and clamshell packaging, displays	$333,333.33	3
136	Blister and clamshell packaging	$2,800,000.00	21
137	Blister and clamshell packaging	$1,200,000.00	10
138	Clamshells food packaging, trays, blister packaging, foot brace	$4,000,000.00	30
139	Healthcare reusable and disposable plastic cups and trays, face shield	$1,166,666.67	10
Total		**$1,066,986,676.7**	**6,798**

Based on the annual revenue of companies, of 139 single-use plastics manufacturers, 104 of them are small companies, 22 are medium, 12 are micro, and only one is a large company. The size of the company is based on the total number of their employees.

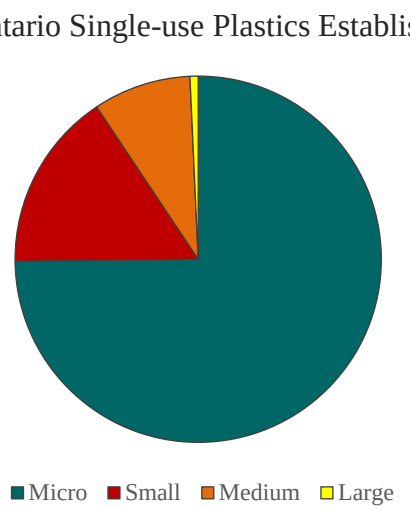

Figure 12. Percentage of Ontario Single-use Plastics Establishments by Size

Table 11 shows that the total amount of revenue allocated to single-use plastics for the 139 found companies is $1,066,986,676.7 and 6,798 people are working in this sector.

As discussed above, a suitable alternative material is chosen to replace the banned plastics if the net cost of converting to the alternative is positive. Table 12 shows the proposed alternative materials used by each company and the calculated NPV for the materials and cost of changing products.

Table 12. NPV for Changing Materials and Production

#	Products	Material for Conversion	Equipment for Conversion	Material Cost Difference	Costs of Changing Equipment	NPV for Materials	NPV for Total Cost
1	Signs, costume plastic fabrication, poly bag, zipper bag	Kraft paper, PLA-coated kraft paper	Paper machinery	$ 90,950.11	$ 1,092,576.25	$ 262,289.51	$ 1,354,865.76
2	Polybag, zipper bag, wicket, roll stock, laminated pouch	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 236,907.34	$ 2,275,233.00	$ 683,213.13	$ 2,958,446.13
3	Retail Bags, polymailers, stretch film, zipper bag, label	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 185,791.99	$ 1,772,347.00	$ 535,802.41	$ 2,308,149.41
4	Flexible Food Packaging, clamshell packaging, meat PE tray, corrugated box	PLA	-	$ 38,516.65	$ -	$ 111,077.52	$ 111,077.52
5	Laminated pouch, roll stock, flexible fruit packaging, wicket, polybag, snack web, carton box	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 285,969.47	$ 2,185,152.50	$ 824,702.57	$ 3,009,855.07
6	Polybag, roll stock	Kraft paper	Paper machinery	$ 135,612.17	$ 825,611.00	$ 391,089.66	$ 1,216,700.66
7	Jute bag, plastic retail bag	Kraft paper	Paper machinery	$ 68,670.88	$ 412,805.50	$ 198,038.80	$ 610,844.30
8	Garbage Bags	PLA	-	$ 121,075.76	$ -	$ 349,168.37	$ 349,168.37
9	Flexible food packaging, shrink wrap, garbage bag	PLA	-	$ 167,791.34	$ -	$ 483,890.62	$ 483,890.62
10	garbage bag, grocery bags, wicket bag, flexible food packaging, Paper bag	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 307,369.37	$ 1,413,161.00	$ 886,417.37	$ 2,299,578.37
11	retail bags, garbage bag	Kraft paper, PLA	Paper machinery	$ 189,746.64	$ 412,805.50	$ 547,207.17	$ 960,012.67
12	garbage Bags, roll stock	Kraft paper, PLA	Paper machinery	$ 195,281.33	$ 679,770.75	$ 563,168.57	$ 1,242,939.32
13	Flexible food packaging, garbage bag, retail bag, industrial sheet	PLA, kraft paper	Paper machinery	$ 233,163.80	$ 914,405.50	$ 672,417.17	$ 1,586,822.67
14	garbage bags, retail bags, paper bag, carton box, label, tissue, gift wrap	PLA, kraft paper	Paper machinery	$ 189,746.64	$ 914,405.50	$ 547,207.17	$ 1,461,612.67
15	Poly bag, roll stock	Kraft paper	Paper machinery	$ 135,612.17	$ 989,461.00	$ 391,089.66	$ 1,380,550.66
16	Garbage bags	PLA	-	$ 121,075.76	$ -	$ 349,168.37	$ 349,168.37
17	stretch film, flexible food packaging, snack web, shrink film, zipper bag	PLA, PLA-coated kraft paper	Paper machinery	$ 105,486.81	$ 1,947,091.50	$ 304,211.63	$ 2,251,303.13
18	Shrink film, candy twist wrap, bag	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 55,231.45	$ 1,359,541.50	$ 159,281.05	$ 1,518,822.55
19	Paper roll, plastic roll stock	Kraft paper	Paper machinery	$ 74,205.57	$ 412,805.50	$ 214,000.20	$ 626,805.70
20	Garbage bags	PLA	-	$ 121,075.76	$ -	$ 349,168.37	$ 349,168.37
21	garbage bags, Poly bag, roll stock	Kraft paper, PLA	Paper machinery	$ 256,687.93	$ 825,611.00	$ 740,258.03	$ 1,565,869.03

22	poly bags, roll stock, poly gloves	Kraft paper, PLA	Paper machinery	$ 143,752.88	$ 825,611.00	$ 414,566.54	$ 1,240,177.54
23	poly bags, roll stock	Kraft paper	Paper machinery	$ 135,612.17	$ 825,611.00	$ 391,089.66	$ 1,216,700.66
24	garbage bag	PLA	-	$ 121,075.76	$ -	$ 349,168.37	$ 349,168.37
25	shrink film, stretch film, industrial sheet	PLA	-	$ 10,136.62	$ -	$ 29,232.83	$ 29,232.83
26	PE gown, shoe cover, non-woven cover, hard head protection, Latex gloves	PLA	-	$ 39,075.44	$ -	$ 112,689.00	$ 112,689.00
27	Garbage Bags, stretch film	PLA	-	$ 127,913.97	$ -	$ 368,888.94	$ 368,888.94
28	Paper bag, plastic bags, zipper bag	Kraft paper, PLA-coated kraft paper	Paper machinery	$ 98,214.39	$ 1,092,576.25	$ 283,238.85	$ 1,375,815.10
29	Plastic bag, shrink film, laminated pouch	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 69,515.39	$ 1,092,576.25	$ 200,474.27	$ 1,293,050.52
30	Poly bags, zipper bag, film, garbage bag, industrial sheet	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 215,324.30	$ 1,594,176.25	$ 620,970.13	$ 2,215,146.38
31	Retail bags	Kraft paper	Paper machinery	$ 68,670.88	$ 412,805.50	$ 198,038.80	$ 610,844.30
32	Zipper bag, retail bag, wicket, pallet cover	Kraft paper, PLA-coated kraft paper	Paper machinery	$ 172,419.96	$ 1,505,381.75	$ 497,239.05	$ 2,002,620.80
33	Stretch Films, Shrink Films, Strapping, tape, conveyor belt, Industrial sheet, pallet wrapping machine	PLA	-	$ 10,136.62	$ -	$ 29,232.83	$ 29,232.83
34	Plastic Film, Laminated snack Packaging	PLA-coated kraft paper	Paper machinery	$ 54,386.94	$ 679,770.75	$ 156,845.58	$ 836,616.33
35	snack web, clamshell packaging, flexible packaging, bubble wrap	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 92,922.99	$ 1,768,920.75	$ 267,979.05	$ 2,036,899.80
36	Shrink film, poly bag, label	Kraft paper, PLA	Paper machinery	$ 64,705.02	$ 430,805.50	$ 186,601.72	$ 617,407.22
37	Plastic Films and Sheets	PLA	-	$ 3,298.42	$ -	$ 9,512.25	$ 9,512.25
38	Plastic Films and Sheets	PLA	-	$ 3,298.42	$ -	$ 9,512.25	$ 9,512.25
39	Stretch film	PLA	-	$ 6,838.20	$ -	$ 19,720.58	$ 19,720.58
40	Laminated Pouches	PLA-coated kraft paper	Paper machinery	$ (2,453.91)	$ 679,770.75	$ (7,076.78)	$ 672,693.97
41	Plastic Films and Sheets	PLA	-	$ 3,298.42	$ -	$ 9,512.25	$ 9,512.25
42	Industrial sheet, stretch film	PLA	-	$ 6,838.20	$ -	$ 19,720.58	$ 19,720.58
43	Laminated pouch, mailing bag, flexible food packaging, paper bag	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 89,705.22	$ 1,359,541.50	$ 258,699.37	$ 1,618,240.87
44	shrink wrap, flexible food packaging, meat PS tray, roll stock, Industrial sheet	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 111,976.05	$ 1,123,955.50	$ 322,925.87	$ 1,446,881.37
45	Pharmaceutical bag, semi-rigid PE packaging, industrial sheet,	PLA	-	$ 31,800.56	$ -	$ 91,709.12	$ 91,709.12
46	Plastic rigid plate, wicket	Kraft paper	Paper machinery	$ 74,205.57	$ 457,770.75	$ 214,000.20	$ 671,770.95

47	Stretch film, shrink films	PLA	-	$ 10,136.62	$ -	$ 29,232.83	$ 29,232.83
48	Packaging for automotive, household, marine, agricultural and recreational markets	PLA	-	$ 21,257.55	$ -	$ 61,304.30	$ 61,304.30
49	Foam takeout container, foam tray, foam plate	PLA	-	$ 47,049.29	$ -	$ 135,684.67	$ 135,684.67
50	Jars, containers, Bottles	Glass, Aluminum	Glass processing machinery, Aluminum machinery	$ 878,387.40	$ 4,166,167.00	$ 4,734,258.04	$ 8,900,425.04
51	Beverage bottle, detergent bottle	Aluminum	Aluminum machinery	$ 57,574.35	$ 863,814.25	$ 166,037.70	$ 1,029,851.95
52	Jars, containers, Bottles	Glass, Aluminum	Glass processing machinery, Aluminum machinery	$ 878,387.40	$ 4,166,167.00	$ 2,241,924.22	$ 6,408,091.22
53	Jars, containers, Bottles	Glass, Aluminum	Glass processing machinery, Aluminum machinery	$ 878,387.40	$ 4,166,167.00	$ 2,241,924.22	$ 6,408,091.22
54	Carton box, Plastic food Packaging	PLA	-	$ 11,419.73	$ -	$ 32,933.17	$ 32,933.17
55	Flexible food Packaging, cutlery, and PP Containers	PLA, Wood	Wood machinery	$ 71,606.86	$ 919,273.75	$ 206,505.84	$ 1,125,779.59
56	Clamshell food container, cup, cutlery, straw, stirrer stick, paper cup, face shield, latex gloves	PLA, wood, PLA-coated paper reel	Wood machinery, Straw making machinery	$ 87,964.30	$ 1,074,765.75	$ 253,678.76	$ 1,328,444.51
57	Caps and Closures	Aluminum	Aluminum machinery	$ 20,937.16	$ 289,774.15	$ 60,380.31	$ 350,154.46
58	Molded Products, Clamshell Packaging	PLA	-	$ 13,548.46	$ -	$ 39,072.17	$ 39,072.17
59	PP takeout container	PLA	-	$ 4,998.57	$ -	$ 14,415.28	$ 14,415.28
60	PS+PET+Paper (Cups, Containers, Cutlery, lid, dinnerware)	PLA, wood	Wood machinery	$ 118,910.42	$ 948,773.75	$ 342,923.78	$ 1,291,697.53
61	PP takeout container, foam dinnerware, clamshell container, Carton box, paper cup	PLA	-	$ 65,596.32	$ -	$ 189,172.12	$ 189,172.12
62	PE Biscuit trays	PLA	-	$ 13,548.46	$ -	$ 39,072.17	$ 39,072.17
63	Bottle Caps, injection molding	Aluminum	Aluminum machinery	$ 20,937.16	$ 388,614.25	$ 60,380.31	$ 448,994.56
64	Caps and Closures	Aluminum	Aluminum machinery	$ 20,937.16	$ 388,614.25	$ 60,380.31	$ 448,994.56
65	PS food Containers, PET clamshell container, cutlery	PLA, wood	Wood machinery	$ 115,786.32	$ 948,773.75	$ 333,914.23	$ 1,282,687.98
66	Caps and Closures	Aluminum	Aluminum machinery	$ 20,937.16	$ 388,614.25	$ 60,380.31	$ 448,994.56
67	Clamshell food Containers, cutlery	PLA, wood	Wood machinery	$ 68,737.03	$ 948,773.75	$ 198,229.56	$ 1,147,003.31
68	Semi-rigid PP Food containers, lids	PLA	-	$ 8,122.67	$ -	$ 23,424.83	$ 23,424.83

69	Clamshell food Containers, blister packaging, bottle, detergent bottle, reusable food container	PLA, aluminum	Aluminum machinery	$ 80,546.86	$ 863,814.25	$ 232,287.74	$ 1,096,101.99
70	Clamshell Food Container	PLA	-	$ 13,548.46	$ -	$ 39,072.17	$ 39,072.17
71	Clamshell Packaging and Trays	PLA	-	$ 13,548.46	$ -	$ 39,072.17	$ 39,072.17
72	Rigid gift boxes, clamshell packaging	PLA	-	$ 13,548.46	$ -	$ 39,072.17	$ 39,072.17
73	Blister Packaging, Clamshells, Display Trays	PLA	-	$ 22,972.51	$ -	$ 66,250.03	$ 66,250.03
74	Display, blister and clamshell packaging	PLA	-	$ 22,972.51	$ -	$ 66,250.03	$ 66,250.03
75	Blister packaging, face shield, carton packaging	PLA	-	$ 9,424.05	$ -	$ 27,177.86	$ 27,177.86
76	laminated pouch, bottle sleeve, wicket bag, flower sleeve	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 24,193.47	$ 1,092,576.25	$ 69,771.14	$ 1,162,347.39
77	Roll stock, flexible Packaging	Kraft paper, PLA	Paper machinery	$85,625.30	$ 412,805.50	$ 246,933.37	$ 659,738.87
78	Beverage bottle, laminated pouch, snack web, flexible food packaging, detergent bottle, carton box, industrial film and wrap	Aluminum, PLA-coated kraft paper, PLA	Aluminum machinery, Paper machinery	$ 120,927.11	$ 2,223,355.75	$ 348,739.68	$ 2,572,095.43
79	Roll stock, pouch, poly bags	Kraft paper, PLA-coated kraft paper, Kraft paper	Paper machinery	$ 133,158.26	$ 1,505,381.75	$ 384,012.88	$ 1,889,394.63
80	Plastic Bags, stretch film, flexible food packaging	Kraft paper, PLA	Paper machinery	$ 86,928.81	$ 412,805.50	$ 250,692.55	$ 663,498.05
81	flexible food packaging, blister and clamshell, industrial cover, carton box	PLA	-	$ 34,392.24	$ -	$ 99,183.21	$ 99,183.21
82	Bags, Flexible Packaging, wicket bag, stretch film, industrial cover, boat cover	Kraft paper, PLA	Paper machinery	$ 161,134.38	$ 825,611.00	$ 464,692.75	$ 1,290,303.75
83	Laminated Pouches, Bags, flexible packaging	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 77,636.70	$ 1,092,576.25	$ 223,895.19	$ 1,316,471.44
84	Stretch film, garbage bag, shrink film, meat PS tray, flexible packaging, tape, paper bag, latex gloves, protective coverall, tissue, detergent bottle	PLA	-	$ 165,684.45	$ -	$ 477,814.61	$ 477,814.61
85	Bubble wrap, industrial film, corrugated box	PLA	-	$ 13,567.86	$ -	$ 39,128.13	$ 39,128.13
86	pet food packaging, flexible food packaging, candy twist wrap	PLA-coated kraft paper, PLA	Paper machinery	$77,226.40	$ 679,770.75	$ 222,711.93	$ 902,482.68

87	Zipper bag, Pouch, laminated packaging film, roll stock, flexible food packaging	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 337,347.57	$ 3,358,117.75	$ 972,871.02	$ 4,330,988.77
88	grocery bag, zipper bag, flexible packaging, poly bag, garbage bag, carton box, paper bag	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 120,709.64	$ 1,434,576.25	$ 348,112.52	$ 1,782,688.77
89	Bags, flexible packaging, Films and Sheets	Kraft paper, PLA	Paper machinery	$ 116,730.43	$ 1,000,355.50	$ 336,636.94	$ 1,336,992.44
90	Zipper bagflexible packaging, shrink wrap, pouch, poly bag, wicket, carton box, label	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 94,771.78	$ 2,185,152.50	$ 273,310.76	$ 2,458,463.26
91	frozen food bag, zipper bag, roll stock	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 115,168.82	$ 1,394,923.25	$ 332,133.42	$ 1,727,056.67
92	Paper packaging, pouch, flexible food packaging, wicket, snack web	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 137,558.33	$ 1,727,381.75	$ 396,702.17	$ 2,124,083.92
93	Zipper bag, Grocery Bags, flexible food packaging, wicket, laminated snack pack	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 298,816.33	$ 2,185,152.50	$ 861,751.41	$ 3,046,903.91
94	flexible packaging bag, paper bag, woven bag, burlap	PLA	-	$ 26,276.47	$ -	$ 75,778.27	$ 75,778.27
95	Laminated pouch, retail bag, flexible food bag, zipper bag, industrial cover	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 107,180.22	$ 1,772,347.00	$ 309,095.24	$ 2,081,442.24
96	Roll stock, stretch film, bag, laminated pouch	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 147,260.74	$ 1,505,381.75	$ 424,682.79	$ 1,930,064.54
97	Flexible food bags, biohazard bag, carton box, industrial sheet	PLA	-	$ 38,221.73	$ -	$ 110,227.01	$ 110,227.01
98	Stretch film, Shrink wrap, autoclave bag, Pallet cover, woven bulk bag	PLA-coated kraft paper, PLA	Paper machinery	$ 39,680.13	$ 973,320.75	$ 114,432.88	$ 1,087,753.63
99	retail bag, roll stock, garbage bag, shrink wrap, stretch wrap, construction bag, pallet cover	Kraft paper, PLA	Paper machinery	$ 40,979.45	$ 1,110,576.25	$ 118,179.94	$ 1,228,756.19
100	Poly bag, laminated pouches, roll stock	PLA-coated kraft paper, kraft paper	Paper machinery	$ 133,158.26	$ 1,550,347.00	$ 384,012.88	$ 1,934,359.88
101	Medical Healthcare Packaging Films, Food Flexible Packaging, Tags and Labels	PLA-coated kraft paper, PLA	Paper machinery	$ (19,626.45)	$ 679,770.75	$(56,600.38)	$ 623,170.37
102	Flexible food Packaging, snack web	PLA	-	$ 65,806.67	$ -	$ 189,778.76	$ 189,778.76
103	Laminated snack pack, roll stock, paper packaging	PLA-coated kraft paper, kraft paper	Paper machinery	$ 71,751.66	$ 1,208,347.00	$ 206,923.42	$ 1,415,270.42

104	Foam food container, PS cup, bubble wrap, cutlery, poly bag, snack web, flexible food packaging, label, tissue, paper cup, corrugated box, foam sheet	Wood, PLA, kraft paper, PLA-coated kraft paper	Wood machinery, Paper machinery	$ 243,018.99	$ 2,122,315.25	$ 700,838.40	$ 2,823,153.65
105	PS cup, PS dinnerware, straw, poly bag, stretch film, sheet, stirrer stick, garbage bag, hearing protection, label, carton box, napkin, paper bag	Wood, PLA, kraft paper, PLA-coated paper reel	Wood machinery, Paper machinery, Straw making machinery	$ 258,895.55	$ 1,448,900.00	$ 746,624.54	$ 2,195,524.54
106	Poly bags, zipper bag, garbage bag, cutlery, foam plate, foam cup, stretch wrap, bubble wrap, hearing protection, tape, protective coverall, tissue, wipe	Wood, PLA, kraft paper, PLA-coated paper reel, PLA-coated kraft paper	Wood machinery, Paper machinery, Straw making machinery	$334,669.80	$ 1,783,350.00	$ 965,148.64	$ 2,748,498.64
107	roll stock, poly bag, zipper bag, laminated pouch, gift box, carton box	PLA-coated kraft paper, kraft paper	Paper machinery	$ 162,701.78	$ 2,185,152.50	$ 469,212.93	$ 2,654,365.43
108	Pouches, flexible food packaging, Bottles, Laminated snack pack, Garden Bags, paper bag, Industrial sheet	Aluminum, PLA-coated kraft paper, kraft paper	Aluminum machinery, Paper machinery	$ 120,927.11	$ 2,588,905.75	$ 348,739.68	$ 2,937,645.43
109	Poly bag, shrink film, garbage bag, laminated pouch, pallet cover	PLA-coated kraft paper, kraft paper	Paper machinery	$ 156,629.09	$ 1,092,576.25	$ 451,700.02	$ 1,544,276.27
110	Bubble bag, zipper bag, PP food container, stretch film face mask, latex gloves	PLA-coated kraft paper, PLA	Paper machinery	$ 48,109.94	$ 1,181,370.75	$ 138,743.46	$ 1,320,114.21
111	Stretch film, clamshell food container	PLA	-	$ 20,386.66	$ -	$ 58,792.75	$ 58,792.75
112	blister packaging, clamshell packaging, snack web, flexible food packaging, roll stock, semi-rigid PP packaging, laminated pouch	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 157,533.21	$ 2,294,397.00	$ 454,307.38	$ 2,748,704.38
113	laminated pouch, snack web, flexible food packaging, shrink wrap, blister packaging, carton packaging	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 76,075.23	$ 1,689,091.50	$ 219,392.09	$ 1,908,483.59
114	Blister packaging, semi-rigid PP packaging, snack web, roll stock, food packaging, carton box	Kraft paper, PLA-coated kraft paper, PLA	Paper machinery	$ 154,434.85	$ 1,725,091.50	$ 445,372.09	$ 2,170,463.59

115	PE Gloves, garbage bag, flexible food packaging, zipper bag, PP food container, cutlery, clamshell Food Containers, Paper Bags, carton box, Poly Bags, Tissue paper, jewelry box, garment bag	Wood, Kraft paper, PLA-coated kraft paper, PLA	Wood machinery, Paper machinery	$ 243,915.32	$ 2,150,594.50	$ 703,423.30	$ 2,854,017.80
116	Shrink wrap, clamshell packaging, retail bag, gift box, display	Kraft paper, PLA	Paper machinery	$ 82,518.14	$ 964,355.50	$ 237,972.67	$ 1,202,328.17
117	Bubble Sheets, mailer bag, Roll Packs, Plastic Packaging, paper wrap, Foam sheet	Kraft paper, PLA-coadet kraft paper, PLA	Paper machinery	$ 173,511.39	$ 1,201,820.75	$ 500,386.58	$ 1,702,207.33
118	stretch film, shrink film, bubble wrap, Tape, first aid box, corrugated packaging, foam sheet	PLA	-	$ 23,704.48	$ -	$ 68,360.95	$ 68,360.95
119	Bubble wrap, laminated snack rolls, clamshell food container, corrugated box, foam sheet	PLA-coated kraft paper, PLA	Paper machinery	$ 81,503.26	$ 1,181,370.75	$ 235,045.88	$ 1,416,416.63
120	blister packaging, bottle, cap, laminated pouch, Carton packaging, label	Aluminum, PLA, PLA-coated kraft paper	Aluminum machinery, Paper machinery	$ 85,481.65	$ 1,833,359.15	$ 246,519.09	$ 2,079,878.24
121	Flexible food packaging, Containers	PLA	-	$ 16,418.30	$ -	$ 47,348.45	$ 47,348.45
122	shrink wrap, blister and clamshell, corrugated packaging	PLA	-	$ 42,314.21	$ -	$ 122,029.24	$ 122,029.24
123	Shrink wrap, blister packaging, bag, clamshell food packaging, carton box, label	Kraft paper, PLA	Paper machinery	$ 94,941.81	$ 964,355.50	$ 273,801.08	$ 1,238,156.58
124	Flexible Candy and Confectionary Packaging, confectionary packaging, carton box, plastic gift box, tag	PLA-coated kraft paper, PLA	Paper machinery	$ 67,935.40	$ 1,231,320.75	$ 195,917.76	$ 1,427,238.51
125	Blister packaging, shrink wrap, insulation foam	PLA	-	$ 12,722.47	$ -	$ 36,690.11	$ 36,690.11
126	blister packaging, shrink wrap, display	PLA	-	$12,722.47	$ -	$ 36,690.11	$ 36,690.11
127	Blister packaging, laminated pouch, tape, sheet, snack web	PLA-coated kraft paper, PLA	Paper machinery	$ 6,970.14	$ 679,770.75	$ 20,101.08	$ 699,871.83
128	bubble wrap, poly bag, laminated pouch, stretch wrap, shrink wrap, garbage bag, pallet cover, Carton box, kraft paper ,tape, foam sheet	Kraft paper, PLA-coadet kraft paper, PLA	Paper machinery	$ 203,732.94	$ 1,887,726.25	$ 587,542.01	$ 2,475,268.26
129	flexible packaging	PLA	-	$ 11,419.73	$ -	$ 32,933.17	$ 32,933.17

130	PE Gloves, flexible Packaging, Stretch Wrap	PLA	-	$ 26,398.65	$ -	$ 76,130.62	$ 76,130.62
131	Clamshell packaging, blister packaging, laminated pouch, gasket and washer, injection molding, foam sheet	Kraft paper, PLA-coadet kraft paper, PLA	Paper machinery	$20,518.60	$ 1,231,320.75	$ 59,173.25	$ 1,290,494.00
132	Clamshell packaging, shrink wrap, corrugated box	PLA	-	$ 32,810.33	$ -	$ 94,621.16	$ 94,621.16
133	Glass and plastic beverage bottles, Closures and Caps	Aluminum	Aluminum machinery	$ 78,511.50	$ 1,275,780.40	$ 226,418.01	$ 1,502,198.41
134	Cutlery, Straws, bottle, caps, PP container	Wood, PLA-coated paper reel, aluminum, PLA	Wood machinery, Straw making machinery	$141,107.50	$ 1,831,130.40	$ 406,937.55	$ 2,238,067.95
135	blister and clamshell packaging, displays	PLA	-	$ 22,972.51	$ -	$ 66,250.03	$ 66,250.03
136	Blister and clamshell packaging	PLA	-	$ 22,972.51	$ -	$ 66,250.03	$ 66,250.03
137	Blister and clamshell packaging	PLA	-	$ 22,972.51	$ -	$ 66,250.03	$ 66,250.03
138	Clamshells food packaging, trays, blister packaging, foot brace	PLA	-	$36,520.97	$ -	$ 105,322.20	$ 105,322.20
139	Healthcare reusable and disposable plastic cups and trays, face shield	PLA	-	$ 4,998.57	$ -	$ 14,415.28	$ 14,415.28

The calculations of the CBA model show that there are a few manufacturers that might be hit by the ban. The negative net present value of the CBA in the model suggests that the SUP would be unduly averse to them and that material substitution is not a suitable strategy for responding to the plastics materials ban. These manufacturers are unable to bear the costs of substitution because their annual revenues are small and it is challenging for them to cover the costs of substitution, particular with respect to the machine costs. While it is possible for companies to purchase used machines or use less costly alternative materials to cut their costs, this study evenly assumes that all manufacturers would purchase new machinery. For those manufacturers that are predicted to shut down their SUPs production lines, it is assumed that they will benefit from the scrap value of their single-use plastics machinery, which is another limitation of this study and will be discussed more in Scopes and Limitations section.

As the results of the CBA show, 132 of the manufacturers will see positive returns if they convert production to use an alternative material, protecting their revenues and jobs. This is even taking into assuming that they are unable to pass along the additional costs to their customers by increasing prices of their products. By deducting the net present value of benefits from the net present value of costs, the overall NPV for benefits is calculated which determines how companies could be affected by plastics substitution. Table 13 shows the overall NPV for benefits of individual companies over the period of three years and the percentage of benefit lost after material substitution.

Table 13. NPV for Overall Benefits for Individual Companies

Number	NPV for Overall Benefits (NPV Total Benefits – NPV Total Costs)	% of Lost Benefit
14	$ (617,702.82)	-59.36%
91	$ (589,855.80)	-91.62%

18	$ (337,799.40)	-46.45%
99	$ (284,320.34)	-2.40%
87	$ (210,348.64)	-3.90%
28	$ (160,439.46)	-32.25%
124	$ (115,790.05)	-105.66%
46	$ 151,693.15	-4.68%
1	$ 460,509.88	-27.44%
37	$ 554,354.47	-32.23%
52	$ 586,217.76	-33.80%
95	$ 639,090.22	-3.99%
58	$ 662,248.07	-29.40%
135	$ 669,723.78	-17.65%
85	$ 1,022,574.77	-8.89%
6	$ 1,096,894.19	-22.46%
20	$ 1,379,201.19	-28.67%
107	$ 1,486,251.04	-9.52%
31	$ 1,545,953.13	-13.77%
129	$ 1,648,892.06	-45.18%
134	$ 2,291,223.40	-6.39%
82	$ 2,641,045.94	-18.28%
33	$ 3,086,572.13	-54.64%
73	$ 3,136,606.94	-13.46%
21	$ 3,347,980.69	-8.20%
121	$ 3,419,049.36	-8.89%
88	$ 3,484,242.31	-80.68%
94	$ 3,641,671.29	-64.11%
72	$ 3,695,689.65	-1.40%
36	$ 3,729,470.23	-2.30%
12	$ 4,008,617.92	-8.88%
15	$ 4,138,366.48	-5.14%
137	$ 4,203,273.60	-4.33%
24	$ 4,209,614.20	-8.06%
139	$ 4,362,463.53	-134.20%
70	$ 4,495,689.65	-24.80%
71	$ 4,495,689.65	-3.43%
69	$ 4,742,790.11	-5.98%
47	$ 4,753,454.92	-31.68%
34	$ 5,456,158.33	-10.00%
74	$ 5,508,213.14	-45.12%
7	$ 5,566,689.27	-115.11%
63	$ 5,673,695.67	-1.51%
64	$ 5,673,695.67	-4.67%
50	$ 6,093,883.93	-5.08%

116	$ 6,251,822.53	-38.18%
98	$ 6,347,709.32	-6.13%
128	$ 6,684,166.14	-8.12%
123	$ 6,750,755.93	-5.34%
38	$ 6,780,793.05	-120.89%
25	$ 6,819,905.46	-9.37%
22	$ 6,873,672.18	-5.35%
90	$ 7,323,241.42	-6.16%
2	$ 7,359,703.92	-1.26%
53	$ 7,386,217.76	-10.95%
48	$ 7,446,450.57	-11.61%
105	$ 7,730,407.25	-2.63%
132	$ 7,824,303.28	-7.44%
49	$ 8,813,263.58	-4.29%
62	$ 8,895,689.65	-1.97%
106	$ 8,976,496.72	-10.52%
93	$ 9,611,162.12	-2.55%
17	$ 10,288,384.04	-30.32%
136	$ 10,603,273.60	-20.22%
102	$ 11,256,445.47	-11.16%
55	$ 11,831,792.31	-12.65%
54	$ 12,116,015.08	-11.43%
10	$ 12,519,270.91	-20.76%
122	$ 12,877,799.71	-19.36%
29	$ 13,767,563.02	-7.84%
41	$ 13,780,793.05	-1.58%
131	$ 14,023,354.30	-173.20%
51	$ 14,339,516.51	-7.79%
103	$ 14,521,704.49	-108.83%
19	$ 14,550,727.87	-8.88%
138	$ 14,976,188.22	-113.20%
5	$ 14,976,958.45	-74.63%
110	$ 14,981,991.28	-10.65%
126	$ 15,488,377.01	-2.00%
130	$ 17,258,934.49	-1.44%
30	$ 17,474,327.00	-2.57%
133	$ 17,656,526.95	-1.78%
113	$ 18,355,891.33	-52.59%
100	$ 18,713,481.93	-22.72%
45	$ 19,416,021.71	-1.29%
13	$ 19,568,543.03	-3.47%
66	$ 19,673,695.67	-27.16%
26	$ 20,738,209.47	-17.51%

4	$	22,409,229.02	-9.93%
32	$	22,645,221.01	-21.76%
125	$	23,488,377.01	-63.58%
111	$	25,534,802.05	-4.10%
75	$	26,360,053.73	-25.28%
35	$	26,556,018.81	-1.68%
60	$	26,661,634.88	-5.11%
27	$	27,248,726.61	-5.43%
117	$	27,712,464.06	-12.72%
108	$	27,921,316.55	-0.36%
79	$	28,758,447.18	-6.70%
92	$	30,356,448.54	-4.18%
9	$	30,782,646.82	-6.20%
16	$	31,409,614.20	-3.42%
78	$	32,385,986.21	-38.15%
97	$	33,366,005.13	-16.81%
83	$	33,671,286.36	-2.11%
43	$	34,684,758.02	-2.64%
42	$	34,839,112.41	-13.29%
119	$	34,871,502.42	-10.01%
86	$	38,825,191.11	-19.73%
8	$	39,409,614.20	-0.28%
81	$	39,887,789.99	-81.58%
84	$	41,715,650.96	-15.41%
76	$	42,857,048.72	-6.94%
109	$	46,457,062.20	-4.13%
77	$	47,235,244.26	-27.34%
44	$	54,607,567.89	-14.20%
96	$	62,576,610.25	-28.32%
59	$	63,334,532.97	-9.89%
118	$	63,625,274.19	-6.23%
57	$	63,772,535.77	-47.14%
65	$	66,921,696.18	-11.61%
80	$	66,990,267.66	-11.61%
23	$	67,138,366.48	-13.78%
67	$	67,308,432.60	-2.15%
114	$	78,088,554.27	-4.38%
104	$	78,356,281.78	-34.59%
127	$	85,727,664.65	-10.95%
61	$	89,043,486.19	-0.84%
11	$	90,976,303.48	-7.33%
39	$	91,839,112.41	-7.33%
101	$	92,720,387.19	-2.23%

112	$ 109,472,349.97	-6.17%
3	$ 110,313,766.48	-3.13%
89	$ 138,763,156.25	-44.56%
56	$ 147,435,154.38	-0.55%
115	$ 180,477,128.80	-0.89%
120	$ 185,106,383.60	-0.34%
40	$ 239,620,080.70	-3.25%
68	$ 299,474,471.67	-1.35%

As shown in Table 13, there are seven manufacturers that are very likely to be severely hit by the ban. The percentage of benefit that these manufacturers would lose Their negative overall benefits are warning them that material substitution will not be a profitable strategy they should use as a response to the ban. These manufacturers are not easily capable of bearing the costs of substitution mainly because their annual revenue is not high enough to cover the excessive costs of substitution. By deducting the NPV of benefits (revenue + CCA + corporation tax) from the NPV of the overall benefit (benefits - costs) of companies, it was understood that although other 132 SUP companies could still make profit out of producing alternative products, the net present value of their benefits would decrease due to the costs of substitution.

Contrary to Table 13 that shows the NPV for overall benefits (benefits - costs), Table 14 is showing what companies are bearing the highest costs and losing their benefits the most, regardless of whether their overall benefits are negative or positive.

Table 14. The Burden of Material Substitution Expenses

#	Products	NPV for Total Benefits	NPV for Benefits - Costs	Lost Benefit Due to Material Substitution
50	Jars, containers, Bottles	$ 14,994,308.97	$ 6,093,883.93	$ (8,900,425.04)
52	Jars, containers, Bottles	$ 6,994,308.97	$ 586,217.76	$ (6,408,091.22)
53	Jars, containers, Bottles	$ 13,794,308.97	$ 7,386,217.76	$ (6,408,091.22)
115	PE Gloves, garbage bag, flexible food packaging, zipper bag, PP food container, cutlery, clamshell Food Containers, Paper Bags, carton box,	$ 184,921,896.60	$ 180,477,128.80	$ (4,444,767.80)

	Poly Bags, Tissue paper, jewelry box, garment bag 43%			
112	blister packaging, clamshell packaging, snack web, flexible food packaging, roll stock, semi-rigid PP packaging, laminated pouch 57%	$ 113,911,704.35	$ 109,472,349.97	$ (4,439,354.38)
106	Poly bags, zipper bag, garbage bag, cutlery, foam plate, foam cup, stretch wrap, bubble wrap, hearing protection, tape, protective cover all, tissue, wipe 38%	$ 13,250,245.37	$ 8,976,496.72	$ (4,273,748.64)
87	Zipper bag, Pouch, laminated packaging film, roll stock, flexible food packaging100%	$ 3,716,240.13	$ (210,348.64)	$ (3,926,588.77)
104	Foam food container, PS cup, bubble wrap, cutlery, poly bag, snack web, flexible food packaging, label, tissue, paper cup, corrugated box, foam sheet57%	$ 82,203,085.43	$ 78,356,281.78	$ (3,846,803.65)
93	Zipper bag, Grocery Bags, flexible food packaging, wicket, laminated snack pack100%	$ 13,245,616.03	$ 9,611,162.12	$ (3,634,453.91)
90	Zipper bag flexible packaging, shrink wrap, pouch, poly bag, wicket, carton box, label 100%	$ 10,805,304.67	$ 7,323,241.42	$ (3,482,063.26)
128	bubble wrap, poly bag, laminated pouch, stretch wrap, shrink wrap, garbage bag, pallet cover, Carton box, kraft paper, tape, foam sheet70%	$ 10,097,084.40	$ 6,684,166.14	$ (3,412,918.26)
114	Blister packaging, semi-rigid PP packaging, snack web, roll stock, food packaging, carton box 60%	$ 81,332,617.87	$ 78,088,554.27	$ (3,244,063.59)
105	PS cup, PS dinnerware, straw, poly bag, stretch film, sheet, stirrer stick, garbage bag, hearing protection, label, carton box, napkin, paper bag 29%	$ 10,949,581.79	$ 7,730,407.25	$ (3,219,174.54)
5	Laminated pouch, roll stock, flexible fruit packaging, wicket, polybag, snack web, carton box 86%	$ 18,187,813.52	$ 14,976,958.45	$ (3,210,855.07)
78	Beverage bottle, laminated pouch, snack web, flexible food packaging, detergent bottle, carton box, industrial film and wrap 75%	$ 35,545,631.63	$ 32,385,986.21	$ (3,159,645.43)
17	stretch film, flexible food packaging, snack web, shrink film, zipper bag	$ 13,269,287.18	$ 10,288,384.04	$ (2,980,903.13)
2	Polybag, zipper bag, wicket, roll stock, laminated pouch	$ 10,318,150.04	$ 7,359,703.92	$ (2,958,446.13)
108	Pouches, flexible food packaging, Bottles, Laminated snack pack, Garden Bags, paper bag, Industrial sheet	$ 30,858,961.97	$ 27,921,316.55	$ (2,937,645.43)
113	laminated pouch, snack web, flexible food packaging, shrink wrap, blister packaging, carton packaging	$ 21,287,974.92	$ 18,355,891.33	$ (2,932,083.59)
88	grocery bag, zipper bag, flexible packaging, poly bag, garbage bag, carton box, paper bag	$ 6,356,081.09	$ 3,484,242.31	$ (2,871,838.77)
84	Stretch film, garbage bag, shrink film, meat PS tray, flexible packaging, tape, paper bag, latex gloves, protective cover all, tissue, detergent bottle	$ 44,563,765.57	$ 41,715,650.96	$ (2,848,114.61)

10	garbage bag, grocery bags, wicket bag, flexible food packaging, Paper bag	$ 15,320,449.28	$ 12,519,270.91	$ (2,801,178.37)
134	Cutlery, Straws, bottle, caps, PP container	$ 5,051,341.36	$ 2,291,223.40	$ (2,760,117.95)
30	Poly bags, zipper bag, film, garbage bag, industrial sheet	$ 20,191,073.38	$ 17,474,327.00	$ (2,716,746.38)
92	Paper packaging, pouch, flexible food packaging, wicket, snack web	$ 33,068,082.46	$ 30,356,448.54	$ (2,711,633.92)
117	Bubble Sheets, mailer bag, Roll Packs, Plastic Packaging, paper wrap, Foam sheet	$ 30,417,871.39	$ 27,712,464.06	$ (2,705,407.33)
95	Laminated pouch, retail bag, flexible food bag, zipper bag, industrial cover	$ 3,308,082.46	$ 639,090.22	$ (2,668,992.24)
107	roll stock, poly bag, zipper bag, laminated pouch, gift box, carton box	$ 4,140,616.47	$ 1,486,251.04	$ (2,654,365.43)
120	blister packaging, bottle, cap, laminated pouch, Carton packaging, label	$ 187,737,811.84	$ 185,106,383.60	$ (2,631,428.24)
3	Retail Bags, polymailers, stretch film, zipper bag, label	$ 112,915,465.88	$ 110,313,766.48	$ (2,601,699.41)
35	snack web, clamshell packaging, flexible packaging, bubble wrap	$ 29,144,468.62	$ 26,556,018.81	$ (2,588,449.80)
109	Poly bag, shrink film, garbage bag, laminated pouch, pallet cover	$ 48,976,538.47	$ 46,457,062.20	$ (2,519,476.27)
44	shrink wrap, flexible food packaging, meat PS tray, roll stock, Industrial sheet	$ 57,078,049.26	$ 54,607,567.89	$ (2,470,481.37)
60	PS+PET+Paper (Cups, Containers, Cutlery, lid, dinnerware)	$ 28,997,432.40	$ 26,661,634.88	$ (2,335,797.53)
91	frozen food bag, zipper bag, roll stock	$ 1,724,750.87	$ (589,855.80)	$ (2,314,606.67)
123	Shrink wrap, blister packaging, bag, clamshell food packaging, carton box, label	$ 8,976,512.51	$ 6,750,755.93	$ (2,225,756.58)
96	Roll stock, stretch film, bag, laminated pouch	$ 64,800,224.79	$ 62,576,610.25	$ (2,223,614.54)
43	Laminated pouch, mailing bag, flexible food packaging, paper bag	$ 36,890,548.89	$ 34,684,758.02	$ (2,205,790.87)
69	Clamshell food Containers, blister packaging, bottle, detergent bottle, reusable food container	$ 6,941,992.10	$ 4,742,790.11	$ (2,199,201.99)
13	Flexible food packaging, garbage bag, retail bag, industrial sheet	$ 21,742,915.71	$ 19,568,543.03	$ (2,174,372.67)
82	Bags, Flexible Packaging, wicket bag, stretch film, industrial cover, boat cover	$ 4,812,449.69	$ 2,641,045.94	$ (2,171,403.75)
99	retail bag, roll stock, garbage bag, shrink wrap, stretch wrap, construction bag, pallet cover	$ 1,882,085.85	$ (284,320.34)	$ (2,166,406.19)
89	Bags, flexible packaging, Films and Sheets	$ 140,895,298.69	$ 138,763,156.25	$ (2,132,142.44)
76	laminated pouch, bottle sleeve, wicket bag, flower sleeve	$ 44,957,046.11	$ 42,857,048.72	$ (2,099,997.39)
86	pet food packaging, flexible food packaging, candy twist wrap	$ 40,902,773.79	$ 38,825,191.11	$ (2,077,582.68)
21	garbage bags, Poly bag, roll stock	$ 5,415,449.72	$ 3,347,980.69	$ (2,067,469.03)
9	Flexible food packaging, shrink wrap, garbage bag	$ 32,791,737.44	$ 30,782,646.82	$ (2,009,090.62)
32	Zipper bag, retail bag, wicket, pallet cover	$ 24,647,841.81	$ 22,645,221.01	$ (2,002,620.80)
119	Bubble wrap, laminated snack rolls, clamshell food container, corrugated box, foam sheet	$ 36,839,469.05	$ 34,871,502.42	$ (1,967,966.63)

18	Shrink film, candy twist wrap, bag	$ 1,617,073.15	$ (337,799.40)	$ (1,954,872.55)
100	Poly bag, laminated pouches, roll stock	$ 20,647,841.81	$ 18,713,481.93	$ (1,934,359.88)
83	Laminated Pouches, Bags, flexible packaging	$ 35,575,307.80	$ 33,671,286.36	$ (1,904,021.44)
79	Roll stock, pouch, poly bags	$ 30,647,841.81	$ 28,758,447.18	$ (1,889,394.63)
56	Clamshell food container, cup, cutlery, straw, stirrer stick, paper cup, face shield, latex gloves	$ 149,315,148.89	$ 147,435,154.38	$ (1,879,994.51)
110	Bubble bag, zipper bag, PP food container, stretch film face mask, latex gloves	$ 16,824,155.49	$ 14,981,991.28	$ (1,842,164.21)
131	Clamshell packaging, blister packaging, laminated pouch, gasket and washer, injection molding, foam sheet	$ 15,865,398.30	$ 14,023,354.30	$ (1,842,044.00)
65	PS food Containers, PET clamshell container, cutlery	$ 68,726,434.16	$ 66,921,696.18	$ (1,804,737.98)
4	Flexible Food Packaging, clamshell packaging, meat PE tray, corrugated box	$ 24,210,956.53	$ 22,409,229.02	$ (1,801,727.52)
81	flexible food packaging, blister and clamshell, industrial cover, carton box	$ 41,677,623.20	$ 39,887,789.99	$ (1,789,833.21)
61	PP takeout container, foam dinnerware, clamshell container, Carton box, paper cup	$ 90,828,308.32	$ 89,043,486.19	$ (1,784,822.12)
138	Clamshells food packaging, trays, blister packaging, foot brace	$ 16,736,160.42	$ 14,976,188.22	$ (1,759,972.20)
80	Plastic Bags, stretch film, flexible food packaging	$ 68,742,915.71	$ 66,990,267.66	$ (1,752,648.05)
12	garbage Bags, roll stock	$ 5,753,157.24	$ 4,008,617.92	$ (1,744,539.32)
22	poly bags, roll stock, poly gloves	$ 8,615,449.72	$ 6,873,672.18	$ (1,741,777.54)
29	Plastic bag, shrink film, laminated pouch	$ 15,496,663.54	$ 13,767,563.02	$ (1,729,100.52)
55	Flexible food Packaging, cutlery, and PP Containers	$ 13,545,121.90	$ 11,831,792.31	$ (1,713,329.59)
122	shrink wrap, blister and clamshell, corrugated packaging	$ 14,538,978.94	$ 12,877,799.71	$ (1,661,179.24)
116	Shrink wrap, clamshell packaging, retail bag, gift box, display	$ 7,890,200.69	$ 6,251,822.53	$ (1,638,378.17)
98	Stretch film, Shrink wrap, autoclave bag, Pallet cover, woven bulk bag	$ 7,871,512.95	$ 6,347,709.32	$ (1,523,803.63)
133	Glass and plastic beverage bottles, Closures and Caps	$ 19,158,725.36	$ 17,656,526.95	$ (1,502,198.41)
11	retail bags, garbage bag	$ 92,437,916.14	$ 90,976,303.48	$ (1,461,612.67)
14	garbage bags, retail bags, paper bag, carton box, label, tissue, gift wrap	$ 843,909.85	$ (617,702.82)	$ (1,461,612.67)
130	PE Gloves, flexible Packaging, Stretch Wrap	$ 18,717,765.12	$ 17,258,934.49	$ (1,458,830.62)
124	Flexible Candy and Confectionary Packaging, confectionary packaging, carton box, plastic gift box, tag	$ 1,311,448.45	$ (115,790.05)	$ (1,427,238.51)
103	Laminated snack pack, roll stock, paper packaging	$ 15,936,974.90	$ 14,521,704.49	$ (1,415,270.42)
28	Paper bag, plastic bags, zipper bag	$ 1,215,375.64	$ (160,439.46)	$ (1,375,815.10)
1	Signs, costume plastic fabrication, poly bag, zipper bag	$ 1,815,375.64	$ 460,509.88	$ (1,354,865.76)
102	Flexible food Packaging, snack web	$ 12,597,774.23	$ 11,256,445.47	$ (1,341,328.76)

118	stretch film, shrink film, bubble wrap, Tape, first aid box, corrugated packaging, foam sheet	$ 64,924,835.15	$ 63,625,274.19	$ (1,299,560.95)
127	Blister packaging, laminated pouch, tape, sheet, snack web	$ 86,979,086.48	$ 85,727,664.65	$ (1,251,421.83)
77	Roll stock, flexible Packaging	$ 48,482,533.13	$ 47,235,244.26	$ (1,247,288.87)
23	poly bags, roll stock	$ 68,355,067.14	$ 67,138,366.48	$ (1,216,700.66)
6	Polybag, roll stock	$ 2,313,594.86	$ 1,096,894.19	$ (1,216,700.66)
15	Poly bag, roll stock	$ 5,355,067.14	$ 4,138,366.48	$ (1,216,700.66)
101	Medical Healthcare Packaging Films, Food Flexible Packaging, Tags and Labels	$ 93,931,107.56	$ 92,720,387.19	$ (1,210,720.37)
97	Flexible food bags, biohazard bag, carton box, industrial sheet	$ 34,565,382.14	$ 33,366,005.13	$ (1,199,377.01)
73	Blister Packaging, Clamshells, Display Trays	$ 4,305,956.97	$ 3,136,606.94	$ (1,169,350.03)
74	Display, blister and clamshell packaging	$ 6,677,563.18	$ 5,508,213.14	$ (1,169,350.03)
136	Blister and clamshell packaging	$ 11,772,623.64	$ 10,603,273.60	$ (1,169,350.03)
137	Blister and clamshell packaging	$ 5,372,623.64	$ 4,203,273.60	$ (1,169,350.03)
135	blister and clamshell packaging, displays	$ 1,839,073.81	$ 669,723.78	$ (1,169,350.03)
27	Garbage Bags, stretch film	$ 28,412,765.56	$ 27,248,726.61	$ (1,164,038.94)
121	Flexible food packaging, Containers	$ 4,575,997.81	$ 3,419,049.36	$ (1,156,948.45)
67	Clamshell food Containers, cutlery	$ 68,455,435.91	$ 67,308,432.60	$ (1,147,003.31)
26	PE gown, shoe cover, non-woven cover, hard head protection, Latex gloves	$ 21,854,098.48	$ 20,738,209.47	$ (1,115,889.00)
45	Pharmaceutical bag, semi-rigid PE packaging, industrial sheet,	$ 20,531,380.82	$ 19,416,021.71	$ (1,115,359.12)
48	Packaging for automotive, household, marine, agricultural and recreational markets	$ 8,531,354.87	$ 7,446,450.57	$ (1,084,904.30)
68	Semi-rigid PP Food containers, lids	$ 300,541,996.50	$ 299,474,471.67	$ (1,067,524.83)
51	Beverage bottle, detergent bottle	$ 15,369,368.46	$ 14,339,516.51	$ (1,029,851.95)
125	Blister packaging, shrink wrap, insulation foam	$ 24,512,667.12	$ 23,488,377.01	$ (1,024,290.11)
126	blister packaging, shrink wrap, display	$ 16,512,667.12	$ 15,488,377.01	$ (1,024,290.11)
111	Stretch film, clamshell food container	$ 26,438,694.80	$ 25,534,802.05	$ (903,892.75)
20	Garbage bags	$ 2,229,969.56	$ 1,379,201.19	$ (850,768.37)
24	garbage bag	$ 5,060,382.57	$ 4,209,614.20	$ (850,768.37)
8	Garbage Bags	$ 40,260,382.57	$ 39,409,614.20	$ (850,768.37)
16	Garbage bags	$ 32,260,382.57	$ 31,409,614.20	$ (850,768.37)
34	Plastic Film, Laminated snack Packaging	$ 6,292,774.66	$ 5,456,158.33	$ (836,616.33)
25	shrink film, stretch film, industrial sheet	$ 7,578,738.29	$ 6,819,905.46	$ (758,832.83)
33	Stretch Films, Shrink Films, Strapping, tape, conveyor belt, Industrial sheet, pallet wrapping machine	$ 3,845,404.95	$ 3,086,572.13	$ (758,832.83)
40	Laminated Pouches	$ 240,292,774.66	$ 239,620,080.70	$ (672,693.97)
46	Plastic rigid plate, wicket	$ 823,464.09	$ 151,693.15	$ (671,770.95)
94	flexible packaging bag, paper bag, woven bag, burlap	$ 4,304,999.56	$ 3,641,671.29	$ (663,328.27)

49	Foam takeout container, foam tray, foam plate	$ 9,470,998.25	$ 8,813,263.58	$ (657,734.67)
19	Paper roll, plastic roll stock	$ 15,177,533.57	$ 14,550,727.87	$ (626,805.70)
129	flexible packaging	$ 2,269,375.23	$ 1,648,892.06	$ (620,483.17)
36	Shrink film, poly bag, label	$ 4,346,877.44	$ 3,729,470.23	$ (617,407.22)
31	Retail bags	$ 2,156,797.43	$ 1,545,953.13	$ (610,844.30)
7	Jute bag, plastic retail bag	$ 6,177,533.57	$ 5,566,689.27	$ (610,844.30)
62	PE Biscuit trays	$ 9,486,311.82	$ 8,895,689.65	$ (590,622.17)
58	Molded Products, Clamshell Packaging	$ 1,252,870.24	$ 662,248.07	$ (590,622.17)
70	Clamshell Food Container	$ 5,086,311.82	$ 4,495,689.65	$ (590,622.17)
71	Clamshell Packaging and Trays	$ 5,086,311.82	$ 4,495,689.65	$ (590,622.17)
72	Rigid gift boxes, clamshell packaging	$ 4,286,311.82	$ 3,695,689.65	$ (590,622.17)
75	Blister packaging, face shield, carton packaging	$ 26,938,781.59	$ 26,360,053.73	$ (578,727.86)
54	Carton box, Plastic food Packaging	$ 12,670,998.25	$ 12,116,015.08	$ (554,983.17)
85	Bubble wrap, industrial film, corrugated box	$ 1,563,302.89	$ 1,022,574.77	$ (540,728.13)
139	Healthcare reusable and disposable plastic cups and trays, face shield	$ 4,898,928.81	$ 4,362,463.53	$ (536,465.28)
59	PP takeout container	$ 63,870,998.25	$ 63,334,532.97	$ (536,465.28)
63	Bottle Caps, injection molding	$ 6,122,690.23	$ 5,673,695.67	$ (448,994.56)
64	Caps and Closures	$ 6,122,690.23	$ 5,673,695.67	$ (448,994.56)
66	Caps and Closures	$ 20,122,690.23	$ 19,673,695.67	$ (448,994.56)
38	Plastic Films and Sheets	$ 7,226,355.30	$ 6,780,793.05	$ (445,562.25)
41	Plastic Films and Sheets	$ 14,226,355.30	$ 13,780,793.05	$ (445,562.25)
37	Plastic Films and Sheets	$ 999,916.72	$ 554,354.47	$ (445,562.25)
57	Caps and Closures	$ 64,122,690.23	$ 63,772,535.77	$ (350,154.46)
42	Industrial sheet, stretch film	$ 35,152,382.98	$ 34,839,112.41	$ (313,270.58)
39	Stretch film	$ 92,152,382.98	$ 91,839,112.41	$ (313,270.58)
132	Clamshell packaging, shrink wrap, corrugated box	$ 8,087,517.15	$ 7,824,303.28	$ (263,213.87)
47	Stretch film, shrink films	$ 4,818,687.74	$ 4,753,454.92	$ (65,232.83)

If we categorize the amounts of lost benefits in Table 13 into very low, low, medium, high, and very high scales, we could realize the severity of the implication of the SUPs ban based on the decrease in manufacturers' benefits. "X" represents the amount of lost benefit.

$X \geq \$ (5{,}000{,}000.00)$: very high

$\$ (3{,}000{,}000.00) < X \leq \$ (5{,}000{,}000.00)$: high

$ (2,000,000.00) < X ≤ $ (3,000,000.00) : medium

$ (1,000,000.00) < X ≤ $ (2,000,000.00) : low

X ≤ $ (1,000,000.00) : very low

Based on the above categorization, three companies could lose a great portion of their benefit as a result of material substitution. In fact, the ban may have a very high impact on these manufacturers in terms of benefit reduction even though their NPV is positive. Based on the assumptions of this study, all these three companies can continue production with glass, even though glass manufacturing is very costly. The database of SUPs manufacturers show that the annual revenue of these companies are $3,300,000.00, $2,300,000.00, and $3,000,000.00, respectively. It is an important factor that helps these manufacturers meet the expenses of conversion and benefit from it, despite the high costs of glass production. This leads to the prediction that feasibility of material substitution can strongly depend on the amount of revenue generated by the company.

Table 13 shows that 12 companies may be highly affected by the ban on their products and lose 3 to 5 million dollars of their benefits over the next three years. By digging more into the products of these companies, it can be observed that plastics bag category is common among all of these 12 companies. The assumption of this study is that except for plastics flexible food packaging and garbage bags, other types of plastics bags will be substituted by kraft paper or PLA-coated paper bags. In addition, two of the three straw producers are also among highly affected companies. This shows that replacing plastics by paper could decrease their overall benefits in a high level. This is because using paper as an alternative to plastics requires changing the whole production line as the processes of producing plastics and papers are completely different.

The calculations of this study predict that there are 33 companies that may lose 1 to 2 million of their overall benefits over three years. This study considers this amount of loss as “medium impact” of the policy. Companies #91 and #99, with negative NPV for overall benefits are in this group of affected companies.

Assuming that the SUPs ban will have a low impact on those companies that lose 1 to 2 million dollars of their overall benefits in a three-year period, 53 manufacturers may experience a low impact if they alter their production lines. Although the number of companies affected by the ban in a low level is higher than the first three groups, four of the companies that were identified as experiencing negative benefits as a result of substitution fall in this category (#14, #18, #28, and #124). The important conclusion that can be drawn is that although the ban may not decrease the overall benefits of many single-use plastics companies substantially, there might still be companies that will be unable to continue their business.

Finally, based on Table 13 and the assumption that the ban will have a very low impact on manufacturers that lose less than $1,000,000.00 of their benefit if they switch into alternative materials, there are 38 companies that fall in this level. Products such as clamshell packaging, stretch films, blister packaging, caps and closures, and shrink films are the main products in this group. Two main reasons could explain why the implications of the ban on these companies are very low: 1) this study assumes that clamshell packaging, blister packaging, stretch films, and shrink films will be substituted by PLA, which means that manufacturers will have the opportunity to use the machinery they already possess. 2) although the process of raw material found in this study show that PLA is more costly than petrochemical plastics resins, the lightweight of these products plays an important role.

4-4- Case Study: Small Single-use Plastics Manufacturers

In the previous section, the overall economic impacts of the ban on 139 single-use plastics manufacturers in the province of Ontario were discussed. Previous research has shown that that small businesses are sometimes more vulnerable to disruptions (see for example, Wedawatta & Ingirige, 2016; Juergensen, Guimón, & Narula, 2020). Based on the database of Ontario SUPs manufacturers and according to the Government of Canada website, most plastics processing manufacturers in Canada are small and medium-sized enterprises and almost all of them are Canadian-owned firms (Government of Canada, 2011). Thus, this study analyzes the impacts of the ban on small manufacturers that are predicted to be affected the most if the disruption takes into effect. In the original model, the calculations show that the net present value of the overall benefits (benefits-costs) will be negative for seven companies as a result of material substitution costs. These companies are identified by numbers 14,18, 28, 87, 91, 99, and 128 to respect the confidentiality of the individual companies in the model which is based on numerous assumptions about production costs and decisions. Further information of companies can be found in Appendix A. The analysis in this section investigates different aspects to discover what factor(s) might influence these companies the most, what features they have in common, and what solutions they can use to boost the likelihood of staying in the market. Finally, while a very detailed sensitivity analysis may not be necessary for private projects like this thesis, predicting how these manufacturers behave to the sensitivity analysis improves the robustness of this model and validates the analysis.

- **Company #99**

Company #99 is a small family-owned business that started its plastics production and printing services in the early 2000s. The firm is located in the GTA. According to the company website and the database of single-use plastics manufacturers in Ontario, it is currently producing different types of plastics bags and packaging solution with 9 employees and generating $257,142.9 in SUPs sales. Their production lines include retail bag, commercial bag, roll stock, pallet cover, garbage bag, shrink film, and stretch wrap. Except for pallet covers, and commercial bags that are excluded from the analysis of this study, their other lines might be affected by the ban. The alternative materials assigned to these products are PLA, kraft paper, and PLA-coated kraft paper which illustrate the requirement for both material and machine substitution. Database of SUPs manufacturers in Ontario shows that the annual revenue of this company is not high enough to meet the costs of substitution. In addition, the results of the CBA model show that the company will face a negative benefit if it switches to non-single-use plastics. Given that the calculated period for capital cost recovery for this company equals to 2.71 years, the model assumes that the company has the opportunity to recover the investment in less than 3years. Based on the assumption of this study, even though the NPV for overall benefit is negative, this company can make profit out of alternative production after 2.71 years. Below, the sensitivity analysis for company #99 is explained and shown graphically.

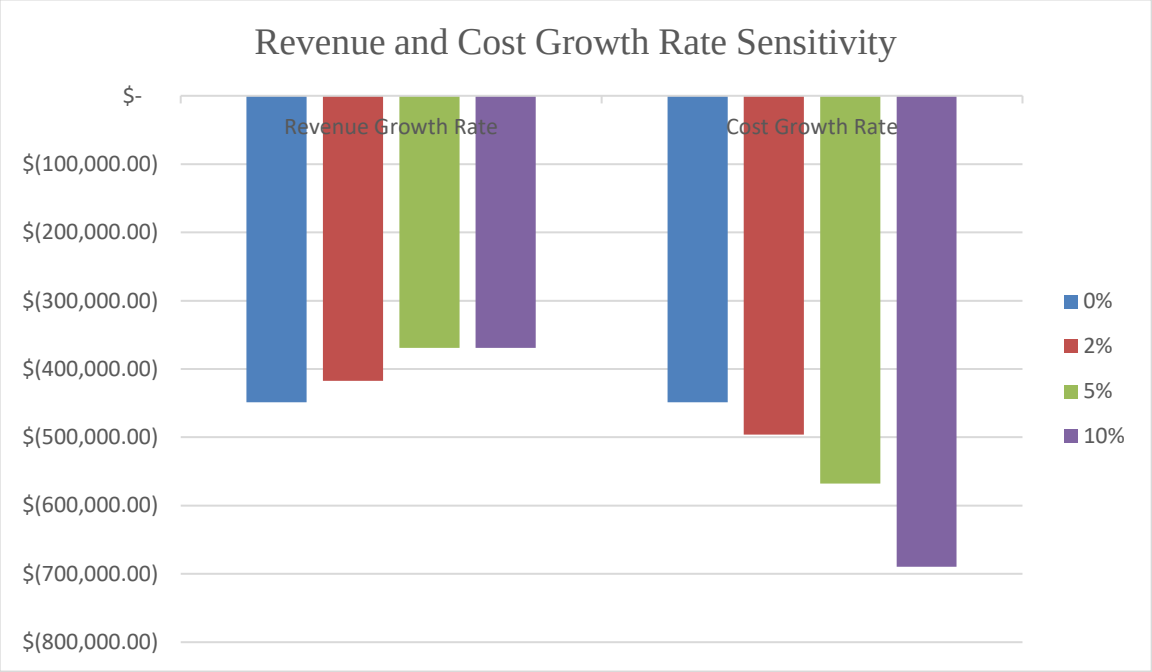

Figure 13. Revenue Growth Rate and Cost Growth Rate fot Company #99

Figure 13 shows how the NPV for overall benefit would change for company #99 if revenue and costs grow at different rates. The blue bar shows the NPV for overall benefit of the initial model. It can be observed that even with 2%, 5%, or 10% growth rates, the

NPV for overall benefit remains negative. However, given that the PBP is less than 3years, a growth in annual revenue helps this company recover the costs sooner than 2.71 years.

On the other hand, the cost growth decreases the NPV for overall benefit. But calculations of this model show that if costs grow at rates of 2%, 5%, or 10%, the PBP may still be less than three years and it may not change the decision for company #99.

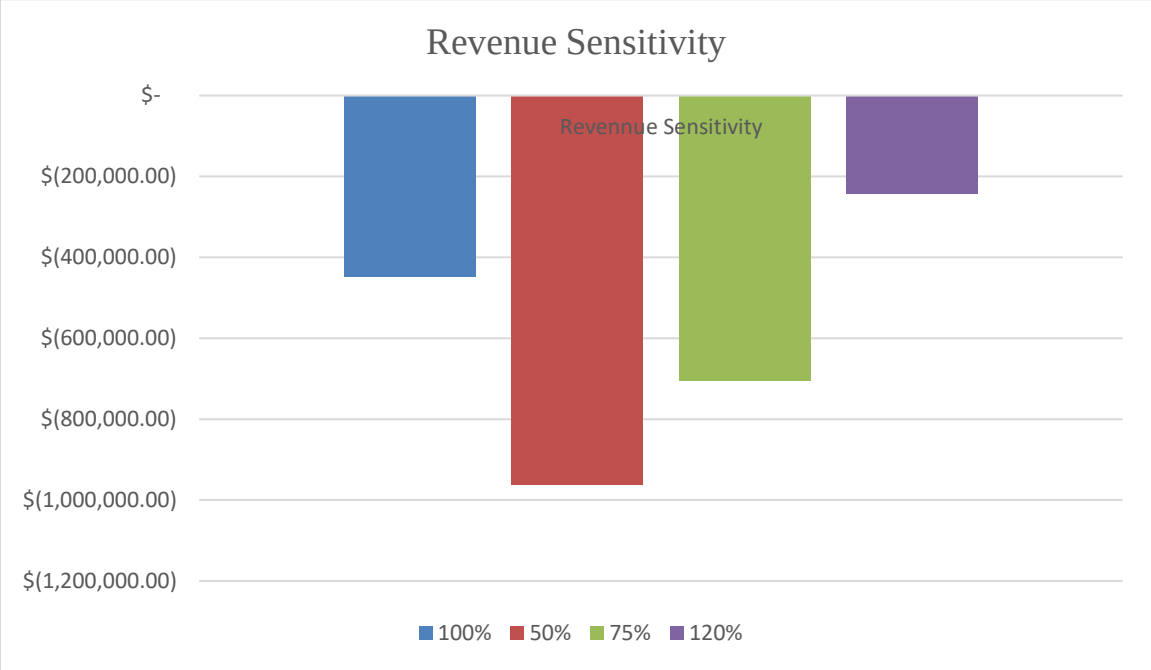

Figure 14. Revenue Sensitivity for Company #99

The sensitivity for annual revenue of company #99 is shown in Figure 14. It is obvious that as the revenue decreases, the NPV for overall benefit decreases. Calculations of the model shows that if the annual revenue drops 50%, the payback period will be equal to 3.08 years. This number is very critical and makes decision more challenging in this situation. The company should evaluate possible solutions that could cut the costs and reconsider the decision-making. The green bar on Figure 14 shows that if revenues were 25% less than expected value, the NPV for overall benefit could decrease and the payback period would

increase by 0.31 year. Again, a 2.88-year payback period is a critical number and warns the company to be more conservative for making decision because of the existence of any uncertainty in economic condition. Finally, if revenue were 20% more than expected value, the NPV for the overall benefit would remain negative, but it could decrease the PBP to 2.59 years. Selecting a 3-year payback period was a conservative approach opted by this study, but the results of sensitivity for this company express how small the difference between failure and survivor of a company can be. In fact, sensitivity test in this case is more illustrative, rather than predictive, meaning that it can enable manufacturers with similar situation and the missing portion of SUPs manufacturers to predict the outcomes of material substitution.

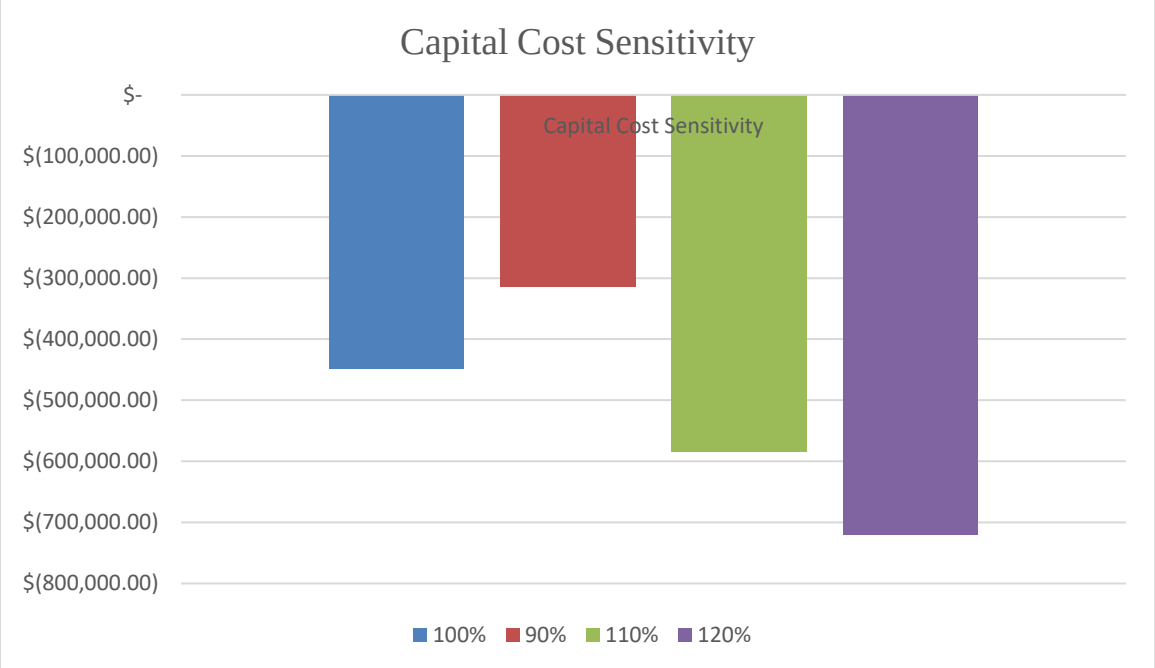

Figure 15. Capital Cost Sensitivity for Company #99

The capital cost sensitivity for company #99 was conducted to test the results if the prices of machines and other costs associated to capital costs change, because although the

payback period will remain less than 3years -despite all the changes made to the capital cost- there might be this option for companies to choose less expensive machines and equipment so that they could recover their investment earlier than 2.72 years.

- **Company #87**

According to the results of the model, another single-use plastics manufacturer that will be affected by the ban is a producer of flexible film-based plastics packaging products. This company is producing different types of flexible bags such as zipper bags, roll stock, snack web, and pouches for food industry and has 3 employees. The company has announced that they are making a contribution to the circular economy by following 4R (reduce, reuse, recycle, recover) principle. While this company has started to have a positive impact on the environment by choosing recyclable materials, it will still need to make a transition to producing a packaging that is not considered single-use plastics. This company is generating $600,000.00 a year which does not cover the costs of substitution based on the results of the model. The calculated PBP is equal to 5.88 years, which means the factory

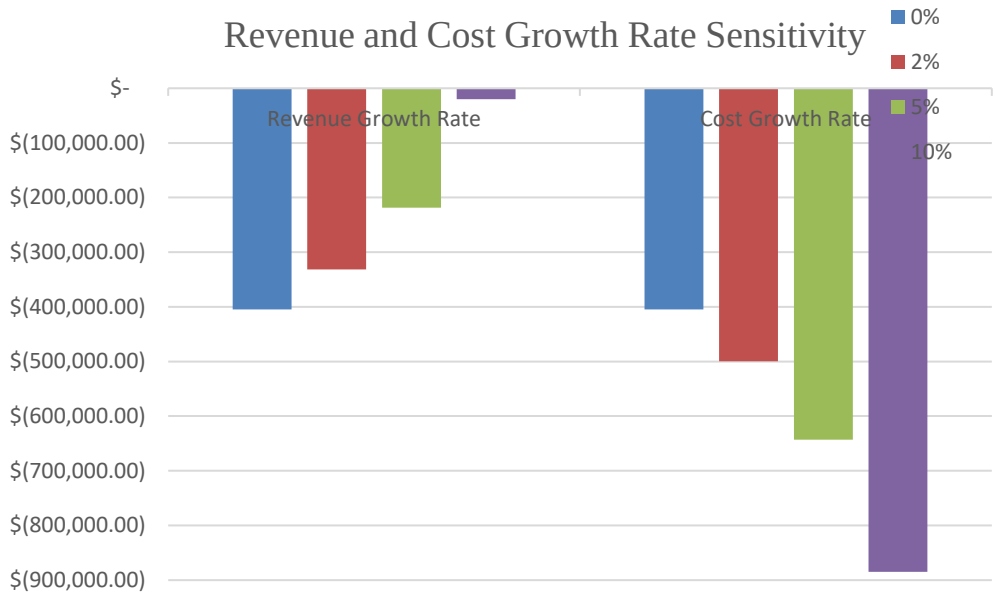

Figure 16.Revenue Growth Rate and Cost Growth Rate Sensitivity for Company #87

should be closed and just benefit from the scrap value of selling machinery which is $ 263,550.00. However, the sensitivity analysis shows that the results could change when some of the parameters change.

Figure 16 shows that when the annual revenue grows at a range between 2% to 10%, the total benefit of the company remains negative and the payback period would not change substantially, and a growth rate in costs would just make substitution more costly for company #87.

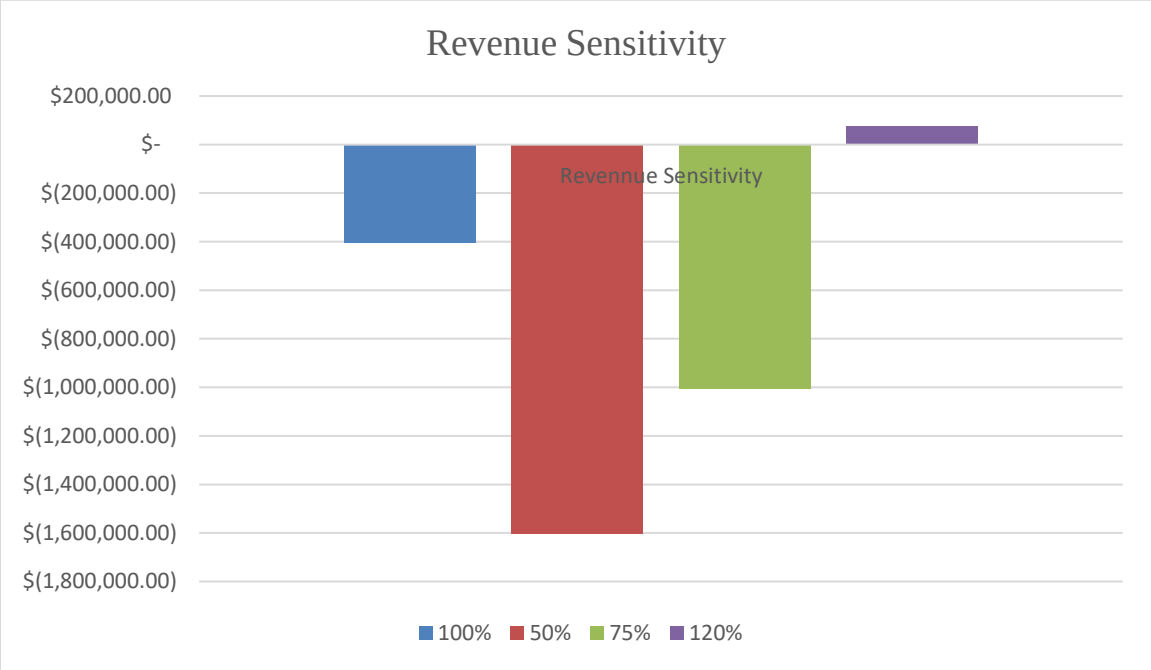

Figure 17. Revenue Sensitivity for Company #87

The revenue sensitivity shows that there would be an inflection point for this company if the annual revenue were 20% more that the initial amount. This could change the decision for this company since a 20% more revenue could make material substitution beneficial. The results of sensitivity test are governed by several factors, but identifying opportunities is a key to increase annual revenue. The sensitivity analysis predicts that if company #87 finds a way to increase its revenue at least 20%, it could benefit from material substitution

and stay in the market. The decision of the company is in fact governed by different factors that each could change the results; hence it will not be entirely accurate to be certain about the decision of this company, but given that the amin aim of sensitivity analysis in this study is improving the robustness of the CBA model in different economic conditions, it helps companies with similar situation to make their decisions more effectively.

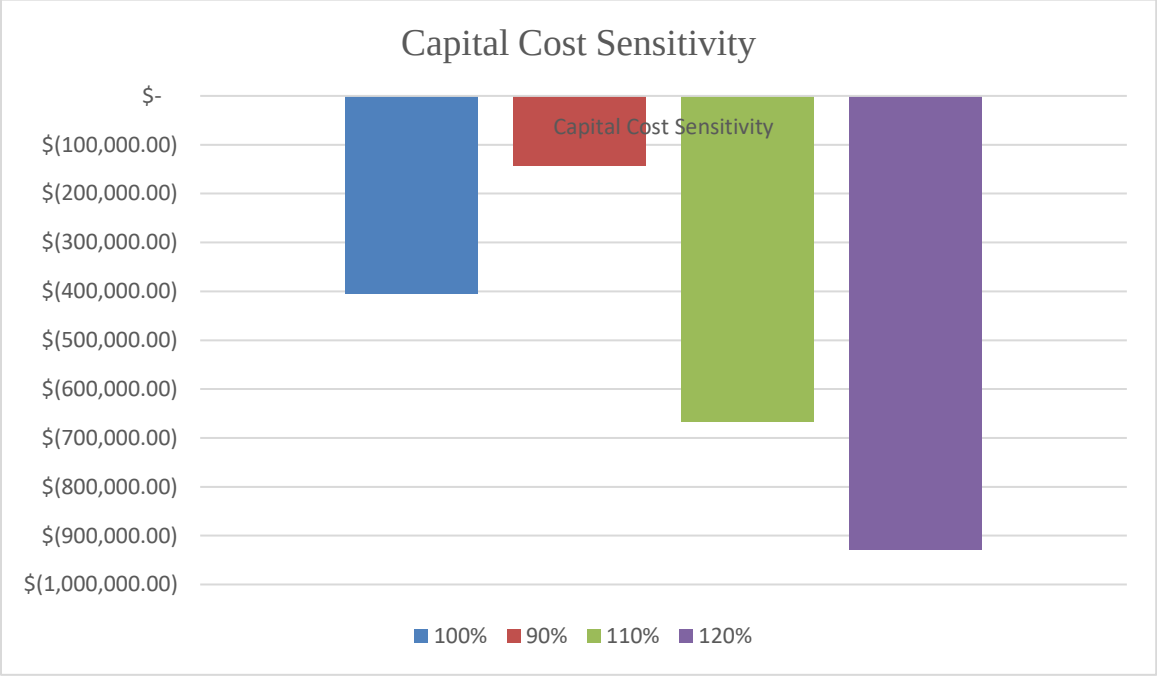

Figure 18. Capital cost Sensitivity for Company #87

Figure 18 above shows that the costs of material substitution are too high to make profit for the company. Even if the capital costs were 10% less, substitution is unlikely to be beneficial.

- **Company #28**

Company number 28 is a micro business with 1 employee working in single-use plastic lines of this manufacturer. The items produced in this company include paper bags, plastic bags, and zipper bags. The annual revenue generated from SUPs are $200,000.00. Based

on the assumptions of this thesis, this company should alter its products from plastics to papers. For this purpose, changes in machinery and material are required for both SUPs

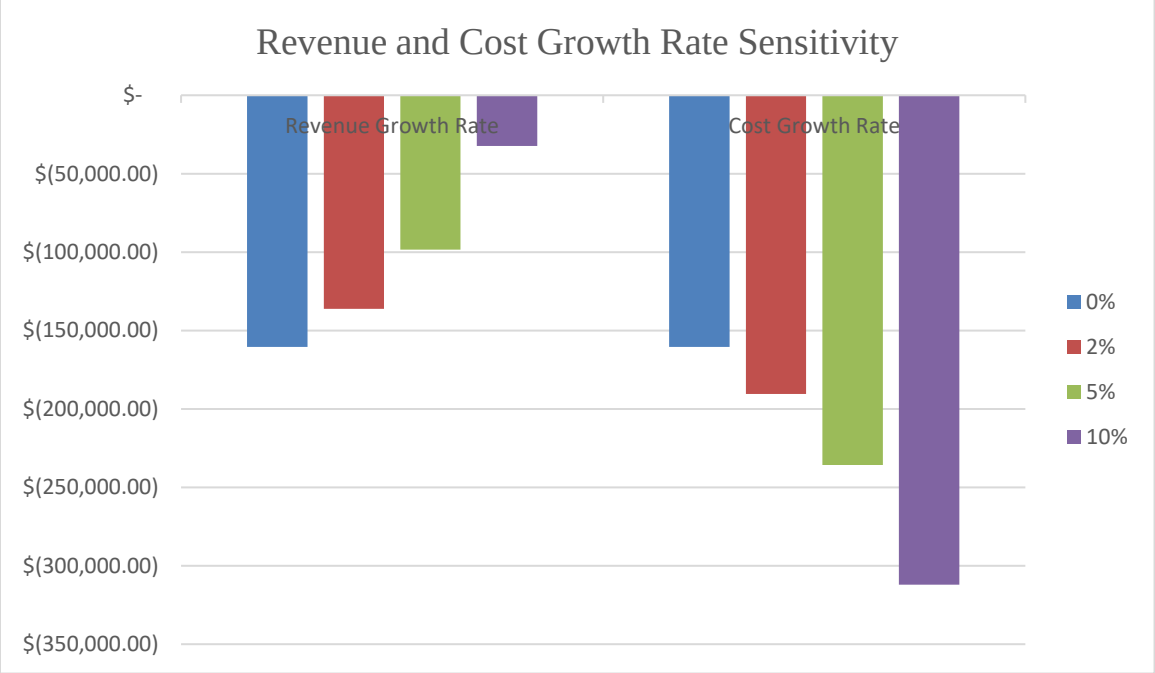

Figure 19. Revenue Growth Rate and Cost Growth Rate for Company #28

products. The results of the CBA model suggest that the total costs will be more than the total benefits if the company switches to paper and the overall benefit will be negative with a payback period of 3.57 years and a scrap value of $79,515.00 for plastics machinery. The assumption of this study is that companies will continue production with a negative benefit only if the payback period is less than or equal to 3 years.

Company #28 does not show significant changes in results when different growth rates are applied. The annual revenue of the company is too low that it may not be able to cover the costs even if it increases 10% per year.

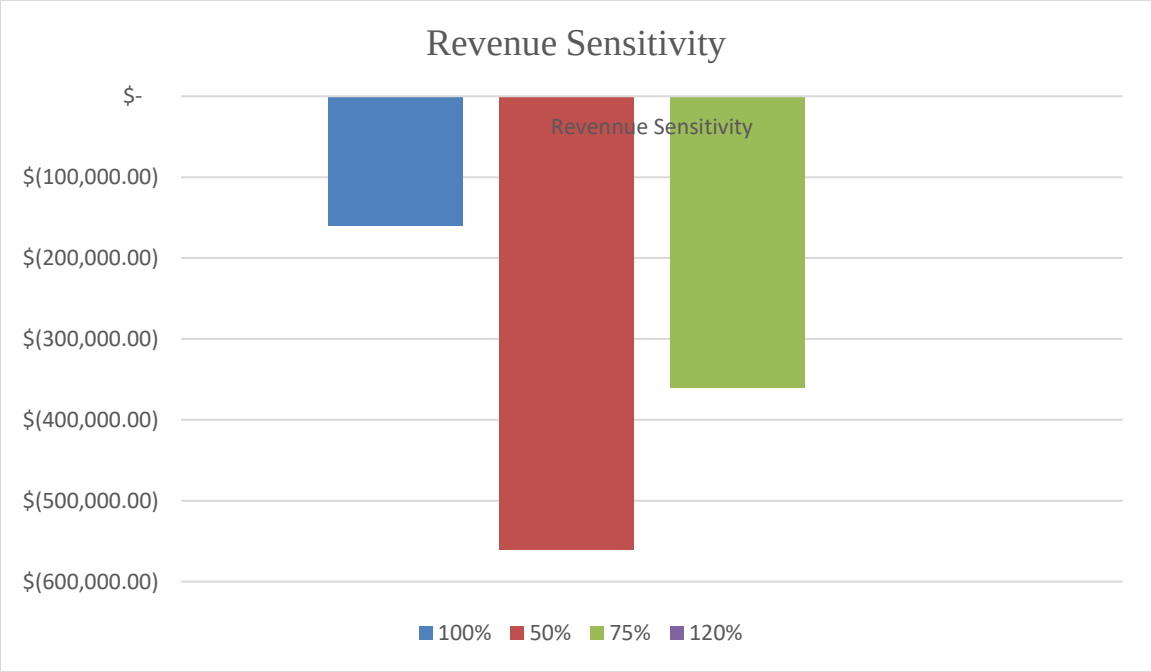

Figure 20. Revenue Sensitivity for Company #28

The payback period for company #28 is 3.57 years. The sensitivity analysis for revenue indicate that if revenues were 20% more than expected amount, it may still remain negative. Even though the NPV for total benefit would not be too low if the revenue were 20% more than the initial amount, it still would not make a return on investment in less than 3 years.

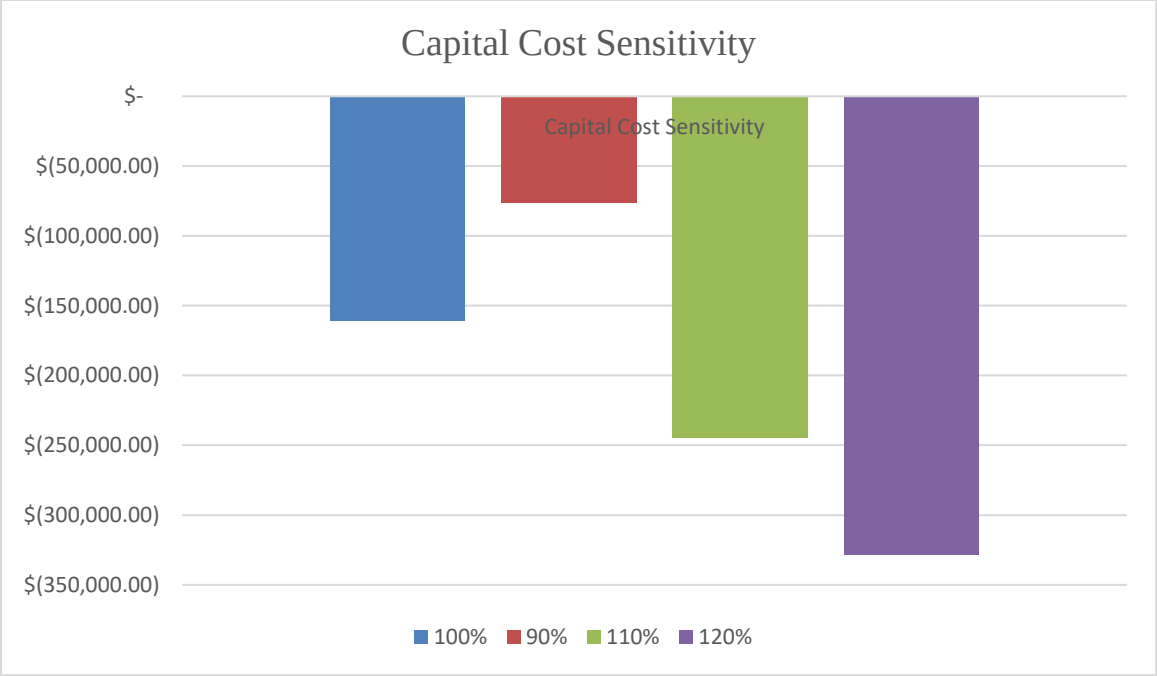

Figure 21. Capital Sensitivity for Company #28

- **Company #91**

Company #91 is among the firms that will severely be affected by the ban. According to available data provided by business directories, it is estimated that this company has 1 employee and an annual revenue of $260,000.00. The company is producing zipper bags, roll stock, and flexible food packaging. A change in machinery and material are required for producing PLA-coated kraft paper pouch and paper bags as alternatives for zipper bag and roll stock. The company can keep producing flexible food packaging with existing machines, but still needs to switch from petrochemical plastics to PLA. The cost burden of substitution makes this company unable to bear the expenses. The results of this study suggest factory closure as a solution to prevent further losses. Moreover, the payback period of 6.30 years is not low enough and it seems to be very risky for the company to

continue production. Figures 22, 23, and 24 show the results of sensitivity analysis for this company.

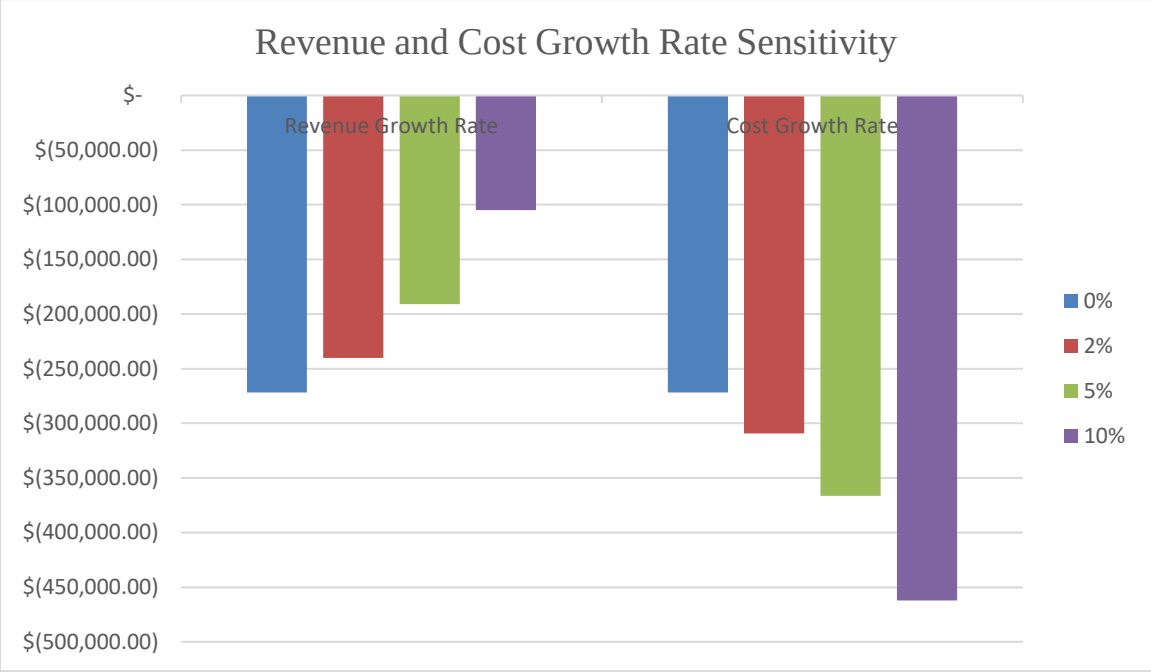

Figure 22. Revenue Growth Rate and Cost Growth Rate for Company #91

As it was mentioned, company #99 is among companies what will be negatively affected by the ban since the revenues may not cover the costs of substitution. As the cost growth rate increases, it simply makes it even more detrimental for this company to make a substitution as a response to the SUPs ban. Also, even the possibility of revenue growing at the highest rate (10%) may not make a difference in terms of benefit for the company. Therefore, company #91 is very likely to shut down the business as all the products are considered harmful single-use plastics.

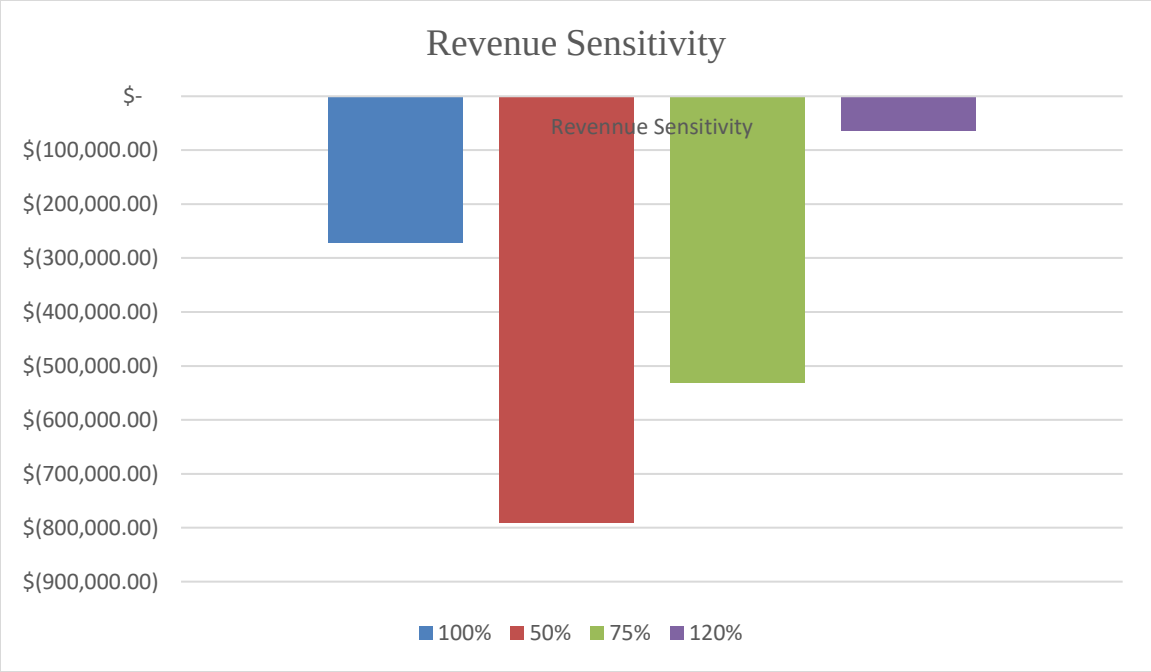

Figure 23. Revenue Sensitivity for Company #91

Reducing the initial revenue by 50% and 25% makes it more likely for company #91 to shut down the business as the NPV for overall benefit drops dramatically. Moreover, the presumption of 20% more revenue may not help this company cover the costs.

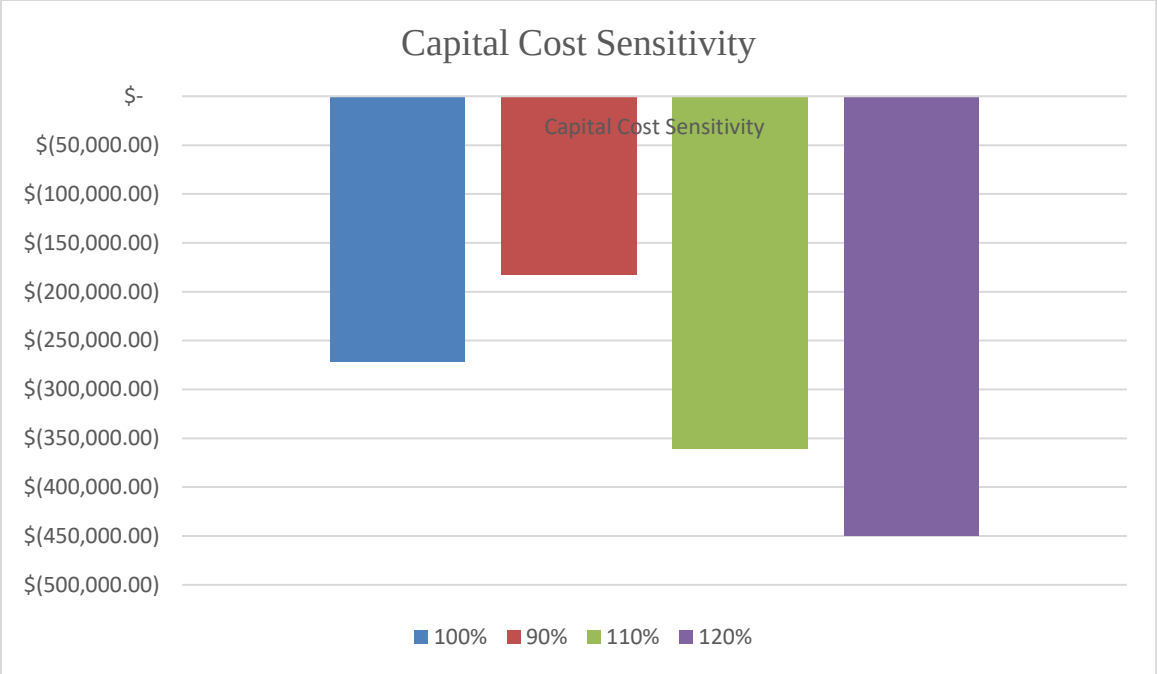

Figure 24. Capital Cost Sensitivity Analysis for Company #91

Appraising company #91 from different perspectives, it was detected that along with low annual revenue and high material cost difference, there is another reason that contributes to a negative NPV for the overall benefit for this company. The company has three production lines in total which two of them should be altered to paper production lines, based on the assumptions of this study. This imposes a high capital cost to the company in a way that if we apply 90% of the initial capital costs, substitution may remain an economically infeasible solution.

- **Company #18**

Company #18 is a micro company with $300,000.00 revenue and 2 employees located in Mississauga. The firm owns three production lines: candy wrap, shrink film, and bag. The alternative materials considered for these products are PLA-coated paper, PLA, and paper, respectively. The capital cost imposed on the company outweigh the benefits it makes out

of production and the ban would lead to a negative benefit for the company with a payback period of 3.33 years, which means that the company should shut down the whole business since all the products are considered single-use plastics. The scrap value of machinery is $232,980.00. The results of the sensitivity analysis indicate that material substitution would not be profitable when parameters change.

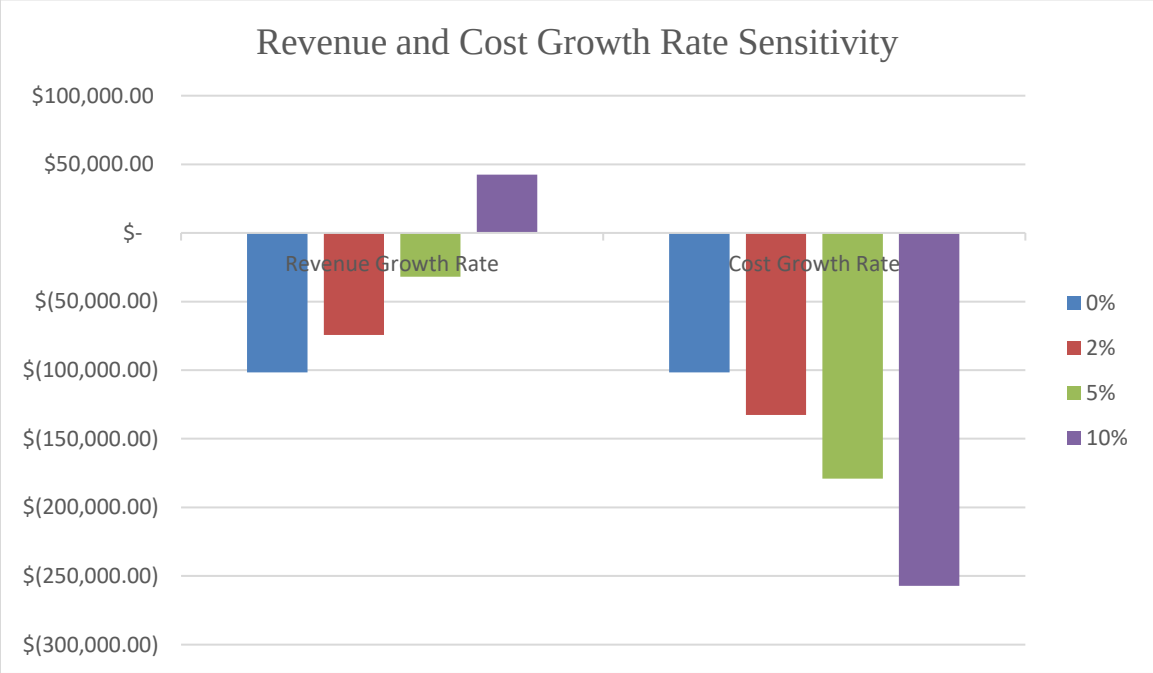

Figure 25. Revenue Growth Rate and Costs Growth Rate Sensitivity for Company#18

Despite getting a negative NPV for the overall benefit in the initial model, the sensitivity analysis for the revenue growth rate shows that this company is sensitive to changes in revenue growth rates. While a 2% revenue growth rate does not change the results considerably, they might change the decision of this company if the revenue growth rates were 5% or 10%. The figure shows that the benefits of material substitution could outweigh the costs with 10% annual growth in revenue. The NPV for overall benefit remains negative

if the revenue growth rate increases by 10%, but the payback period would be 3.03 years. This number is very closed to the desired payback period in this study. In such critical situations, the company should figure out ways that could decrease the costs and redo a cost-benefit analysis.

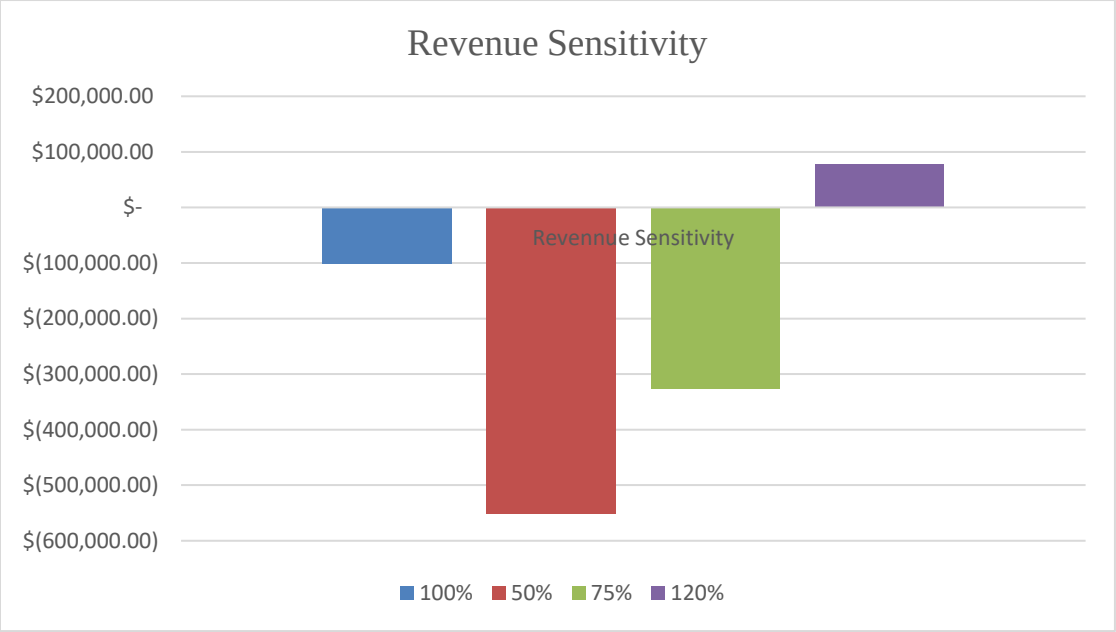

Figure 26. Revenue Sensitivity for Company #18

According to the calculations of the model and the figure above, company #18 could have the opportunity to benefit from material substitution if the revenue were 20% more than the initial amount.

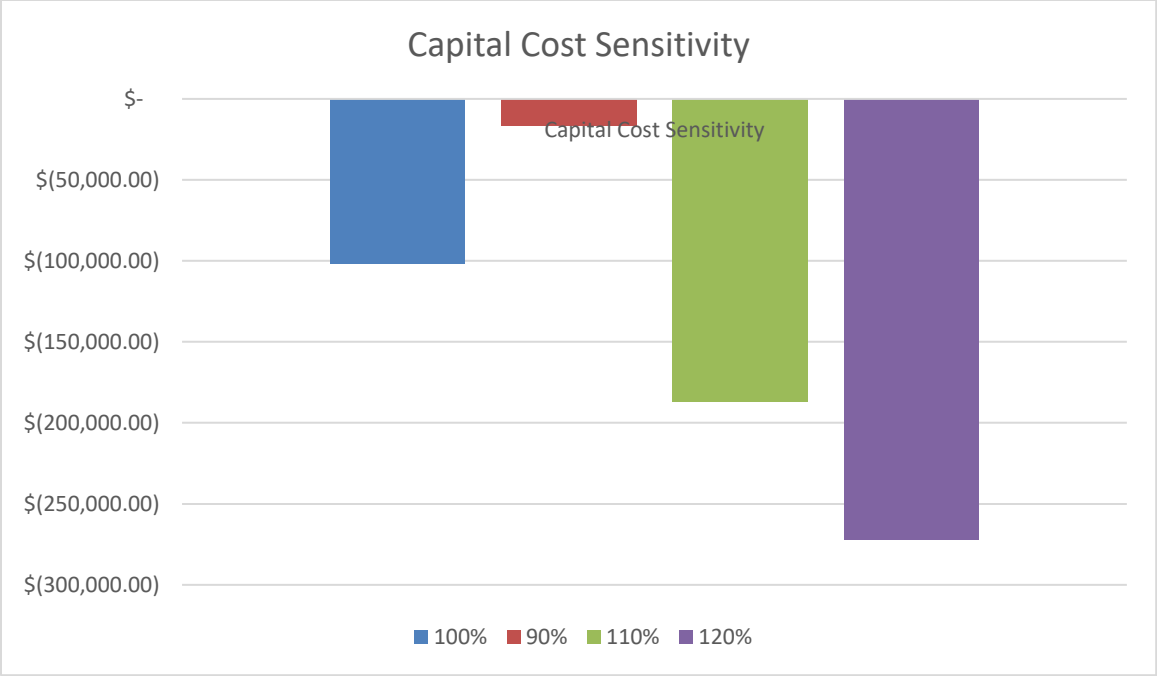

Figure 27. Capital Cost Sensitivity for Company #18

If the company chooses to purchase more expensive machinery, or if the prices of alternative machinery needed for company #18 were more than the calculated amount in this study, material substitution. This is a solution that companies with the same situation could have, but due to the limitations of this study, other possible solutions are not considered.

- **Company #14**

One of the companies that will be severely hit by the ban is a micro company with a total of 3 employees. The company is located in a small city called Ripley. It is producing packaging supplies such as plastics garbage bags and retail bags, paper bags, carton boxes, labels, tissue papers, and gift wraps. The allocated revenue to the two plastics production lines (garbage bag and retail bag) equals to $114,286.00. The company needs to change its machines for producing retail bags and switch to PLA to produce garbage bags. The

company has announced that they are making specific logos for their environmentally friendly products. The logo is used for recyclable, reusable, biodegradable, and compostable products, and for products that are made with recycled and sustainable materials. The only clarification on the website of this company is that the bags are made of Oxo-biodegradable plastics. Since there is no further detail on materials, the assumption is that they should still substitute Oxo-biodegradable plastics by PLA. The results of the model show that the PBP exceeds 10 years and changing parameters in the sensitivity analysis does not change the results. In fact, the sensitivity analysis shows that neither with a higher revenue nor a lower cost the company is going to be able to bear the costs of substitution. Therefore, the strategy for this company would be to shut the SUP lines down. The allocated number of staff to SUP lines equals to 1 and the calculated scrap value for plastics machine is $159,075.00. The figures below demonstrate how the total benefit changes when four parameters of revenue growth rate, cost growth rate, revenue, capital cost, and discount rate changes.

The following figure shows the severity of the impact of material substitution on company #14. The amount of revenue allocated to SUPs lines is too low and paper machinery is required for paper bag production. The difference in material cost difference is not low enough to neglect, or it is very unlikely that even a less costly material would compensate the cost difference.

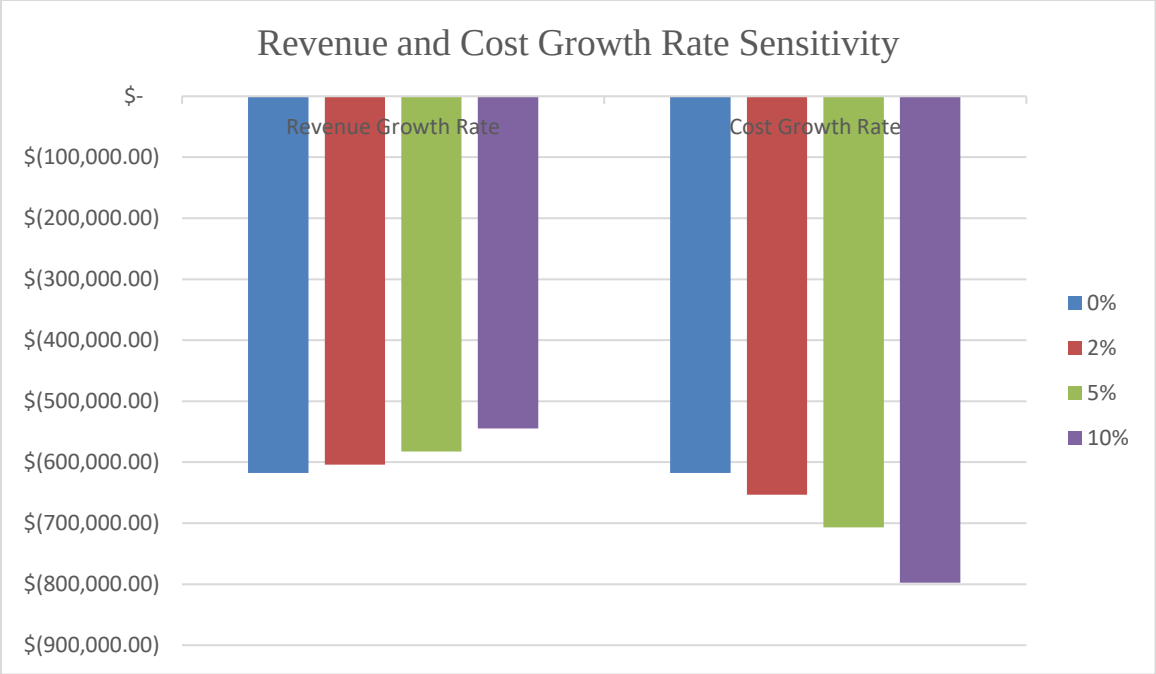

Figure 28. Revenue Growth Rate and Costs Growth Rate Sensitivity for Company #14

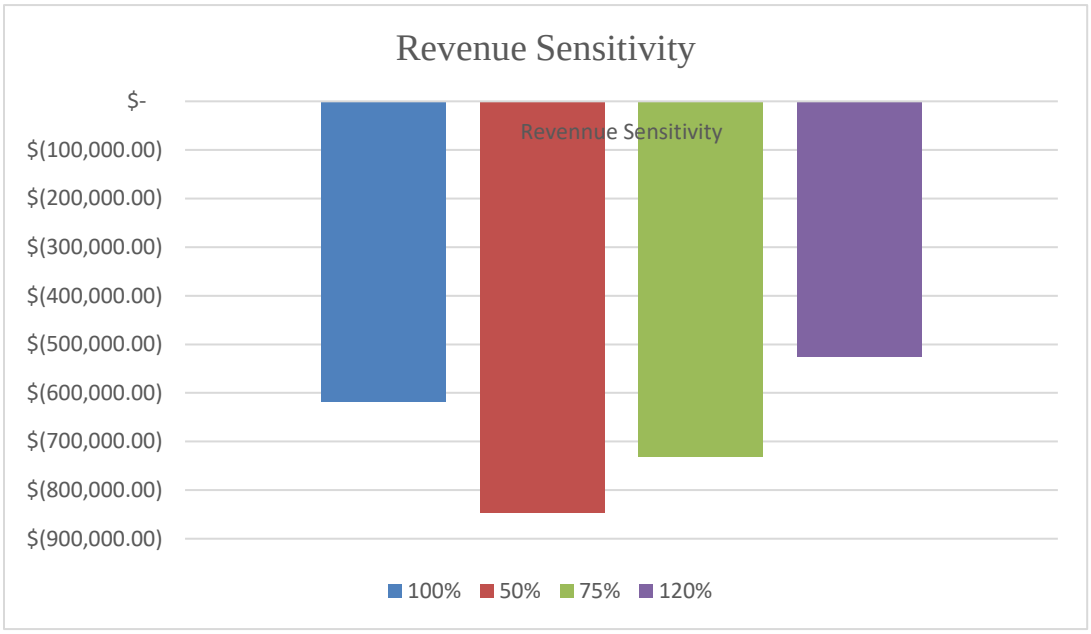

Figure 29. Revenue Sensitivity for Company #14

As it was mentioned, the revenue that company #14 makes from SUPs production is very low. Undoubtedly, less revenue damage the company more in case of material substitution, and a 20% increase in revenue would not help the company overcome the costs.

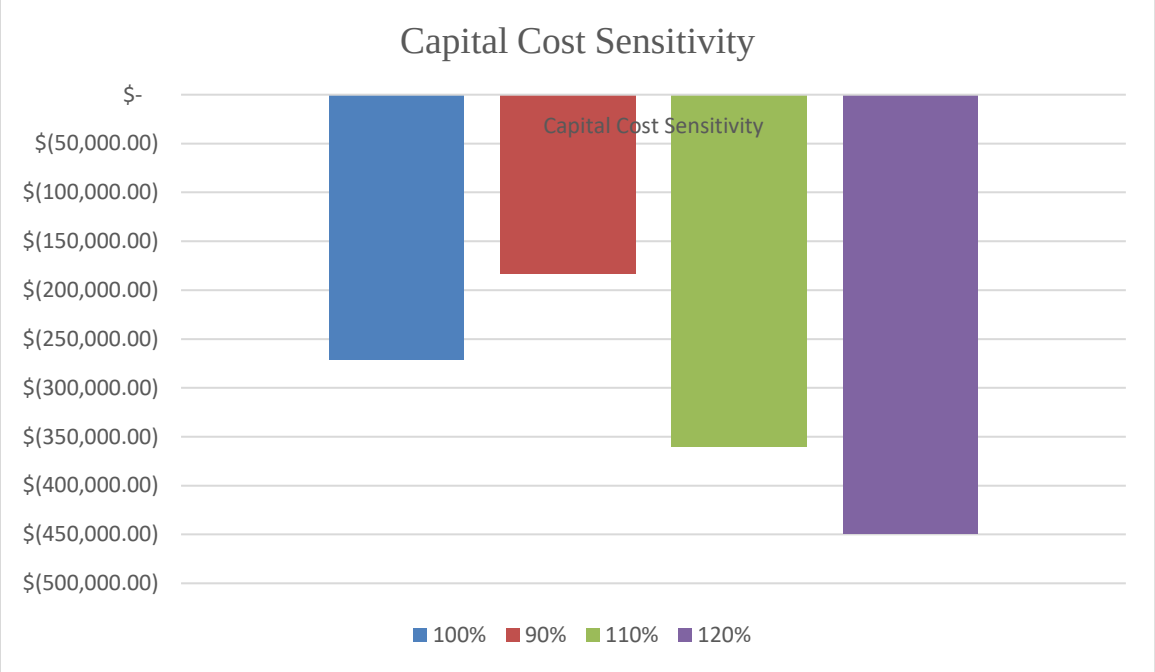

Figure 30. Capital Cost Sensitivity Analysis for Company #14

Even by assuming that the costs could be 10% less that the calculated amount in the initial model, the benefits will not outweigh the costs. For such companies with too low revenue and high costs where the payback period is also too long, material substitution is not a solution companies would prefer.

- **Company #124**

Company number 124 is a small company located in Scarborough. Candy wrap, confectionary packaging, carton boxes, rigid plastic gift boxes, and tags are the products produced by this company. Based on these products, there are two SUPs lines including candy and confectionary packaging. The total allocated revenue to SUP lines is

$200,000.00 and the number of people working in SUP lines equals to 3. The results of the model indicate that the total benefit of this company will turn negative if they switch to alternative materials and the payback period would be 5.34 years, and the scrap value of SUP machinery is $204,075.00. The following figures better show how the results change when revenue growth rate and the revenue increase.

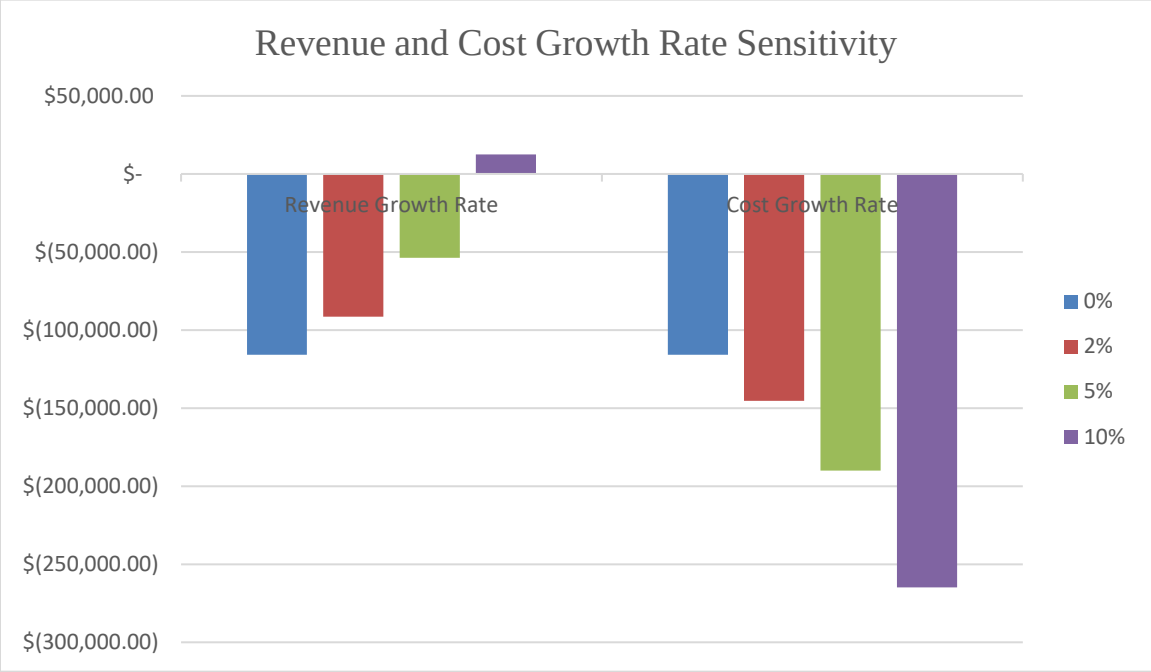

Figure 31. Revenue Growth Rate and Costs Growth Rate Sensitivity for Company #124

After conducting the sensitivity analysis, it was realized that in case the revenue grows at a rate of 10%, the overall benefit could turn into a positive value.

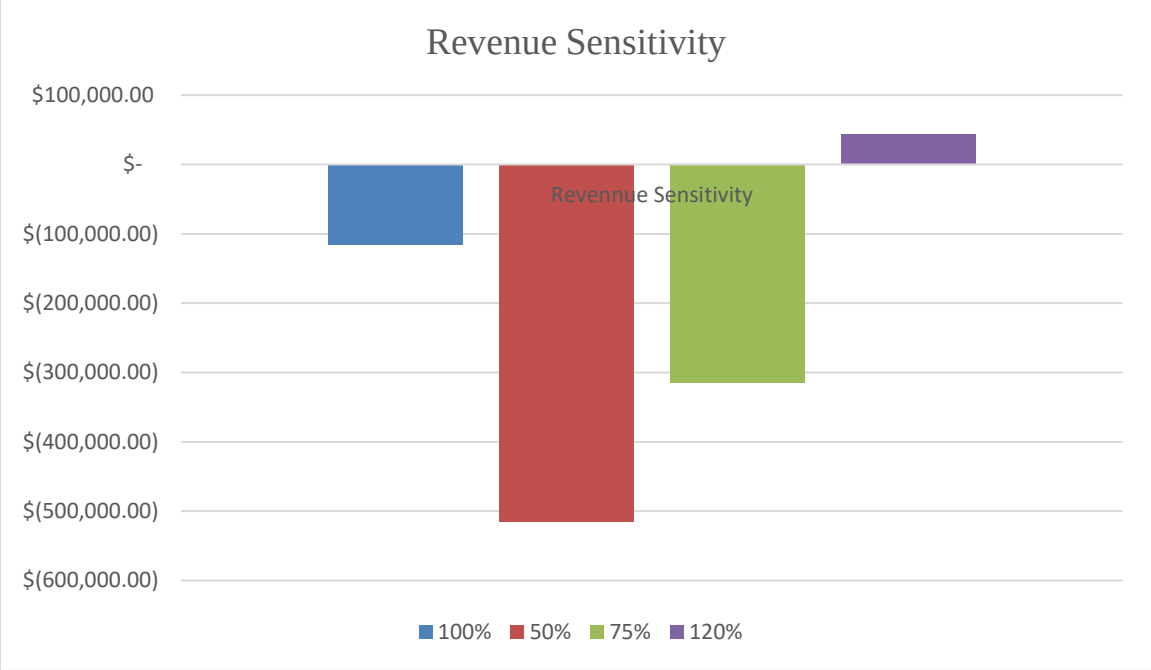

Figure 32. Revenue Sensitivity for Company #124

Revenue sensitivity analysis show that if company #124 generated 20% more revenue from its SUPs production, it could be able to bear the costs of material substitution. Meaning that if the company finds ways to generate $40,000.00 more per year, it could overcome the costs (given that the annual revenue allocated to SUPs is $200,000.00).

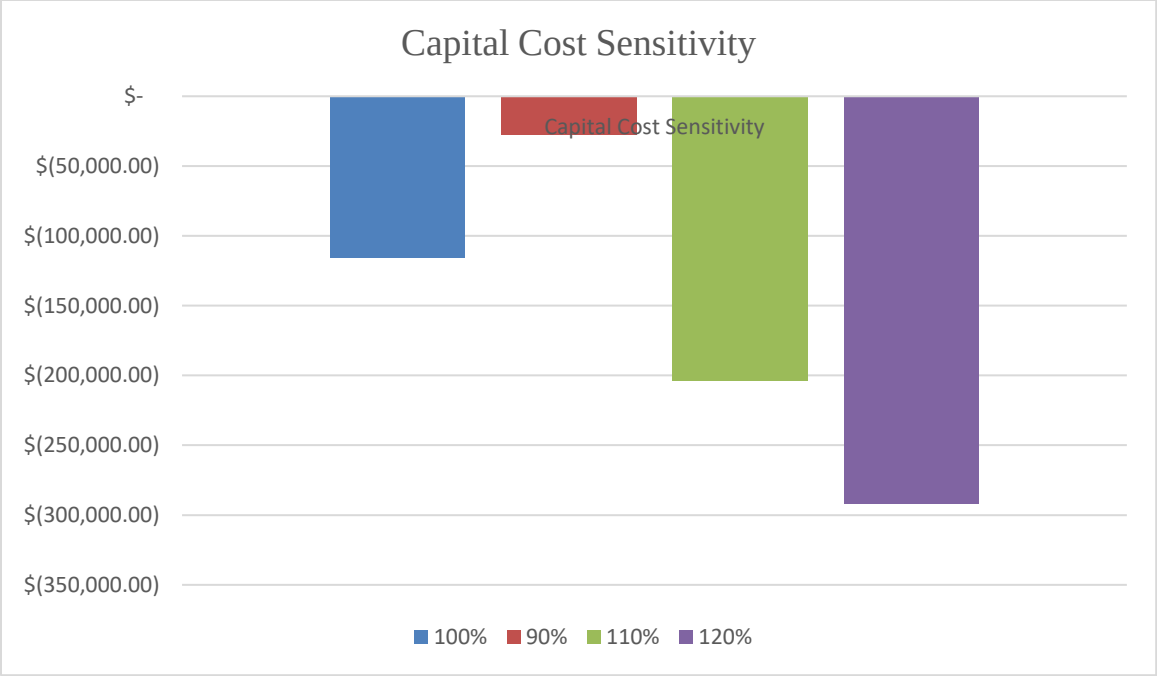

Figure 33. Capital Cost Sensitivity for Company #124

It is possible that the purchasing machines can be more or less than the calculated amount in this study. Therefore, this study predicts more and less costs than the initial ones to improve the robustness of the result of the CBA model. However, for this case, cheaper machinery may not make profit for company #124 and it is predicted that this company would shut down its SUPs lines or use a completely different strategy to respond to the ban.

4-5- Sensitivity Analysis for 139 Single-use Plastics Manufacturers in Ontario

The model proposed in this study is founded on some assumptions that might affect the results. Therefore, a series of sensitivity analyses are carried out to improve the robustness of the proposed CBA model. The sensitivity analysis is also important to evaluate the results of the model in case the economic condition changes and consequently, any of the parameters change. The sensitivity analysis is conducted for different ranges of capital cost,

revenue growth rate, cost growth rate, revenue, and discount rates. A separate evaluation was conducted for the seven manufacturers that had negative net present value in the model under the initial economic conditions. This section examines the implications of the model on the single-use plastics manufacturers in Ontario under different economic conditions (i.e., slow economic growth, medium economic growth, faster economic growth, medium revenue growth, etc.). More details of sensitivity analyses results can be found in Appendices B to F.

4-5-1- Revenue Growth Rate

The annual revenue of manufacturers was assumed to stay the same during the period of the analysis. For sensitivity analysis, in order to realize how the proposed model behaves if the annual revenue grows at different rates, the revenues were increased at the rates of 2%, 5%, and 10% per year. The results of the sensitivity analysis show that no changes occur in the results of the initial proposed model if the revenue growth rates were 2% or 5%; but when this rate increases to 10%, the number of companies affected by the ban decreases to 5 companies. In other words, if the annual revenue of companies grows 10% per year, company #18 and #124 might have the opportunity to be able to continue production with a positive total benefit. Revenue growth rate depends upon internal factors and external factors such as market condition and competitors (Muhammad et al., 2008). Testing a different range of growth rates improves the robustness of the results of the model in different economic conditions. Although companies do not have control over external factors such as economic condition and public policies, they could try to increase their revenue growth rate by efficient strategies namely market sensing, brand management, and customer relationship management (Morgan, Slotegraaf, & Vorhies, 2009) and internally

using their financial, human, and physical resources more efficiently (Muhammad et al., 2008). Appendix B shows the results of revenue growth rate for 139 SUPs companies in Ontario.

4-5-2- Cost Growth Rate

Different cost growth rates are tested in a similar way to revenue growth rate. At first, it is assumed that costs will stay the same during the three-year period of the cost-benefit analysis. For sensitivity analysis however, 2%, 5%, and 10% growth rates for costs are tested. These growth rates are applied to operating costs. The sensitivity analysis of cost growth rates of the proposed model indicates that none of the applied growth rates may make any significant changes to the results of the initial model except for company #52 that may face negative NPV if costs grow at 5% and 10%. Those seven companies are still predicted to be affected negatively by the ban. Although external factors of cost growth rates such as inflation are out of control of manufacturers, they could possibly cut their operating expenses, namely they might be able to use less costly materials. The inflation rate is subject to change and it is uncertain in unstable economic conditions. Therefore, manufacturers should be aware of this factor and take it into consideration. It should also be noted that the cost growth rates are only applied to the changes made to costs of material (difference of plastics and alternative materials), which is one of the limitations of this study. Appendix C shows the results of revenue growth rate for 139 SUPs companies.

4-5-3- Discount Rate

A discount rate of 2% is used for the initial CBA model to calculate the NPV of benefits and costs. By increasing the discount rate, the present value of the future cash flow decreases. The sensitivity of net present values is tested by changing the discount rate from

2% to 5% and 10%. According to the results of the sensitivity analysis of the proposed model, while increasing the discount rate to 5% and 10% decreases the NPV of total benefits of companies, it does not change the results of the model substantially. Therefore, the study predicts that although the net present value of company's investment declines as the discount rate increases, 132 of 139 the found companies in Ontario may still benefit from substitution. This range of discount rates were tested to analyze the implications of the ban on single-use plastics. Selecting the appropriate discount rate is a critical decision as a higher discount rate increases the level of risk associated with investment (Investopedia, 2020). Appendix D shows the results of revenue growth rate for 139 SUPs companies.

4-5-4- Revenue Sensitivity

As mentioned in Chapter 3, the annual revenue of companies was obtained from a few business directories. In order to improve the robustness of the model in different economic conditions, the total benefits of companies were calculated with 50% and 25% less revenue than the expected amount and 20% more than that. The results of the sensitivity analysis of revenues predict that by decreasing the revenues, more companies could be affected by the ban. If the annual revenues decrease by 50%, 12 companies face negative NPV and may have to shut their businesses down. Along with the 7 manufacturers that were affected the most in the initial model, it is predicted that company number 1, 46, 52, 95, and 107 may get negative benefits as a result of material substitution. The total benefits were calculated with 75% of expected values as well and this time, the results show that in addition to the seven companies in the original model, two other companies might be affected (#46 and #52). On the other hand, if annual revenues were 20% more than

expected amount, only four manufacturers might be affected by the ban: #99, #91, #28, and #14. It shows that the results are sensitive to substantial change in revenue and again, small and micro enterprises are more vulnerable to changes to their revenues. Since the information of a portion of single-use plastics manufacturers is not available in public resources, the evaluation of this study is on 139 single-use plastics manufacturers in Ontario. Therefore, this sensitivity analysis is conducted to improve the robustness of the results. The results of revenue growth rate sensitivity can be found in Appendix E.

4-5-5- Capital Cost Sensitivity

The model also investigates how the model would respond in case the capital costs were 10 to 20 percent higher and 10% lower. The results show that if the capital costs were 10% less than the calculated cost in this study, it may not make any substantial changes to the results. Those seven companies with negative total benefits may still face the same result, however, their payback period declines as the capital cost decreases which makes decision-making more critical. On the other hand, increasing capital costs by 10% and 20% adds company #52 to the list of companies with negative NPV of overall benefit. The importance of capital cost sensitivity is that purchasing prices of machines and equipment were found online, through some industrial machinery dealerships that were mentioned in Chapter3. While it has been tried to use the middle price for machinery, it is possible that manufacturers choose to purchase less or more expensive machines. Those companies with negative NPV for total benefits are likely to decide to purchase cheaper machinery as a way to cut their capital costs. Moreover, they can purchase used machinery instead of new ones. It is one of the limitations of this study that assumes all manufacturers buy new machines and import them from the United States. Although manufacturers have different

options for purchasing their machines and equipment, the results of the sensitivity analysis on capital costs suggest that changing capital costs in this range may not make substantial changes. Appendix F shows the results of revenue growth rate for 139 SUPs companies.

4-6- Proposed Results of the Sensitivity Analysis

The proposed results of sensitivity analysis of the cost-benefit model in this study suggest that while the results of the initial model may change in case the parameters change, the change is not substantial and the level of impact of the ban on manufacturers is not likely to change dramatically. The sensitivity analysis shows that the results of the CBA model in this study are robust to changes in economic conditions. There are only a few companies that need to be more cautious about their analysis since testing different values for some parameters change their results. For instance, Company #52 is one of the companies that showed relatively higher sensitivity to changing some parameters. This helps similar manufacturers to have an overview of material substitution, but also highlights the importance of a more precise analysis prior to the implementation of the ban. The results of sensitivity analysis for all the found SUP manufacturers in Ontario can be seen in the Appendices.

4-7- Unemployment Implications

Watts (1991) defines capital switching as the process of shifting from an economic activity to another when return on investment is not satisfactory. He states that capital switching may be followed by one of the three consequences: 1) changing the activity of the production facility while the point pattern of operations stays the same, 2) selling the production site to another company. In such an event, the production line is lost, but the

operations are continued under the new ownership, and 3) ceasing the activities and closing the plant, which is followed by loss of sales and employment.

When a potentially disruptive public policy such as the single-use plastics ban is passed, possible consequences should be considered prior to its implementation. If policymakers figure out possible alternative paths and evaluate the trajectory of disruptive public policies, they could decrease possible risks and negative implications of such disruptions. An assumption of this study is that manufacturers will shut down the production facility or SUPs production lines if they face negative NPV for their total benefits by substituting plastics with alternative materials. One of the outcomes of factory closure as one of the consequences of capital switching is job loss (Watts, 1991). Companies that are unable to respond to the ban on their products might close their business, either entirely or for the affected production lines. In this case, there will be corresponding job losses. Studies show there are many adverse health and social impacts, such as sleeping difficulties, psychological distress, sleeplessness, etc. even for short-term unemployment (Myles et al. 2016; Brand, 2015; Strully, 2009; Grunberg, Moore, & Greenberg, 2006) and they are even more significant among young people (Vancea & Utzet, 2017). Moreover, there are studies that associate unemployment to family problems. Broman, Hamilton, and Hoffman (1990) interviewed auto workers whose plant was scheduled to close. The interviewees were divided into groups of workers that anticipated unemployment and those who had recently been unemployed. The results of the survey show that both groups experienced conflicts with their spouse and children and were likely to hit or slap them. The conflict was more intense in recently unemployed group of workers. The impacts of unemployment on health makes the improvement of public health facilities and counseling services more crucial.

Therefore, this study suggests that the Government of Ontario to employ precautionary actions particularly to control the negative impacts of unemployment due to the SUPs ban by dedicating a budget to health and counseling services.

In conjunction with social problems, unemployment can have negative impacts on the economic growth as well (Mohseni, & Jouzaryan, 2016). Studies show that there is a negative relationship between unemployment and GDP growth (Kukaj, 2018; Levin, 2012; Makaringe & Khobai, 2018).

In the announcement of Prime Minister Justin Trudeau, he claimed the about 42,000 jobs will be created through plastic waste management improvement. However, he did not clearly explain what jobs will be lost and how they will be replaced by new ones. This study predicts some possibilities related to jobs after the single-use plastics ban takes into effect:

- New jobs might be created and replaced by old ones: for instance, by investing in innovation, R&D, waste management and recycling industry, new jobs in these sections may be created and replaced by the jobs that were lost in single-use plastics manufacturing plants.
- Some SUPs workers might be transferred: when single-use plastics are prohibited to be produced, alternative products will be produced, sold, and used instead. Therefore, some workers who have lost their jobs in SUPs industry might be transferred elsewhere (i.e., alternative industries). However, displaced workers may not find their new jobs satisfying enough or it is of lower quality from different aspects (Brand, 2015).

- Some workers might lose their jobs: it is very likely that a portion of workers who are currently working at SUPs manufacturing facilities will lose their jobs. When SKF Canada Ltd. (a bearings supplier) was shut down, 58% of employees were optimistic about finding a new job after three months (Grayson, 1985). However, the results of this study show that over 60% of them were not able to find a job even a year after factory closure. The results of this study propose that

4-8- Disruption Implications

The concept of disruption and some of its examples were discussed in Chapter 2. Now, it is clearer why it is very likely that the proposed single-use plastics ban by the Federal Government of Canada to be a potentially disruptive public policy. It goes without saying that implementing the new policy was less complicated before the occurrence of COVID-19 outbreak. Now that the economy has already been affected by the current COVID-19, the government may need to adapt to the situation and make required changes as has already been done. When the Federal Government of Canada first proposed a ban on single-use plastics products in June 2019, it was supposed to be implemented as early as 2021; however, when the COVID-19 outbreak occurred, the demand for some PPE and some other single-use plastics products such as disposable plastics gloves and bags[28] boosted at a large extend that the government asked businesses and manufacturers to help supply the unprecedented demand for such products (Government of Canada, 2020). In spite of that, many non-essential businesses went into lockdown (Ontario, 2020). Many companies had

[28] Reusable bags are not allowed in some stores within Canada during the COVID-19 pandemic. Also, some stores have waived the fee on single-use plastics bags (Nova Scotia Environmental Network, 2020).

to lay off their employees as a response to the pandemic. Table 15 shows the percentage of workforce laid off in Ontario and in manufacturing sector during the COVID-19.

Table 15. Percentage of workforce laid off because of COVID-19

Percentage of workforce laid off due to COVID-19	0% to less than 1%	1% to less than 10%	10% to less than 20%	20% to less than 30%	30% to less than 40%	40% to less than 50%	50% to less than 60%	60% to less than 70%	70% to less than 80%	80% to less than 90%	90% to less than 100%	100%
Ontario	61.1	2.2	3.1	3.3	2.3	1	3.8	2.3	2.5	2.4	4.6	11.4
Manufacturing	50.3	4.7	6.4	5.3	3.6	3.1	4.5	3.5	4.1	4	4.9	5.7[29]

The calculations and results of the CBA model in this study predict that based on the constraints and assumptions of this study, among 139 found single-use plastics manufacturers in Ontario there are seven companies that would likely be unable to continue producing. According to Table 10, there are 20 employees in these companies working in SUPs lines. Given that the total number of employees working at SUPs manufacturing companies is 6,798, that is about 0.3% of the total number of employees working at SUPs sector. Although the job losses are relatively insignificant and would probably be compensated through existing means, the government could help decreasing plausible impacts of unemployment by taking some actions regarding this portion of job loss.

4-9- Policy Discussion

During the past decade, plastics pollution issues (Shilla, 2019), have motivated governments to take various actions against this petrochemical substance. Levies on disposable plastics bags and banning single-use plastics production and importation are examples of prevalent actions among governments (UNEP, 2018). Therefore, it is

[29] Source: Statistics Canada, 2020

important that manufacturers prepare themselves for the possibility of a total single-use plastics ban in advance in quest for preventing potential negative consequences. Although not all single-use plastics products will be banned in Canada now, there is a potential for a stricter ban in the future. So far, checkout bags, stir sticks, beverage six-pack rings, cutlery, straws, food packaging made from plastics that are difficult to recycle are on the list of products that will be banned by the end of 2021 (Press Release, 2020). The consumption of some other single-use plastics such as garbage bags, stretch wraps, shrink films, beverage containers and lids, and snack packaging are relatively high (CCME, 2018), but they are not covered in this ban. Accordingly, this study took a relatively conservative approach by including more single-use plastics products in the model. Evaluating various single-use plastics products and possible alternatives helps predicting how the market might look like if other products are banned. In addition, it gives an overview to the manufacturers of other single-use plastics products and helps them be prepared for a potential stricter ban in the future.

There are some uncertainties about different aspects of the announced single-use plastics ban that needs to be clarified by the government. Banning plastics medical devices is a debatable topic in which the government, scientists, and healthcare sector should come to a consensus through meticulous scientific research. While it seems unlikely, it is important that manufacturers and healthcare sector be cautious about the possibility of banned single-use plastic medical devices. Moreover, the government should be certain about the availability of a feasible and affordable alternatives in order to control the risks of such critical bans. Unless the government is clear and specific about how it is planning to deal with the ban, the goals of the policy may not be fully achieved.

4-10- Scope and Limitations

This section discusses the scope and limitations of this study and explains how they could affect the model.

Due to lack of available data, this study used empirical data by collecting information about single-use plastics manufacturers and their costs and benefits from available resources that were mentioned in previous chapters and created a database manually. Given the limits to the availability of relevant datasets, data relies on assumptions in this study. In order to improve the robustness of the model in different economic conditions, a series of sensitivity analyses were conducted for variables and results were evaluated. Based on available data, among existing plastics manufacturers in Ontario, 607 manufacturers that are currently producing plastics products were found. Given that there are 1,160 plastics establishments in Ontario (Statistics Canada, 2019), over 50 percent of the total number of plastics manufacturers in Ontario were found and evaluated. Although there might be a skew in the data, the sample is representative and generalizable to the population. Therefore, the CBA model in this study is also applicable to a new and complete single-use plastics manufacturing database.

Environmental cost-benefit analyses are in fact the evaluation of environmental policies and projects that often have indirect consequences (Atkinson & Mourato, 2008). In the case of SUPs ban, the costs and benefits of the government are basically environment-related and are applied indirectly and quantifying environmental factors are challenging. This study is concentrated on economic impacts of a single-use plastics ban on manufacturers in Ontario, thus the environmental costs-benefit analysis is out of the scope of this study.

In addition, this study does not take into account the benefits or costs to the suppliers of the original materials or the alternative materials and any possible shortage of materials. Therefore, effects can be excluded from the model.

Another limitation that will affect the results of the model is that it is assumed that all manufacturers will purchase new machinery and a specific alternative material for each single-use plastics item. In reality, however, there is a likely possibility that some manufacturers will buy used machines or less costly materials to cut their expenses and improve their return on investment. This seems even more likely for small manufacturers with low annual revenues. In this thesis, one alternative material has been assigned to each SUPs product, but manufacturers might choose to use another material. One of the reasons is because some new materials (i.e., bioplastics) have not been entirely embraced by all companies yet, for their mechanical properties and financial matters. Moreover, this study assumes that manufacturers will benefit from the scrap value of machinery used for banned single-use plastics production as a one-time benefit. However, for those manufacturers with multiple single-use plastics production lines whose products will not entirely be banned, it might be a possible option (if feasible) to increase the production capacity of products that need the same machinery but are not considered single-use plastics. Alternatively, they could sell the machines at their salvage value to manufacturers that are producing items that are allowed to be produced.

CHAPTER 5 CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5-1- Conclusions

As it was discussed in the introduction, disruptive public policies could profoundly impact the society, the economy, etc. The proposed ban on harmful single-use plastics by the Federal Government of Canada is a potential disruption that may affect the functioning of the single-use plastics industry.

Although a plethora of studies has been devoted towards environmental and social impacts of plastics phase-out, there is no comprehensive analysis of the financial impacts of such bans on manufacturers. The number of studies on the advantages and disadvantages of plastics also indicate that there is still no consensus among researchers about whether the benefits of plastics outweigh their drawbacks or not.

This thesis aimed at evaluating the economic impacts of the single-use plastics ban on Ontario plastics manufacturers. The contribution of this study is that the cost-benefit model covers and analyzes a wide range of single-use plastics products and a one-by-one analysis on 139 single-use plastics companies within Ontario.

The methodology used in this study is a mutually exclusive cost-benefit analysis that compares different alternative materials with petrochemical plastics from a financial point of view. Primary data was collected manually for 607 plastics manufacturers in Ontario from available business directories. Based on the production lines of the 607 found manufacturers, 139 of them are producing single-use plastics items. Other information

about manufacturers such as their annual revenue, the total number of employees, location, etc. were collected from available resources.

Parameters of operating costs, capital costs, and benefits for plastics and their alternatives were detected. When the required data was collected, the net present value for total costs and the net present value for benefits for each company were calculated. Then, the CBA model was generated and applied to 139 single-use plastics manufacturers in Ontario. Evaluation of material substitution was conducted based on the NPV of the overall benefit of companies that was calculated by subtracting the expected NPV of total benefits from the expected NPV of costs associated with material substitution.

Given that manufacturers would keep their businesses as long as the net present value of their overall benefit to substitution is non-negative, the outcomes and results of the model specify that the most drastic impact is on some small and micro manufacturers. One of the findings of this thesis is that small and micro businesses are more vulnerable to single-use plastics ban and it is more challenging for them to deal with such disruptions.

Seven manufacturers were detected as the most affected companies by the ban. Based on the assumptions of this study, they will have to shut down either the entire business or their single-use plastics lines. It was realized that one common feature among these seven companies is that they are all small and micro businesses with low revenues. The allocated revenues to single-use plastics items are less than $ 500,000.00 for these companies which is not enough to cover the costs of substitution. The single-use plastics products produced by these manufacturers mainly fall in the category of plastic bags. As this study assumes, most items in this category should be replaced by kraft paper or PLA-coated kraft paper

and require changing the machinery. The results of the model show that the amount of revenue and number of jobs lost as a result of the ban seem unlikely to have a major impact on the economy. The lost jobs would probably be compensated through existing means and manufacturers might have the opportunity to recoup the decline in their revenue through sales, which essentially occurs via increasing the price of products. All these results and observations bring up the question of is the proposed ban a punctuated equilibrium or not? While the results of this study suggest that the ban may only cause incremental minor changes, it is uncertain if the implications will remain minor for a public CBA or not.

Although the level of impact on manufacturers depends on what type of products are being produced and what alternative materials and machinery are used, the annual revenue of companies is a much more determinative factor of whether the company is capable of substituting plastics with alternative materials or not. In fact, if a company is generating a high revenue out of production, it is likely to be capable of bearing the costs of substitution even though the revenue might decrease in the first few years. A good example would be glass jar production. As it was discussed in Chapter 4, glass production is more costly compared to other materials selected for this study, yet it did not affect involved companies in this study since their revenues could bear the costs of substituting plastics with glass.

The previous paragraph illustrates the point that the results of this study are subject to change. First, while this study allocates one alternative material to each product, there might be other materials chosen by a manufacturer that could affect the results. In fact, manufacturers can choose other materials to substitute with plastics. Second, manufacturers may have the opportunity to purchase machinery and materials at a lower or higher price based on their targets and the situation of the company. Finally, some

manufacturers could take other actions as a response to this disruption depending on their capabilities and targets. For instance, some manufacturers might continue producing single-use plastics items that will not (or is very unlikely to) be banned.

In order to reduce the effects of these limitations on the results of this study, a sensitivity analysis on cost and benefit parameters was first conducted to test how the results may change in different economic conditions. Then, a similar, but more specific sensitivity analysis was done on seven companies that are likely to be the most vulnerable to the disruption.

Based on the results of the model, the number of jobs that may be lost due to the disruption is equal to 20. This number does not seem to have a considerable impact on the economy.

Although this thesis does not consider environmental and societal impacts of SUPs ban in the model, it involves the following groups of audience, directly or indirectly:

1. Companies whose businesses are partially or entirely involved with single-use plastics and will be affected by the ban. This study will help them with their decision-making process and provides an overview of how the ban would affect their business. It particularly helps those companies that showed high sensitivity to changes in parameters and those that are very likely to face business failure as a result of the policy implementation.

2. The Government of Canada, the Government of Ontario, Environment and Climate Change Canada, and the Ministry of the Environment, Conservation and Parks and that are taking actions against environmental pollutions and seeking to reduce plastics waste and its harmful environmental impacts via policies and

environmental programs (i.e., single-use plastics ban). They should collaborate with each other and evaluate the consequences of this policy from different perspectives to minimize the implications of the ban.

3. Suppliers, retailers, and manufacturers of other industries that will supply the alternative materials and products. This thesis provides information about approximately 50% of existing SUPs manufacturers in Ontario and helps them to forecast the demand for alternative materials to be prepared to compensate the lost portion of single-use plastics.

4. Single-use plastics consumers, especially because a great portion of these products are consumer goods that are used by households. The results of this research can help them be prepared for coming changes, change their consumption behavior, and improve their decision making at the time of purchase, consumption, and waste management after use.

While this thesis has analyzed the ban from a financial perspective, there are still uncertainties about how the details of the policy. One of the most critical points of this ban that needs to be clarified is whether the government is planning to ban the usage and production of single-use plastics, or the ban includes importation as well. This is an important question to be answered since the target (which is protecting the environment and reducing plastics pollution) will not be achieved if the demand for plastics will be supplied through importation after policy implementation. Moreover, studies on actual life cycle and environmental impacts of possible alternative materials are required to realize the trade-offs and find out if alternative materials ae actually less harmful for them

environment. Such studies are necessary because in some cases, decision cannot be made easily through limited analyses. For instance, for aluminum, which is highly recyclable but at the same time, energy intensive, a broad analysis is required to decide whether the benefits outweigh the drawbacks or not.

5-2- Recommendations

The proposed CBA model can be extended in various ways. In this section, some recommendations and future work have been suggested.

- Factory closure has impacts on the economy, social health, and manufacturers. The government should strive to find a solution to keep affected businesses in the market to prevent any detrimental consequences. A proper job transition plan could prevent unemployment and its further consequences. It can help employees keep their jobs and decreases the impact of the disruptions. In this study, given that those seven companies with negative overall benefits are small or micro businesses, the number of job losses will not be a serious issue if they close the factory; however, having a plan could help controlling and minimizing any potential negative impact of the disruption.

- During the COVID-19 outbreak, the Government of Canada supported businesses through various financial programs, such as the New Canada Emergency Rent Subsidy (CERS) or Canada Emergency Business Account (CEBA) (Government of Canada, 2020). In order to mitigate the implications of this policy disruption on manufacturers, interest-free or low-interest loans with principal postponements to cover up their income losses seems a good support for companies to cover their

costs until they achieve the expected ROI. Similar relief programs and policies for those businesses that have faced a dramatic drop in their revenues due to the SUPs bans could help manufacturers transition from conventional plastics to alternative materials more conveniently, maintain their income, and stay in the market.

- Canada Revenue Agency or relevant authorities could disregard the half-year rule for affected single-use plastics manufacturers and help them benefit the entire CCA since the base year. This way, they could have the opportunity to increase their benefit and compensate a portion of the capital costs of the base year.

- Instead of strict bans and restrictions, the government can focus on behavioral changes and improve consumption habits to reduce plastics consumption which is a principle of a circular economy. Cultural and behavioral changes require some time; thus actions should be started prior to the implementation of the ban. This is more crucial for products that are more challenging to replace. While substituting plastics bags is not challenging, it may take more time for consumer to get accustomed to replacing products such as plastics bottle. In addition, the government can expand the existing levies on plastic bags into other products such as individual plastics bottles too.

5-3- Future Research

- Further studies on more single-use plastics companies and alternative industries are needed to be conducted by the government to investigate the impacts of material substitution on all involved industries within Canada. The importance of such studies is due to the fact that the plastics industry plays an important role in the

economy of Canada. In 2018, Ontario plastics product manufacturing contributed to approximately 5.6% of the total GDP of manufacturing sector in the province (Statistics Canada, 2020). In order to maintain economic stability, the government and involved parties should assure that the amount of lost revenue in plastics industry as a result of SUP phaseout will be replaced by alternative industries and the demand for alternative products can be supplied.

- One of the limitations of this research is that it evaluates the *economic* implications of the ban on *139 manufacturers*. Future research could work towards including missing companies and expanding the database of this study to all single-use plastics manufacturers in Ontario (or even Canada) and add environmental factors in the CBA model.

- In this study, only one alternative material is attributed to each product based on availability, cost, viability, and function. For future studies, multiple materials could be assessed to find a sustainable alternative option for each product. It is more effective if materials are evaluated from different perspectives (i.e., considering environmental, economic, and social factors).

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APPENDICES

Appendix A: Single-use Plastics Manufacturers

Company Number	Poly bag	Retail bag	Zipper bag	Laminated Pouch	Mail bag	Shrink film	Garbage bag	Wicket	Snack web	Stretch film	Roll stock	Flexible Food	Cup	Dinnerware	Cutlery	Straw	Stirrer Stick	PS Container	Bottle/ Jar	Tray	Blister Packaging	Clamshell Packaging	Semi-rigid Container	PP Container	Cans and Closures	Foam Sheet	Glass	Paper bag	Corrugated box	Detergent Bottle	Label	Tissue	Protecting	Sign	Tape	Display	Custom Molding	Paper Container	Garment Products
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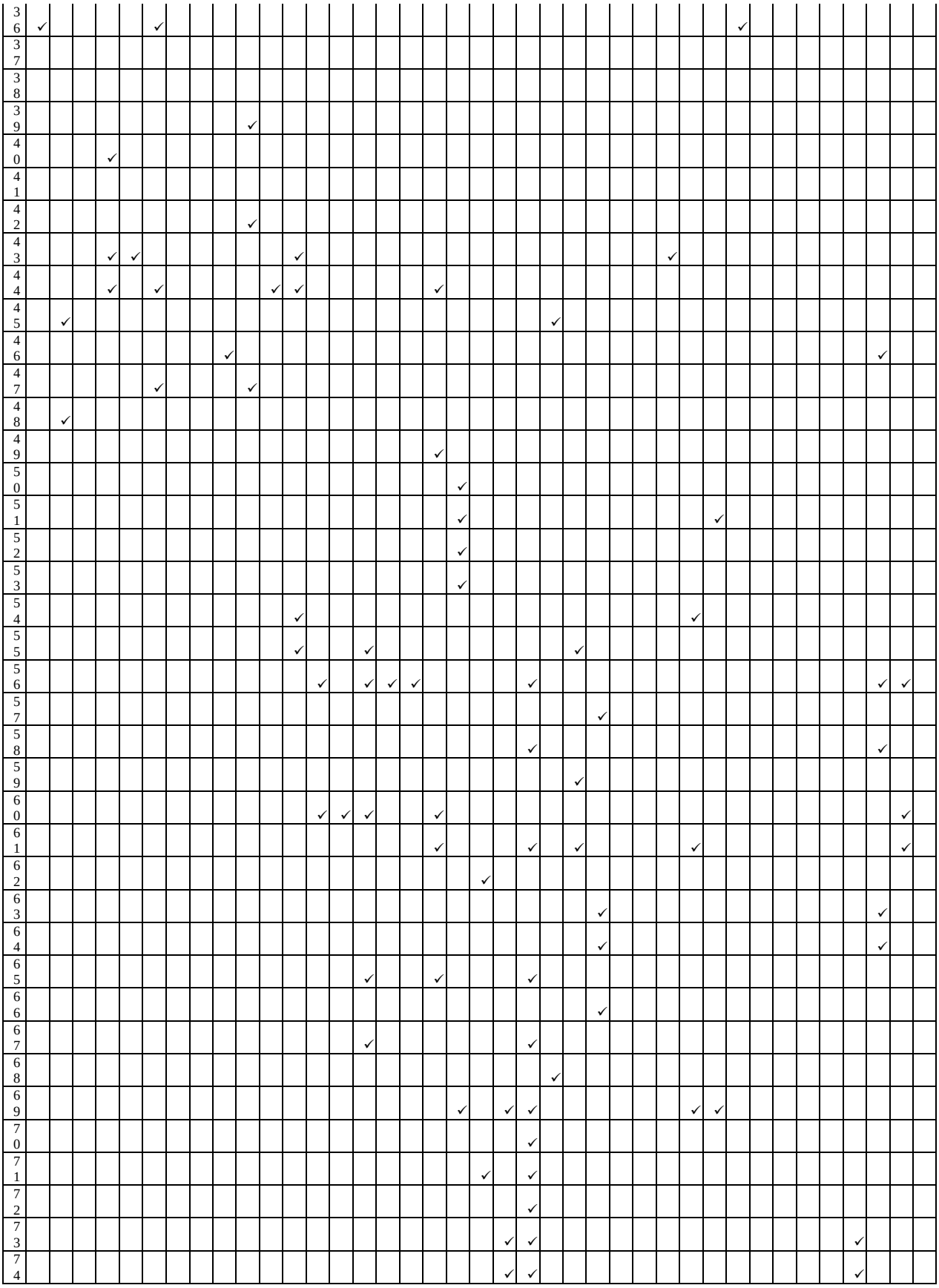

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Appendix A. Single-use Plastics Manufacturers

Appendix B: Revenue Growth Rate Sensitivity Analysis

Appendices B to F show the results of sensitivity analyses in more details for each company. The first column is the number of companies. The second column shows the overall benefit of the initial model. The rest show the NPV of overall benefits for companies when the parameters change. The green cells indicate that the results have changed due to the changes in parameters. For example, the overall benefit of company #18 would turn positive, if the revenues grow at a rate of 10%.

Number	Initial Total Benefit	Revenue Growth Rate		
		2%	5%	10%
1	$ 460,509.88	$503,072.68	$ 569,053.63	$ 684,859.88
2	$ 7,359,703.92	$ 7,639,402.32	$ 8,072,991.42	$ 8,834,003.92
3	$ 110,454,933.49	$ 113,859,957.49	$ 119,138,433.49	$ 128,402,933.49
4	$ 23,222,255.82	$ 23,931,635.82	$ 25,031,318.32	$ 26,961,422.48
5	$ 15,073,618.55	$ 15,594,795.69	$ 16,402,725.69	$ 17,820,761.40
6	$ 1,096,894.19	$ 1,157,698.19	$ 1,251,956.69	$ 1,417,394.19
7	$ 5,566,689.27	$ 5,749,101.27	$ 6,031,876.77	$ 6,528,189.27
8	$ 39,650,831.63	$ 40,866,911.63	$ 42,752,081.63	$ 46,060,831.63
9	$ 31,516,109.38	$ 32,488,973.38	$ 33,997,109.38	$ 36,644,109.38
10	$ 12,760,488.34	$ 13,198,277.14	$ 13,876,938.34	$ 15,068,088.34
11	$ 91,217,520.90	$ 94,014,504.90	$ 98,350,395.90	$ 105,960,520.90
12	$ 4,249,835.35	$ 4,407,925.75	$ 4,652,997.85	$ 5,083,135.35
13	$ 19,851,093.47	$ 20,489,535.47	$ 21,479,249.72	$ 23,216,343.47
14	$ (617,702.82)	$ (603,804.76)	$ (582,259.96)	$ (544,445.68)
15	$ 4,059,571.67	$ 4,211,581.67	$ 4,447,227.92	$ 4,860,821.67
16	$ 31,650,831.63	$ 32,623,695.63	$ 34,131,831.63	$ 36,778,831.63
17	$ 10,639,245.76	$ 11,004,069.76	$ 11,569,620.76	$ 12,562,245.76
18	$ (101,666.12)	$ (74,304.32)	$ (31,888.00)	$ 42,558.88
19	$ 14,550,727.87	$ 15,006,757.87	$ 15,713,696.62	$ 16,954,477.87
20	$ 1,650,831.63	$ 1,711,635.63	$ 1,805,894.13	$ 1,971,331.63
21	$ 3,589,198.11	$ 3,735,127.71	$ 3,961,348.11	$ 4,358,398.11
22	$ 7,114,889.61	$ 7,358,105.61	$ 7,735,139.61	$ 8,396,889.61
23	$ 67,138,366.48	$ 69,205,702.48	$ 72,410,491.48	$ 78,035,366.48
24	$ 4,450,831.63	$ 4,596,761.23	$ 4,822,981.63	$ 5,220,031.63
25	$ 7,170,767.17	$ 7,389,661.57	$ 7,728,992.17	$ 8,324,567.17
26	$ 21,220,644.33	$ 21,869,220.33	$ 22,874,644.33	$ 24,639,311.00
27	$ 27,631,111.06	$ 28,482,367.06	$ 29,801,986.06	$ 32,118,111.06
28	$ (160,439.46)	$ (136,117.86)	$ (98,414.46)	$ (32,239.46)
29	$ 13,977,257.72	$ 14,427,207.32	$ 15,124,720.22	$ 16,348,957.72
30	$ 17,715,544.42	$ 18,299,262.82	$ 19,204,144.42	$ 20,792,344.42
31	$ 1,545,953.13	$ 1,606,757.13	$ 1,701,015.63	$ 1,866,453.13
32	$ 22,645,221.01	$ 23,374,869.01	$ 24,505,971.01	$ 26,491,221.01
33	$ 3,437,433.84	$ 3,542,827.44	$ 3,706,208.84	$ 3,992,967.17

34	$ 5,456,158.33	$ 5,638,570.33	$ 5,921,345.83	$ 6,417,658.33
35	$ 26,821,256.99	$ 27,672,512.99	$ 28,992,131.99	$ 31,308,256.99
36	$ 3,729,470.23	$ 3,855,942.55	$ 4,052,000.23	$ 4,396,110.23
37	$ 790,487.75	$ 814,809.35	$ 852,512.75	$ 918,687.75
38	$ 6,990,487.75	$ 7,203,301.75	$ 7,533,206.50	$ 8,112,237.75
39	$ 91,980,279.42	$ 94,777,263.42	$ 99,113,154.42	$ 106,723,279.42
40	$ 239,620,080.70	$ 246,916,560.70	$ 258,227,580.70	$ 278,080,080.70
41	$ 13,990,487.75	$ 14,416,115.75	$ 15,075,925.25	$ 16,233,987.75
42	$ 34,980,279.42	$ 36,044,349.42	$ 37,693,873.17	$ 40,589,029.42
43	$ 34,967,308.46	$ 36,061,780.46	$ 37,758,433.46	$ 40,736,308.46
44	$ 55,099,813.02	$ 56,802,325.02	$ 59,441,563.02	$ 64,073,813.02
45	$ 19,908,290.88	$ 20,516,330.88	$ 21,458,915.88	$ 23,113,290.88
46	$ 151,693.15	$ 171,961.15	$ 203,380.65	$ 258,526.48
47	$ 4,770,767.17	$ 4,916,696.77	$ 5,142,917.17	$ 5,539,967.17
48	$ 7,938,695.70	$ 8,181,911.70	$ 8,558,945.70	$ 9,220,695.70
49	$ 9,064,315.33	$ 9,344,013.73	$ 9,777,602.83	$ 10,538,615.33
50	$ 8,294,975.25	$ 8,696,281.65	$ 9,318,387.75	$ 10,410,275.25
51	$ 14,339,516.51	$ 14,795,546.51	$ 15,502,485.26	$ 16,743,266.51
52	$ 294,975.25	$ 453,065.65	$ 698,137.75	$ 1,128,275.25
53	$ 7,094,975.25	$ 7,459,799.25	$ 8,025,350.25	$ 9,017,975.25
54	$ 12,367,066.83	$ 12,744,051.63	$ 13,328,454.33	$ 14,354,166.83
55	$ 12,114,342.75	$ 12,503,488.35	$ 13,106,742.75	$ 14,165,542.75
56	$ 147,700,392.56	$ 152,217,261.13	$ 159,219,321.13	$ 171,508,963.99
57	$ 63,772,535.77	$ 65,718,263.77	$ 68,734,535.77	$ 74,028,535.77
58	$ 960,927.83	$ 991,329.83	$ 1,038,459.08	$ 1,121,177.83
59	$ 63,585,584.72	$ 65,519,151.92	$ 68,516,572.22	$ 73,777,484.72
60	$ 27,163,738.38	$ 28,014,994.38	$ 29,334,613.38	$ 31,650,738.38
61	$ 89,810,827.88	$ 92,547,007.88	$ 96,788,640.38	$ 104,233,327.88
62	$ 9,160,927.83	$ 9,440,626.23	$ 9,874,215.33	$ 10,635,227.83
63	$ 5,673,695.67	$ 5,856,107.67	$ 6,138,883.17	$ 6,635,195.67
64	$ 5,673,695.67	$ 5,856,107.67	$ 6,138,883.17	$ 6,635,195.67
65	$ 67,172,747.93	$ 69,240,083.93	$ 72,444,872.93	$ 78,069,747.93
66	$ 19,673,695.67	$ 20,281,735.67	$ 21,224,320.67	$ 22,878,695.67
67	$ 67,308,432.60	$ 69,375,768.60	$ 72,580,557.60	$ 78,205,432.60
68	$ 299,976,575.17	$ 309,097,175.17	$ 323,235,950.17	$ 348,051,575.17
69	$ 5,273,266.47	$ 5,455,678.47	$ 5,738,453.97	$ 6,234,766.47
70	$ 4,760,927.83	$ 4,906,857.43	$ 5,133,077.83	$ 5,530,127.83
71	$ 4,760,927.83	$ 4,906,857.43	$ 5,133,077.83	$ 5,530,127.83
72	$ 3,960,927.83	$ 4,082,535.83	$ 4,271,052.83	$ 4,601,927.83
73	$ 3,667,083.30	$ 3,780,584.10	$ 3,956,533.30	$ 4,265,349.97
74	$ 6,067,083.30	$ 6,253,548.90	$ 6,542,608.30	$ 7,049,949.97
75	$ 26,639,488.81	$ 27,450,208.81	$ 28,706,988.81	$ 30,912,822.14
76	$ 43,307,960.85	$ 44,645,648.85	$ 46,719,335.85	$ 50,358,960.85
77	$ 47,517,794.70	$ 48,977,090.70	$ 51,239,294.70	$ 55,209,794.70
78	$ 32,668,536.64	$ 33,710,890.93	$ 35,326,750.93	$ 38,162,822.36

79	$ 28,758,447.18	$ 29,670,507.18	$ 31,084,384.68	$ 33,565,947.18
80	$ 67,514,035.52	$ 69,581,371.52	$ 72,786,160.52	$ 78,411,035.52
81	$ 40,700,816.79	$ 41,941,218.39	$ 43,864,091.79	$ 47,239,016.79
82	$ 3,064,763.40	$ 3,186,371.40	$ 3,374,888.40	$ 3,705,763.40
83	$ 33,953,836.79	$ 35,011,826.39	$ 36,651,924.29	$ 39,530,536.79
84	$ 42,855,518.72	$ 44,172,938.72	$ 46,215,206.22	$ 49,799,685.39
85	$ 1,294,205.21	$ 1,334,741.21	$ 1,397,580.21	$ 1,507,871.87
86	$ 39,390,291.98	$ 40,606,371.98	$ 42,491,541.98	$ 45,800,291.98
87	$ (404,822.98)	$ (331,858.18)	$ (218,747.98)	$ (20,222.98)
88	$ 4,008,010.18	$ 4,164,363.32	$ 4,406,742.32	$ 4,832,153.03
89	$ 139,145,540.70	$ 143,401,820.70	$ 149,999,915.70	$ 161,580,540.70
90	$ 7,815,486.55	$ 8,099,238.55	$ 8,539,111.55	$ 9,311,153.21
91	$ (271,681.03)	$ (240,062.95)	$ (191,048.53)	$ (105,021.03)
92	$ 30,638,998.98	$ 31,611,862.98	$ 33,119,998.98	$ 35,766,998.98
93	$ 9,893,712.56	$ 10,258,536.56	$ 10,824,087.56	$ 11,816,712.56
94	$ 3,924,221.73	$ 4,045,829.73	$ 4,234,346.73	$ 4,565,221.73
95	$ 921,640.66	$ 989,741.14	$ 1,095,310.66	$ 1,280,600.66
96	$ 62,717,777.27	$ 64,663,505.27	$ 67,679,777.27	$ 72,973,777.27
97	$ 33,889,772.99	$ 34,923,440.99	$ 36,525,835.49	$ 39,338,272.99
98	$ 6,557,404.02	$ 6,776,298.42	$ 7,115,629.02	$ 7,711,204.02
99	$ (448,816.87)	$ (417,546.25)	$ (369,070.45)	$ (283,988.30)
100	$ 18,713,481.93	$ 19,321,521.93	$ 20,264,106.93	$ 21,918,481.93
101	$ 93,002,937.63	$ 95,840,457.63	$ 100,239,187.63	$ 107,959,604.30
102	$ 11,810,221.24	$ 12,175,045.24	$ 12,740,596.24	$ 13,733,221.24
103	$ 14,521,704.49	$ 14,991,922.09	$ 15,720,854.49	$ 17,000,237.82
104	$ 78,848,550.96	$ 81,302,821.50	$ 85,107,437.32	$ 91,785,096.41
105	$ 8,222,676.43	$ 8,520,616.03	$ 8,982,482.68	$ 9,793,126.43
106	$ 9,709,983.33	$ 10,064,673.33	$ 10,614,514.58	$ 11,579,566.66
107	$ 1,486,251.04	$ 1,583,537.44	$ 1,734,351.04	$ 1,999,051.04
108	$ 27,921,316.55	$ 28,824,690.26	$ 30,225,102.26	$ 32,683,030.83
109	$ 46,926,031.96	$ 48,385,327.96	$ 50,647,531.96	$ 54,618,031.96
110	$ 15,233,043.03	$ 15,719,475.03	$ 16,473,543.03	$ 17,797,043.03
111	$ 25,941,207.25	$ 26,731,659.25	$ 27,957,019.75	$ 30,107,707.25
112	$ 110,285,376.77	$ 113,690,400.77	$ 118,968,876.77	$ 128,233,376.77
113	$ 18,848,136.47	$ 19,456,176.47	$ 20,398,761.47	$ 22,053,136.47
114	$ 78,604,844.20	$ 81,037,004.20	$ 84,807,344.20	$ 91,424,844.20
115	$ 181,242,114.09	$ 186,808,018.71	$ 195,436,296.78	$ 210,580,191.01
116	$ 6,461,517.22	$ 6,680,411.62	$ 7,019,742.22	$ 7,615,317.22
117	$ 28,194,898.91	$ 29,086,690.91	$ 30,469,148.91	$ 32,895,565.58
118	$ 64,217,353.33	$ 66,171,767.62	$ 69,201,505.12	$ 74,519,139.05
119	$ 35,136,740.60	$ 36,231,212.60	$ 37,927,865.60	$ 40,905,740.60
120	$ 185,371,621.78	$ 191,046,661.78	$ 199,844,121.78	$ 215,284,955.11
121	$ 3,952,651.55	$ 4,074,259.55	$ 4,262,776.55	$ 4,593,651.55
122	$ 13,617,970.76	$ 14,035,694.24	$ 14,683,250.14	$ 15,819,805.76
123	$ 7,225,688.81	$ 7,468,904.81	$ 7,845,938.81	$ 8,507,688.81

124	$ (115,790.05)	$ (91,468.45)	$ (53,765.05)	$ 12,409.95
125	$ 23,963,309.89	$ 24,692,957.89	$ 25,824,059.89	$ 27,809,309.89
126	$ 15,963,309.89	$ 16,449,741.89	$ 17,203,809.89	$ 18,527,309.89
127	$ 85,992,902.83	$ 88,619,635.63	$ 92,691,602.83	$ 99,838,502.83
128	$ 7,135,078.26	$ 7,400,404.81	$ 7,811,714.63	$ 8,533,623.72
129	$ 1,967,066.83	$ 2,027,870.83	$ 2,122,129.33	$ 2,287,566.83
130	$ 17,923,869.38	$ 18,471,105.38	$ 19,319,431.88	$ 20,808,369.38
131	$ 14,288,592.48	$ 14,744,622.48	$ 15,451,561.23	$ 16,692,342.48
132	$ 7,905,378.84	$ 8,148,594.84	$ 8,525,628.84	$ 9,187,378.84
133	$ 17,656,526.95	$ 18,224,030.95	$ 19,103,776.95	$ 20,647,860.28
134	$ 2,542,275.15	$ 2,663,883.15	$ 2,852,400.15	$ 3,183,275.15
135	$ 1,267,083.30	$ 1,307,619.30	$ 1,370,458.30	$ 1,480,749.97
136	$ 11,133,749.97	$ 11,474,252.37	$ 12,002,099.97	$ 12,928,549.97
137	$ 4,733,749.97	$ 4,879,679.57	$ 5,105,899.97	$ 5,502,949.97
138	$ 15,894,677.80	$ 16,381,109.80	$ 17,135,177.80	$ 18,458,677.80
139	$ 4,652,251.39	$ 4,794,127.39	$ 5,014,063.89	$ 5,400,084.72

Appendix B. Revenue Growth Rate Sensitivity Analysis

Appendix C: Cost Growth Rate Sensitivity Analysis

This table shows the results of NPV of overall benefits when costs grow at rates of 2%, 5%, and 10%.

Number	Initial Total Benefit	Cost Growth Rates		
		0.02	0.05	0.1
1	$ 460,509.88	$ 431,177.29	$ 386,918.71	$ 312,461.93
2	$ 7,359,703.92	$ 7,294,812.09	$ 7,196,797.93	$ 7,031,637.19
3	$ 110,454,933.49	$ 110,403,928.52	$ 110,326,890.57	$ 110,197,079.39
4	$ 23,222,255.82	$ 23,218,538.62	$ 23,212,852.85	$ 23,203,083.29
5	$ 15,073,618.55	$ 15,005,241.42	$ 14,901,859.23	$ 14,727,378.20
6	$ 1,096,894.19	$ 1,068,272.95	$ 1,024,953.89	$ 951,722.90
7	$ 5,566,689.27	$ 5,552,357.79	$ 5,530,664.50	$ 5,493,986.15
8	$ 39,650,831.63	$ 39,639,146.74	$ 39,621,273.71	$ 39,590,563.46
9	$ 31,516,109.38	$ 31,499,916.02	$ 31,475,146.91	$ 31,432,587.49
10	$ 12,760,488.34	$ 12,704,613.49	$ 12,619,923.61	$ 12,476,433.51
11	$ 91,217,520.90	$ 91,191,504.54	$ 91,151,938.21	$ 91,084,549.62
12	$ 4,249,835.35	$ 4,218,303.83	$ 4,170,448.98	$ 4,089,204.03
13	$ 19,851,093.47	$ 19,811,664.53	$ 19,751,855.39	$ 19,650,398.17
14	$ (617,702.82)	$ (653,096.03)	$ (706,727.62)	$ (797,558.33)
15	$ 4,059,571.67	$ 4,028,063.08	$ 3,980,412.99	$ 3,899,963.62
16	$ 31,650,831.63	$ 31,639,146.74	$ 31,621,273.71	$ 31,590,563.46
17	$ 10,639,245.76	$ 10,592,892.36	$ 10,523,061.09	$ 10,405,872.45
18	$ (101,666.12)	$ (132,573.19)	$ (179,091.48)	$ (257,042.50)
19	$ 14,550,727.87	$ 14,535,862.25	$ 14,513,351.93	$ 14,475,269.74
20	$ 1,650,831.63	$ 1,639,146.74	$ 1,621,273.71	$ 1,590,563.46
21	$ 3,589,198.11	$ 3,549,017.19	$ 3,488,012.89	$ 3,384,384.65
22	$ 7,114,889.61	$ 7,085,607.91	$ 7,041,274.93	$ 6,966,292.09
23	$ 67,138,366.48	$ 67,109,870.44	$ 67,066,739.17	$ 66,993,821.18
24	$ 4,450,831.63	$ 4,439,146.74	$ 4,421,273.71	$ 4,390,563.46
25	$ 7,170,767.17	$ 7,169,788.90	$ 7,168,292.55	$ 7,165,721.44
26	$ 21,220,644.33	$ 21,216,873.20	$ 21,211,104.94	$ 21,201,193.66
27	$ 27,631,111.06	$ 27,618,766.22	$ 27,599,883.75	$ 27,567,439.02
28	$ (160,439.46)	$ (190,473.12)	$ (235,804.03)	$ (312,103.36)
29	$ 13,977,257.72	$ 13,950,159.60	$ 13,909,313.94	$ 13,840,708.55
30	$ 17,715,544.42	$ 17,665,152.02	$ 17,588,948.61	$ 17,460,303.46
31	$ 1,545,953.13	$ 1,531,559.05	$ 1,509,771.86	$ 1,472,937.01
32	$ 22,645,221.01	$ 22,600,487.56	$ 22,532,895.08	$ 22,418,928.14
33	$ 3,437,433.84	$ 3,436,455.57	$ 3,434,959.21	$ 3,432,388.11
34	$ 5,456,158.33	$ 5,438,224.37	$ 5,411,168.15	$ 5,365,660.35
35	$ 26,821,256.99	$ 26,779,578.82	$ 26,716,796.25	$ 26,611,451.13
36	$ 3,729,470.23	$ 3,715,190.54	$ 3,693,586.26	$ 3,657,086.46
37	$ 790,487.75	$ 790,169.42	$ 789,682.51	$ 788,845.89
38	$ 6,990,487.75	$ 6,990,169.42	$ 6,989,682.51	$ 6,988,845.89

39	$ 91,980,279.42	$ 91,979,619.48	$ 91,978,610.03	$ 91,976,875.56
40	$ 239,620,080.70	$ 239,607,632.39	$ 239,588,966.93	$ 239,557,876.51
41	$ 13,990,487.75	$ 13,990,169.42	$ 13,989,682.51	$ 13,988,845.89
42	$ 34,980,279.42	$ 34,979,619.48	$ 34,978,610.03	$ 34,976,875.56
43	$ 34,967,308.46	$ 34,933,280.84	$ 34,881,983.28	$ 34,795,804.34
44	$ 55,099,813.02	$ 55,068,226.99	$ 55,020,528.21	$ 54,940,177.67
45	$ 19,908,290.88	$ 19,905,221.85	$ 19,900,527.49	$ 19,892,461.44
46	$ 151,693.15	$ 135,865.62	$ 111,912.44	$ 71,425.49
47	$ 4,770,767.17	$ 4,769,788.90	$ 4,768,292.55	$ 4,765,721.44
48	$ 7,938,695.70	$ 7,936,644.16	$ 7,933,506.15	$ 7,928,114.28
49	$ 9,064,315.33	$ 9,059,774.65	$ 9,052,829.30	$ 9,040,895.49
50	$ 8,294,975.25	$ 8,132,458.50	$ 7,886,175.38	$ 7,469,015.49
51	$ 14,339,516.51	$ 14,317,832.21	$ 14,285,141.37	$ 14,230,218.28
52	$ 294,975.25	$ 132,458.50	$ (113,824.62)	$ (530,984.51)
53	$ 7,094,975.25	$ 6,932,458.50	$ 6,686,175.38	$ 6,269,015.49
54	$ 12,367,066.83	$ 12,365,964.72	$ 12,364,278.96	$ 12,361,382.40
55	$ 12,114,342.75	$ 12,090,414.98	$ 12,054,318.88	$ 11,993,613.50
56	$ 147,700,392.56	$ 147,671,830.06	$ 147,628,735.16	$ 147,556,240.56
57	$ 63,772,535.77	$ 63,765,101.13	$ 63,753,889.39	$ 63,735,043.73
58	$ 960,927.83	$ 959,620.28	$ 957,620.28	$ 954,183.78
59	$ 63,585,584.72	$ 63,585,102.31	$ 63,584,364.43	$ 63,583,096.57
60	$ 27,163,738.38	$ 27,134,703.01	$ 27,090,810.44	$ 27,016,750.78
61	$ 89,810,827.88	$ 89,804,497.25	$ 89,794,814.02	$ 89,778,175.84
62	$ 9,160,927.83	$ 9,159,620.28	$ 9,157,620.28	$ 9,154,183.78
63	$ 5,673,695.67	$ 5,664,284.23	$ 5,650,107.28	$ 5,626,319.62
64	$ 5,673,695.67	$ 5,664,284.23	$ 5,650,107.28	$ 5,626,319.62
65	$ 67,172,747.93	$ 67,144,014.06	$ 67,100,582.67	$ 67,027,315.42
66	$ 19,673,695.67	$ 19,664,284.23	$ 19,650,107.28	$ 19,626,319.62
67	$ 67,308,432.60	$ 67,284,239.41	$ 67,247,753.37	$ 67,186,419.93
68	$ 299,976,575.17	$ 299,975,791.26	$ 299,974,592.20	$ 299,972,531.93
69	$ 5,273,266.47	$ 5,249,365.13	$ 5,213,283.12	$ 5,152,533.17
70	$ 4,760,927.83	$ 4,759,620.28	$ 4,757,620.28	$ 4,754,183.78
71	$ 4,760,927.83	$ 4,759,620.28	$ 4,757,620.28	$ 4,754,183.78
72	$ 3,960,927.83	$ 3,959,620.28	$ 3,957,620.28	$ 3,954,183.78
73	$ 3,667,083.30	$ 3,664,866.25	$ 3,661,475.08	$ 3,655,648.22
74	$ 6,067,083.30	$ 6,064,866.25	$ 6,061,475.08	$ 6,055,648.22
75	$ 26,639,488.81	$ 26,638,579.30	$ 26,637,188.14	$ 26,634,797.77
76	$ 43,307,960.85	$ 43,285,236.70	$ 43,251,081.39	$ 43,193,971.68
77	$ 47,517,794.70	$ 47,501,826.97	$ 47,477,630.89	$ 47,436,652.14
78	$ 32,668,536.64	$ 32,615,367.97	$ 32,535,269.69	$ 32,400,851.82
79	$ 28,758,447.18	$ 28,717,502.83	$ 28,655,706.10	$ 28,551,697.70
80	$ 67,514,035.52	$ 67,497,941.99	$ 67,473,553.49	$ 67,432,244.11
81	$ 40,700,816.79	$ 40,697,497.64	$ 40,692,420.70	$ 40,683,697.29
82	$ 3,064,763.40	$ 3,033,804.24	$ 2,986,905.42	$ 2,907,513.85
83	$ 33,953,836.79	$ 33,925,954.90	$ 33,883,910.38	$ 33,813,245.07

84	$ 42,855,518.72	$ 42,839,528.70	$ 42,815,070.60	$ 42,773,045.58
85	$ 1,294,205.21	$ 1,292,895.79	$ 1,290,892.92	$ 1,287,451.50
86	$ 39,390,291.98	$ 39,370,153.82	$ 39,339,726.06	$ 39,288,425.15
87	$ (404,822.98)	$ (499,797.29)	$ (643,221.96)	$ (884,831.63)
88	$ 4,008,010.18	$ 3,969,683.34	$ 3,911,848.42	$ 3,814,537.82
89	$ 139,145,540.70	$ 139,115,768.33	$ 139,070,776.49	$ 138,994,901.31
90	$ 7,815,486.55	$ 7,765,561.70	$ 7,690,403.83	$ 7,564,419.13
91	$ (271,681.03)	$ (309,397.88)	$ (366,301.99)	$ (462,019.07)
92	$ 30,638,998.98	$ 30,593,548.28	$ 30,524,979.48	$ 30,409,650.77
93	$ 9,893,712.56	$ 9,824,095.60	$ 9,718,816.97	$ 9,541,077.41
94	$ 3,924,221.73	$ 3,921,685.82	$ 3,917,806.92	$ 3,911,142.03
95	$ 921,640.66	$ 878,222.42	$ 812,789.03	$ 702,917.32
96	$ 62,717,777.27	$ 62,675,471.90	$ 62,611,593.39	$ 62,504,007.96
97	$ 33,889,772.99	$ 33,886,084.25	$ 33,880,442.02	$ 33,870,747.27
98	$ 6,557,404.02	$ 6,535,492.18	$ 6,502,511.13	$ 6,447,240.59
99	$ (448,816.87)	$ (496,158.22)	$ (567,952.84)	$ (689,697.43)
100	$ 18,713,481.93	$ 18,671,638.27	$ 18,608,492.59	$ 18,502,235.92
101	$ 93,002,937.63	$ 92,992,146.62	$ 92,976,016.15	$ 92,949,281.46
102	$ 11,810,221.24	$ 11,803,870.32	$ 11,794,156.03	$ 11,777,464.50
103	$ 14,521,704.49	$ 14,492,075.13	$ 14,447,426.24	$ 14,372,465.09
104	$ 78,848,550.96	$ 78,785,587.54	$ 78,690,448.55	$ 78,530,033.21
105	$ 8,222,676.43	$ 8,170,634.79	$ 8,091,833.13	$ 7,958,525.79
106	$ 9,709,983.33	$ 9,644,479.60	$ 9,545,268.43	$ 9,377,368.33
107	$ 1,486,251.04	$ 1,429,770.34	$ 1,344,584.75	$ 1,201,369.95
108	$ 27,921,316.55	$ 27,861,426.86	$ 27,771,247.06	$ 27,620,026.66
109	$ 46,926,031.96	$ 46,890,526.60	$ 46,836,821.34	$ 46,746,120.01
110	$ 15,233,043.03	$ 15,206,492.43	$ 15,166,529.16	$ 15,099,557.41
111	$ 25,941,207.25	$ 25,939,239.76	$ 25,936,230.31	$ 25,931,059.34
112	$ 110,285,376.77	$ 110,227,500.59	$ 110,140,236.53	$ 109,993,596.98
113	$ 18,848,136.47	$ 18,809,365.15	$ 18,750,990.96	$ 18,653,121.41
114	$ 78,604,844.20	$ 78,557,848.59	$ 78,486,914.22	$ 78,367,514.40
115	$ 181,242,114.09	$ 181,178,731.08	$ 181,082,960.13	$ 180,921,484.72
116	$ 6,461,517.22	$ 6,435,708.54	$ 6,396,759.92	$ 6,331,217.26
117	$ 28,194,898.91	$ 28,155,869.96	$ 28,096,831.12	$ 27,997,111.95
118	$ 64,217,353.33	$ 64,215,065.64	$ 64,211,566.42	$ 64,205,553.90
119	$ 35,136,740.60	$ 35,106,967.25	$ 35,062,074.51	$ 34,986,632.71
120	$ 185,371,621.78	$ 185,329,145.02	$ 185,265,185.82	$ 185,157,936.30
121	$ 3,952,651.55	$ 3,951,067.04	$ 3,948,643.39	$ 3,944,478.97
122	$ 13,617,970.76	$ 13,613,887.07	$ 13,607,640.71	$ 13,596,907.92
123	$ 7,225,688.81	$ 7,198,681.13	$ 7,157,898.55	$ 7,089,204.68
124	$ (115,790.05)	$ (145,376.56)	$ (189,950.29)	$ (264,757.10)
125	$ 23,963,309.89	$ 23,962,082.06	$ 23,960,203.98	$ 23,956,976.99
126	$ 15,963,309.89	$ 15,962,082.06	$ 15,960,203.98	$ 15,956,976.99
127	$ 85,992,902.83	$ 85,979,545.02	$ 85,959,488.40	$ 85,926,007.62
128	$ 7,135,078.26	$ 7,080,407.31	$ 6,997,819.18	$ 6,858,621.07

129	$ 1,967,066.83	$ 1,965,964.72	$ 1,964,278.96	$ 1,961,382.40
130	$ 17,923,869.38	$ 17,921,321.67	$ 17,917,424.74	$ 17,910,728.86
131	$ 14,288,592.48	$ 14,263,786.31	$ 14,226,518.46	$ 14,164,249.15
132	$ 7,905,378.84	$ 7,902,212.35	$ 7,897,368.94	$ 7,889,046.76
133	$ 17,656,526.95	$ 17,624,964.17	$ 17,577,395.83	$ 17,497,517.48
134	$ 2,542,275.15	$ 2,494,460.62	$ 2,422,335.93	$ 2,301,053.73
135	$ 1,267,083.30	$ 1,264,866.25	$ 1,261,475.08	$ 1,255,648.22
136	$ 11,133,749.97	$ 11,131,532.92	$ 11,128,141.75	$ 11,122,314.89
137	$ 4,733,749.97	$ 4,731,532.92	$ 4,728,141.75	$ 4,722,314.89
138	$ 15,894,677.80	$ 15,891,153.20	$ 15,885,762.02	$ 15,876,498.67
139	$ 4,652,251.39	$ 4,651,768.98	$ 4,651,031.10	$ 4,649,763.24

Appendix C. Cost Growth Rate Sensitivity Analysis

Appendix D: Discount Rate Sensitivity Analysis

The discount rate for the original model is 2%. Appendix D shows how the NPV of overall benefits would change when the discount rates increase to 5% and 10%.

Number	Initial Total Benefit (DR=2%)	Discount Rate	
		5%	10%
1	$ 460,509.88	$ 453,513.39	$ 443,269.87
2	$ 7,359,703.92	$ 7,346,391.00	$ 7,326,924.69
3	$ 110,454,933.49	$ 110,449,721.68	$ 110,442,137.39
4	$ 23,222,255.82	$ 23,228,442.95	$ 23,237,548.13
5	$ 15,073,618.55	$ 15,076,342.75	$ 15,080,457.28
6	$ 1,096,894.19	$ 1,102,366.26	$ 1,110,458.95
7	$ 5,566,689.27	$ 5,569,564.22	$ 5,573,815.00
8	$ 39,650,831.63	$ 39,670,280.67	$ 39,698,902.50
9	$ 31,516,109.38	$ 31,543,062.58	$ 31,582,727.78
10	$ 12,760,488.34	$ 12,779,538.77	$ 12,807,648.04
11	$ 91,217,520.90	$ 91,239,844.89	$ 91,272,717.50
12	$ 4,249,835.35	$ 4,267,754.14	$ 4,294,156.86
13	$ 19,851,093.47	$ 19,868,429.63	$ 19,893,991.19
14	$ (617,702.82)	$ (607,340.99)	$ (592,043.07)
15	$ 4,059,571.67	$ 4,061,136.24	$ 4,063,488.08
16	$ 31,650,831.63	$ 31,670,280.67	$ 31,698,902.50
17	$ 10,639,245.76	$ 10,615,278.22	$ 10,580,106.71
18	$ (101,666.12)	$ (119,694.55)	$ (146,160.08)
19	$ 14,550,727.87	$ 14,554,491.89	$ 14,560,051.05
20	$ 1,650,831.63	$ 1,670,280.67	$ 1,698,902.50
21	$ 3,589,198.11	$ 3,614,119.21	$ 3,650,833.73
22	$ 7,114,889.61	$ 7,121,669.36	$ 7,131,686.48
23	$ 67,138,366.48	$ 67,143,838.55	$ 67,151,931.24
24	$ 4,450,831.63	$ 4,470,280.67	$ 4,498,902.50
25	$ 7,170,767.17	$ 7,172,395.47	$ 7,174,791.73
26	$ 21,220,644.33	$ 21,226,921.22	$ 21,236,158.50
27	$ 27,631,111.06	$ 27,651,658.55	$ 27,681,896.90
28	$ (160,439.46)	$ (166,269.05)	$ (174,795.31)
29	$ 13,977,257.72	$ 13,966,818.05	$ 13,951,507.46
30	$ 17,715,544.42	$ 17,716,564.65	$ 17,718,148.01
31	$ 1,545,953.13	$ 1,548,828.08	$ 1,553,078.86
32	$ 22,645,221.01	$ 22,643,155.43	$ 22,640,188.33
33	$ 3,437,433.84	$ 3,439,062.14	$ 3,441,458.39
34	$ 5,456,158.33	$ 5,451,444.52	$ 5,444,540.36
35	$ 26,821,256.99	$ 26,796,759.38	$ 26,760,804.16
36	$ 3,729,470.23	$ 3,731,278.86	$ 3,733,961.45
37	$ 790,487.75	$ 791,017.59	$ 791,797.32
38	$ 6,990,487.75	$ 6,991,017.59	$ 6,991,797.32

39	$ 91,980,279.42	$ 91,981,377.88	$ 91,982,994.40
40	$ 239,620,080.70	$ 239,606,236.24	$ 239,585,895.13
41	$ 13,990,487.75	$ 13,991,017.59	$ 13,991,797.32
42	$ 34,980,279.42	$ 34,981,377.88	$ 34,982,994.40
43	$ 34,967,308.46	$ 34,954,817.73	$ 34,936,501.66
44	$ 55,099,813.02	$ 55,092,684.81	$ 55,082,256.01
45	$ 19,908,290.88	$ 19,913,399.18	$ 19,920,916.70
46	$ 151,693.15	$ 155,457.16	$ 161,016.32
47	$ 4,770,767.17	$ 4,772,395.47	$ 4,774,791.73
48	$ 7,938,695.70	$ 7,942,110.41	$ 7,947,135.61
49	$ 9,064,315.33	$ 9,071,873.10	$ 9,082,995.37
50	$ 8,294,975.25	$ 8,353,643.43	$ 8,440,182.68
51	$ 14,339,516.51	$ 14,331,795.93	$ 14,320,475.52
52	$ 294,975.25	$ 353,643.43	$ 440,182.68
53	$ 7,094,975.25	$ 7,153,643.43	$ 7,240,182.68
54	$ 12,367,066.83	$ 12,368,901.24	$ 12,371,600.82
55	$ 12,114,342.75	$ 12,105,625.81	$ 12,092,847.05
56	$ 147,700,392.56	$ 147,693,509.06	$ 147,683,430.39
57	$ 63,772,535.77	$ 63,770,262.54	$ 63,766,930.95
58	$ 960,927.83	$ 963,104.19	$ 966,306.99
59	$ 63,585,584.72	$ 63,586,387.67	$ 63,587,569.31
60	$ 27,163,738.38	$ 27,161,916.54	$ 27,159,286.55
61	$ 89,810,827.88	$ 89,821,364.96	$ 89,836,871.67
62	$ 9,160,927.83	$ 9,163,104.19	$ 9,166,306.99
63	$ 5,673,695.67	$ 5,671,422.44	$ 5,668,090.85
64	$ 5,673,695.67	$ 5,671,422.44	$ 5,668,090.85
65	$ 67,172,747.93	$ 67,170,424.25	$ 67,167,055.73
66	$ 19,673,695.67	$ 19,671,422.44	$ 19,668,090.85
67	$ 67,308,432.60	$ 67,298,551.15	$ 67,284,060.36
68	$ 299,976,575.17	$ 299,977,879.96	$ 299,979,800.12
69	$ 5,273,266.47	$ 5,269,236.10	$ 5,263,346.29
70	$ 4,760,927.83	$ 4,763,104.19	$ 4,766,306.99
71	$ 4,760,927.83	$ 4,763,104.19	$ 4,766,306.99
72	$ 3,960,927.83	$ 3,963,104.19	$ 3,966,306.99
73	$ 3,667,083.30	$ 3,670,773.49	$ 3,676,204.10
74	$ 6,067,083.30	$ 6,070,773.49	$ 6,076,204.10
75	$ 26,639,488.81	$ 26,641,002.64	$ 26,643,230.45
76	$ 43,307,960.85	$ 43,290,240.88	$ 43,264,216.36
77	$ 47,517,794.70	$ 47,523,393.13	$ 47,531,651.87
78	$ 32,668,536.64	$ 32,644,092.22	$ 32,608,226.11
79	$ 28,758,447.18	$ 28,750,074.79	$ 28,737,826.37
80	$ 67,514,035.52	$ 67,519,843.34	$ 67,528,410.22
81	$ 40,700,816.79	$ 40,706,341.40	$ 40,714,471.59
82	$ 3,064,763.40	$ 3,074,335.23	$ 3,088,461.27
83	$ 33,953,836.79	$ 33,944,701.70	$ 33,931,310.95

84	$ 42,855,518.72	$ 42,882,133.48	$ 42,921,300.63
85	$ 1,294,205.21	$ 1,296,384.68	$ 1,299,592.07
86	$ 39,390,291.98	$ 39,389,247.00	$ 39,387,741.99
87	$ (404,822.98)	$ (420,746.18)	$ (444,008.10)
88	$ 4,008,010.18	$ 3,997,638.10	$ 3,982,446.88
89	$ 139,145,540.70	$ 139,142,123.81	$ 139,137,149.54
90	$ 7,815,486.55	$ 7,787,497.67	$ 7,746,413.82
91	$ (271,681.03)	$ (274,787.14)	$ (279,305.45)
92	$ 30,638,998.98	$ 30,626,039.14	$ 30,607,052.61
93	$ 9,893,712.56	$ 9,898,500.42	$ 9,905,651.90
94	$ 3,924,221.73	$ 3,928,442.66	$ 3,934,654.31
95	$ 921,640.66	$ 903,801.02	$ 877,633.23
96	$ 62,717,777.27	$ 62,711,670.23	$ 62,702,755.58
97	$ 33,889,772.99	$ 33,895,912.75	$ 33,904,948.21
98	$ 6,557,404.02	$ 6,543,327.20	$ 6,522,661.22
99	$ (448,816.87)	$ (426,824.10)	$ (394,405.02)
100	$ 18,713,481.93	$ 18,705,109.54	$ 18,692,861.12
101	$ 93,002,937.63	$ 92,986,334.66	$ 92,961,934.03
102	$ 11,810,221.24	$ 11,820,792.11	$ 11,836,348.55
103	$ 14,521,704.49	$ 14,511,624.05	$ 14,496,842.10
104	$ 78,848,550.96	$ 78,844,200.52	$ 78,837,904.20
105	$ 8,222,676.43	$ 8,235,863.60	$ 8,255,339.61
106	$ 9,709,983.33	$ 9,727,366.55	$ 9,753,037.08
107	$ 1,486,251.04	$ 1,469,174.11	$ 1,444,148.64
108	$ 27,921,316.55	$ 27,888,154.48	$ 27,839,480.51
109	$ 46,926,031.96	$ 46,929,585.83	$ 46,934,868.57
110	$ 15,233,043.03	$ 15,215,358.76	$ 15,189,396.05
111	$ 25,941,207.25	$ 25,944,482.07	$ 25,949,301.39
112	$ 110,285,376.77	$ 110,263,175.75	$ 110,230,620.00
113	$ 18,848,136.47	$ 18,825,597.18	$ 18,792,512.50
114	$ 78,604,844.20	$ 78,594,033.71	$ 78,578,211.59
115	$ 181,242,114.09	$ 181,234,472.33	$ 181,223,340.78
116	$ 6,461,517.22	$ 6,453,463.16	$ 6,441,662.58
117	$ 28,194,898.91	$ 28,196,870.84	$ 28,199,836.02
118	$ 64,217,353.33	$ 64,221,161.11	$ 64,226,764.75
119	$ 35,136,740.60	$ 35,124,420.47	$ 35,106,351.81
120	$ 185,371,621.78	$ 185,349,297.36	$ 185,316,532.04
121	$ 3,952,651.55	$ 3,955,288.90	$ 3,959,170.13
122	$ 13,617,970.76	$ 13,624,767.92	$ 13,634,770.83
123	$ 7,225,688.81	$ 7,219,630.43	$ 7,210,766.75
124	$ (115,790.05)	$ (131,480.87)	$ (154,507.03)
125	$ 23,963,309.89	$ 23,965,353.56	$ 23,968,361.11
126	$ 15,963,309.89	$ 15,965,353.56	$ 15,968,361.11
127	$ 85,992,902.83	$ 85,980,572.21	$ 85,962,458.91
128	$ 7,135,078.26	$ 7,127,235.93	$ 7,115,793.95

129	$ 1,967,066.83	$ 1,968,901.24	$ 1,971,600.82
130	$ 17,923,869.38	$ 17,928,109.93	$ 17,934,350.47
131	$ 14,288,592.48	$ 14,265,284.86	$ 14,231,049.56
132	$ 7,905,378.84	$ 7,910,649.33	$ 7,918,405.57
133	$ 17,656,526.95	$ 17,646,533.14	$ 17,631,881.13
134	$ 2,542,275.15	$ 2,529,092.49	$ 2,509,779.98
135	$ 1,267,083.30	$ 1,270,773.49	$ 1,276,204.10
136	$ 11,133,749.97	$ 11,137,440.16	$ 11,142,870.77
137	$ 4,733,749.97	$ 4,737,440.16	$ 4,742,870.77
138	$ 15,894,677.80	$ 15,900,544.35	$ 15,909,177.76
139	$ 4,652,251.39	$ 4,653,054.33	$ 4,654,235.97

Appendix D. Discount Rate Sensitivity Analysis

Appendix E: Revenue Sensitivity Analysis

The following table shows the results of revenue sensitivity. The second column is the results of the original model with found revenues. The next two columns show the NPV of overall benefits calculated with 50% and 75% of the found revenues, and the last column indicate how the overall benefits changes if the revenues were 20% more that the values that were found from used resources.

Number	Initial Total Benefit	Revenue Sensitivity		
		50%	75%	120%
1	$ 460,509.88	$ (239,490.12)	$ 110,509.88	$ 740,509.88
2	$ 7,359,703.92	$ 2,759,703.92	$ 5,059,703.92	$ 9,199,703.92
3	$ 110,454,933.49	$ 54,454,933.49	$ 82,454,933.49	$ 132,854,933.49
4	$ 23,222,255.82	$ 11,555,589.15	$ 17,388,922.48	$ 27,888,922.48
5	$ 15,073,618.55	$ 6,502,189.97	$ 10,787,904.26	$ 18,502,189.97
6	$ 1,096,894.19	$ 96,894.19	$ 596,894.19	$ 1,496,894.19
7	$ 5,566,689.27	$ 2,566,689.27	$ 4,066,689.27	$ 6,766,689.27
8	$ 39,650,831.63	$ 19,650,831.63	$ 29,650,831.63	$ 47,650,831.63
9	$ 31,516,109.38	$ 15,516,109.38	$ 23,516,109.38	$ 37,916,109.38
10	$ 12,760,488.34	$ 5,560,488.34	$ 9,160,488.34	$ 15,640,488.34
11	$ 91,217,520.90	$ 45,217,520.90	$ 68,217,520.90	$ 109,617,520.90
12	$ 4,249,835.35	$ 1,649,835.35	$ 2,949,835.35	$ 5,289,835.35
13	$ 19,851,093.47	$ 9,351,093.47	$ 14,601,093.47	$ 24,051,093.47
14	$ (617,702.82)	$ (846,274.25)	$ (731,988.54)	$ (526,274.25)
15	$ 4,059,571.67	$ 1,559,571.67	$ 2,809,571.67	$ 5,059,571.67
16	$ 31,650,831.63	$ 15,650,831.63	$ 23,650,831.63	$ 38,050,831.63
17	$ 10,639,245.76	$ 4,639,245.76	$ 7,639,245.76	$ 13,039,245.76
18	$ (101,666.12)	$ (551,666.12)	$ (326,666.12)	$ 78,333.88
19	$ 14,550,727.87	$ 7,050,727.87	$ 10,800,727.87	$ 17,550,727.87
20	$ 1,650,831.63	$ 650,831.63	$ 1,150,831.63	$ 2,050,831.63
21	$ 3,589,198.11	$ 1,189,198.11	$ 2,389,198.11	$ 4,549,198.11
22	$ 7,114,889.61	$ 3,114,889.61	$ 5,114,889.61	$ 8,714,889.61
23	$ 67,138,366.48	$ 33,138,366.48	$ 50,138,366.48	$ 80,738,366.48
24	$ 4,450,831.63	$ 2,050,831.63	$ 3,250,831.63	$ 5,410,831.63
25	$ 7,170,767.17	$ 3,570,767.17	$ 5,370,767.17	$ 8,610,767.17
26	$ 21,220,644.33	$ 10,553,977.66	$ 15,887,311.00	$ 25,487,311.00
27	$ 27,631,111.06	$ 13,631,111.06	$ 20,631,111.06	$ 33,231,111.06
28	$ (160,439.46)	$ (560,439.46)	$ (360,439.46)	$ (439.46)
29	$ 13,977,257.72	$ 6,577,257.72	$ 10,277,257.72	$ 16,937,257.72
30	$ 17,715,544.42	$ 8,115,544.42	$ 12,915,544.42	$ 21,555,544.42
31	$ 1,545,953.13	$ 545,953.13	$ 1,045,953.13	$ 1,945,953.13
32	$ 22,645,221.01	$ 10,645,221.01	$ 16,645,221.01	$ 27,445,221.01
33	$ 3,437,433.84	$ 1,704,100.51	$ 2,570,767.17	$ 4,130,767.17

34	$ 5,456,158.33	$ 2,456,158.33	$ 3,956,158.33	$ 6,656,158.33
35	$ 26,821,256.99	$ 12,821,256.99	$ 19,821,256.99	$ 32,421,256.99
36	$ 3,729,470.23	$ 1,649,470.23	$ 2,689,470.23	$ 4,561,470.23
37	$ 790,487.75	$ 390,487.75	$ 590,487.75	$ 950,487.75
38	$ 6,990,487.75	$ 3,490,487.75	$ 5,240,487.75	$ 8,390,487.75
39	$ 91,980,279.42	$ 45,980,279.42	$ 68,980,279.42	$ 110,380,279.42
40	$ 239,620,080.70	$ 119,620,080.70	$ 179,620,080.70	$ 287,620,080.70
41	$ 13,990,487.75	$ 6,990,487.75	$ 10,490,487.75	$ 16,790,487.75
42	$ 34,980,279.42	$ 17,480,279.42	$ 26,230,279.42	$ 41,980,279.42
43	$ 34,967,308.46	$ 16,967,308.46	$ 25,967,308.46	$ 42,167,308.46
44	$ 55,099,813.02	$ 27,099,813.02	$ 41,099,813.02	$ 66,299,813.02
45	$ 19,908,290.88	$ 9,908,290.88	$ 14,908,290.88	$ 23,908,290.88
46	$ 151,693.15	$ (181,640.19)	$ (14,973.52)	$ 285,026.48
47	$ 4,770,767.17	$ 2,370,767.17	$ 3,570,767.17	$ 5,730,767.17
48	$ 7,938,695.70	$ 3,938,695.70	$ 5,938,695.70	$ 9,538,695.70
49	$ 9,064,315.33	$ 4,464,315.33	$ 6,764,315.33	$ 10,904,315.33
50	$ 8,294,975.25	$ 1,694,975.25	$ 4,994,975.25	$ 10,934,975.25
51	$ 14,339,516.51	$ 6,839,516.51	$ 10,589,516.51	$ 17,339,516.51
52	$ 294,975.25	$ (2,305,024.75)	$ (1,005,024.75)	$ 1,334,975.25
53	$ 7,094,975.25	$ 1,094,975.25	$ 4,094,975.25	$ 9,494,975.25
54	$ 12,367,066.83	$ 6,167,066.83	$ 9,267,066.83	$ 14,847,066.83
55	$ 12,114,342.75	$ 5,714,342.75	$ 8,914,342.75	$ 14,674,342.75
56	$ 147,700,392.56	$ 73,414,678.27	$ 110,557,535.42	$ 177,414,678.27
57	$ 63,772,535.77	$ 31,772,535.77	$ 47,772,535.77	$ 76,572,535.77
58	$ 960,927.83	$ 460,927.83	$ 710,927.83	$ 1,160,927.83
59	$ 63,585,584.72	$ 31,785,584.72	$ 47,685,584.72	$ 76,305,584.72
60	$ 27,163,738.38	$ 13,163,738.38	$ 20,163,738.38	$ 32,763,738.38
61	$ 89,810,827.88	$ 44,810,827.88	$ 67,310,827.88	$ 107,810,827.88
62	$ 9,160,927.83	$ 4,560,927.83	$ 6,860,927.83	$ 11,000,927.83
63	$ 5,673,695.67	$ 2,673,695.67	$ 4,173,695.67	$ 6,873,695.67
64	$ 5,673,695.67	$ 2,673,695.67	$ 4,173,695.67	$ 6,873,695.67
65	$ 67,172,747.93	$ 33,172,747.93	$ 50,172,747.93	$ 80,772,747.93
66	$ 19,673,695.67	$ 9,673,695.67	$ 14,673,695.67	$ 23,673,695.67
67	$ 67,308,432.60	$ 33,308,432.60	$ 50,308,432.60	$ 80,908,432.60
68	$ 299,976,575.17	$ 149,976,575.17	$ 224,976,575.17	$ 359,976,575.17
69	$ 5,273,266.47	$ 2,273,266.47	$ 3,773,266.47	$ 6,473,266.47
70	$ 4,760,927.83	$ 2,360,927.83	$ 3,560,927.83	$ 5,720,927.83
71	$ 4,760,927.83	$ 2,360,927.83	$ 3,560,927.83	$ 5,720,927.83
72	$ 3,960,927.83	$ 1,960,927.83	$ 2,960,927.83	$ 4,760,927.83
73	$ 3,667,083.30	$ 1,800,416.63	$ 2,733,749.97	$ 4,413,749.97
74	$ 6,067,083.30	$ 3,000,416.63	$ 4,533,749.97	$ 7,293,749.97
75	$ 26,639,488.81	$ 13,306,155.47	$ 19,972,822.14	$ 31,972,822.14
76	$ 43,307,960.85	$ 21,307,960.85	$ 32,307,960.85	$ 52,107,960.85
77	$ 47,517,794.70	$ 23,517,794.70	$ 35,517,794.70	$ 57,117,794.70
78	$ 32,668,536.64	$ 15,525,679.50	$ 24,097,108.07	$ 39,525,679.50

79	$ 28,758,447.18	$ 13,758,447.18	$ 21,258,447.18	$ 34,758,447.18
80	$ 67,514,035.52	$ 33,514,035.52	$ 50,514,035.52	$ 81,114,035.52
81	$ 40,700,816.79	$ 20,300,816.79	$ 30,500,816.79	$ 48,860,816.79
82	$ 3,064,763.40	$ 1,064,763.40	$ 2,064,763.40	$ 3,864,763.40
83	$ 33,953,836.79	$ 16,553,836.79	$ 25,253,836.79	$ 40,913,836.79
84	$ 42,855,518.72	$ 21,188,852.05	$ 32,022,185.39	$ 51,522,185.39
85	$ 1,294,205.21	$ 627,538.54	$ 960,871.87	$ 1,560,871.87
86	$ 39,390,291.98	$ 19,390,291.98	$ 29,390,291.98	$ 47,390,291.98
87	$ (404,822.98)	$ (1,604,822.98)	$ (1,004,822.98)	$ 75,177.02
88	$ 4,008,010.18	$ 1,436,581.60	$ 2,722,295.89	$ 5,036,581.60
89	$ 139,145,540.70	$ 69,145,540.70	$ 104,145,540.70	$ 167,145,540.70
90	$ 7,815,486.55	$ 3,148,819.88	$ 5,482,153.21	$ 9,682,153.21
91	$ (271,681.03)	$ (791,681.03)	$ (531,681.03)	$ (63,681.03)
92	$ 30,638,998.98	$ 14,638,998.98	$ 22,638,998.98	$ 37,038,998.98
93	$ 9,893,712.56	$ 3,893,712.56	$ 6,893,712.56	$ 12,293,712.56
94	$ 3,924,221.73	$ 1,924,221.73	$ 2,924,221.73	$ 4,724,221.73
95	$ 921,640.66	$ (198,359.34)	$ 361,640.66	$ 1,369,640.66
96	$ 62,717,777.27	$ 30,717,777.27	$ 46,717,777.27	$ 75,517,777.27
97	$ 33,889,772.99	$ 16,889,772.99	$ 25,389,772.99	$ 40,689,772.99
98	$ 6,557,404.02	$ 2,957,404.02	$ 4,757,404.02	$ 7,997,404.02
99	$ (448,816.87)	$ (963,102.59)	$ (705,959.73)	$ (243,102.59)
100	$ 18,713,481.93	$ 8,713,481.93	$ 13,713,481.93	$ 22,713,481.93
101	$ 93,002,937.63	$ 46,336,270.96	$ 69,669,604.30	$ 111,669,604.30
102	$ 11,810,221.24	$ 5,810,221.24	$ 8,810,221.24	$ 14,210,221.24
103	$ 14,521,704.49	$ 6,788,371.15	$ 10,655,037.82	$ 17,615,037.82
104	$ 78,848,550.96	$ 38,484,914.59	$ 58,666,732.78	$ 94,994,005.50
105	$ 8,222,676.43	$ 3,322,676.43	$ 5,772,676.43	$ 10,182,676.43
106	$ 9,709,983.33	$ 3,876,650.00	$ 6,793,316.66	$ 12,043,316.66
107	$ 1,486,251.04	$ (113,748.96)	$ 686,251.04	$ 2,126,251.04
108	$ 27,921,316.55	$ 13,064,173.69	$ 20,492,745.12	$ 33,864,173.69
109	$ 46,926,031.96	$ 22,926,031.96	$ 34,926,031.96	$ 56,526,031.96
110	$ 15,233,043.03	$ 7,233,043.03	$ 11,233,043.03	$ 18,433,043.03
111	$ 25,941,207.25	$ 12,941,207.25	$ 19,441,207.25	$ 31,141,207.25
112	$ 110,285,376.77	$ 54,285,376.77	$ 82,285,376.77	$ 132,685,376.77
113	$ 18,848,136.47	$ 8,848,136.47	$ 13,848,136.47	$ 22,848,136.47
114	$ 78,604,844.20	$ 38,604,844.20	$ 58,604,844.20	$ 94,604,844.20
115	$ 181,242,114.09	$ 89,703,652.55	$ 135,472,883.32	$ 217,857,498.71
116	$ 6,461,517.22	$ 2,861,517.22	$ 4,661,517.22	$ 7,901,517.22
117	$ 28,194,898.91	$ 13,528,232.25	$ 20,861,565.58	$ 34,061,565.58
118	$ 64,217,353.33	$ 32,074,496.19	$ 48,145,924.76	$ 77,074,496.19
119	$ 35,136,740.60	$ 17,136,740.60	$ 26,136,740.60	$ 42,336,740.60
120	$ 185,371,621.78	$ 92,038,288.45	$ 138,704,955.11	$ 222,704,955.11
121	$ 3,952,651.55	$ 1,952,651.55	$ 2,952,651.55	$ 4,752,651.55
122	$ 13,617,970.76	$ 6,747,970.76	$ 10,182,970.76	$ 16,365,970.76
123	$ 7,225,688.81	$ 3,225,688.81	$ 5,225,688.81	$ 8,825,688.81

124	$ (115,790.05)	$ (515,790.05)	$ (315,790.05)	$ 44,209.95
125	$ 23,963,309.89	$ 11,963,309.89	$ 17,963,309.89	$ 28,763,309.89
126	$ 15,963,309.89	$ 7,963,309.89	$ 11,963,309.89	$ 19,163,309.89
127	$ 85,992,902.83	$ 42,792,902.83	$ 64,392,902.83	$ 103,272,902.83
128	$ 7,135,078.26	$ 2,771,441.90	$ 4,953,260.08	$ 8,880,532.81
129	$ 1,967,066.83	$ 967,066.83	$ 1,467,066.83	$ 2,367,066.83
130	$ 17,923,869.38	$ 8,923,869.38	$ 13,423,869.38	$ 21,523,869.38
131	$ 14,288,592.48	$ 6,788,592.48	$ 10,538,592.48	$ 17,288,592.48
132	$ 7,905,378.84	$ 3,905,378.84	$ 5,905,378.84	$ 9,505,378.84
133	$ 17,656,526.95	$ 8,323,193.61	$ 12,989,860.28	$ 21,389,860.28
134	$ 2,542,275.15	$ 542,275.15	$ 1,542,275.15	$ 3,342,275.15
135	$ 1,267,083.30	$ 600,416.63	$ 933,749.97	$ 1,533,749.97
136	$ 11,133,749.97	$ 5,533,749.97	$ 8,333,749.97	$ 13,373,749.97
137	$ 4,733,749.97	$ 2,333,749.97	$ 3,533,749.97	$ 5,693,749.97
138	$ 15,894,677.80	$ 7,894,677.80	$ 11,894,677.80	$ 19,094,677.80
139	$ 4,652,251.39	$ 2,318,918.05	$ 3,485,584.72	$ 5,585,584.72

Appendix E. Revenue Sensitivity Analysis

Appendix F: Capital Cost Sensitivity Analysis

For capital cost sensitivity analysis, the NPV for overall benefits of companies were calculated with 10% less, 10% and 20% more than the calculated amount of the capital costs in the original model.

Number	Original Total Benefit	Capital Cost Sensitivity		
		-10%	10%	20%
1	$ 460,509.88	$ 542,283.40	$ 378,736.36	$ 296,962.85
2	$ 7,359,703.92	$ 7,548,992.72	$ 7,170,415.11	$ 6,981,126.31
3	$ 110,454,933.49	$ 110,591,068.15	$ 110,318,798.84	$ 110,182,664.18
4	$ 23,222,255.82	$ 23,233,363.57	$ 23,211,148.06	$ 23,200,040.31
5	$ 15,073,618.55	$ 15,257,849.76	$ 14,889,387.34	$ 14,705,156.12
6	$ 1,096,894.19	$ 1,177,937.47	$ 1,015,850.92	$ 934,807.65
7	$ 5,566,689.27	$ 5,605,699.69	$ 5,527,678.85	$ 5,488,668.44
8	$ 39,650,831.63	$ 39,685,748.47	$ 39,615,914.79	$ 39,580,997.96
9	$ 31,516,109.38	$ 31,564,498.44	$ 31,467,720.31	$ 31,419,331.25
10	$ 12,760,488.34	$ 12,920,539.64	$ 12,600,437.03	$ 12,440,385.72
11	$ 91,217,520.90	$ 91,291,448.16	$ 91,143,593.65	$ 91,069,666.39
12	$ 4,249,835.35	$ 4,337,826.14	$ 4,161,844.55	$ 4,073,853.75
13	$ 19,851,093.47	$ 19,965,711.32	$ 19,736,475.63	$ 19,621,857.78
14	$ (617,702.82)	$ (511,263.13)	$ (724,142.52)	$ (830,582.21)
15	$ 4,059,571.67	$ 4,146,295.44	$ 3,972,847.90	$ 3,886,124.13
16	$ 31,650,831.63	$ 31,685,748.47	$ 31,615,914.79	$ 31,580,997.96
17	$ 10,639,245.76	$ 10,766,011.29	$ 10,512,480.22	$ 10,385,714.68
18	$ (101,666.12)	$ (16,583.19)	$ (186,749.05)	$ (271,831.98)
19	$ 14,550,727.87	$ 14,591,334.43	$ 14,510,121.32	$ 14,469,514.76
20	$ 1,650,831.63	$ 1,685,748.47	$ 1,615,914.79	$ 1,580,997.96
21	$ 3,589,198.11	$ 3,701,636.99	$ 3,476,759.23	$ 3,364,320.36
22	$ 7,114,889.61	$ 7,194,759.34	$ 7,035,019.88	$ 6,955,150.15
23	$ 67,138,366.48	$ 67,215,888.52	$ 67,060,844.44	$ 66,983,322.40
24	$ 4,450,831.63	$ 4,485,748.47	$ 4,415,914.79	$ 4,380,997.96
25	$ 7,170,767.17	$ 7,173,690.46	$ 7,167,843.89	$ 7,164,920.61
26	$ 21,220,644.33	$ 21,231,913.23	$ 21,209,375.43	$ 21,198,106.53
27	$ 27,631,111.06	$ 27,667,999.95	$ 27,594,222.16	$ 27,557,333.27
28	$ (160,439.46)	$ (76,571.01)	$ (244,307.91)	$ (328,176.36)
29	$ 13,977,257.72	$ 14,048,185.62	$ 13,906,329.81	$ 13,835,401.91
30	$ 17,715,544.42	$ 17,856,691.50	$ 17,574,397.34	$ 17,433,250.26
31	$ 1,545,953.13	$ 1,586,724.16	$ 1,505,182.09	$ 1,464,411.06
32	$ 22,645,221.01	$ 22,765,031.93	$ 22,525,410.09	$ 22,405,599.17
33	$ 3,437,433.84	$ 3,440,357.12	$ 3,434,510.56	$ 3,431,587.27
34	$ 5,456,158.33	$ 5,503,516.83	$ 5,408,799.83	$ 5,361,441.33
35	$ 26,821,256.99	$ 26,940,894.92	$ 26,701,619.06	$ 26,581,981.14
36	$ 3,729,470.23	$ 3,768,347.81	$ 3,690,592.65	$ 3,651,715.07
37	$ 790,487.75	$ 791,438.97	$ 789,536.52	$ 788,585.30
38	$ 6,990,487.75	$ 6,991,438.97	$ 6,989,536.52	$ 6,988,585.30

39	$ 91,980,279.42	$ 91,982,251.48	$ 91,978,307.37	$ 91,976,335.31
40	$ 239,620,080.70	$ 239,651,046.96	$ 239,589,114.43	$ 239,558,148.17
41	$ 13,990,487.75	$ 13,991,438.97	$ 13,989,536.52	$ 13,988,585.30
42	$ 34,980,279.42	$ 34,982,251.48	$ 34,978,307.37	$ 34,976,335.31
43	$ 34,967,308.46	$ 35,056,526.27	$ 34,878,090.64	$ 34,788,872.82
44	$ 55,099,813.02	$ 55,191,249.95	$ 55,008,376.09	$ 54,916,939.16
45	$ 19,908,290.88	$ 19,917,461.80	$ 19,899,119.97	$ 19,889,949.06
46	$ 151,693.15	$ 194,060.32	$ 109,325.97	$ 66,958.80
47	$ 4,770,767.17	$ 4,773,690.46	$ 4,767,843.89	$ 4,764,920.61
48	$ 7,938,695.70	$ 7,944,826.13	$ 7,932,565.27	$ 7,926,434.84
49	$ 9,064,315.33	$ 9,077,883.80	$ 9,050,746.86	$ 9,037,178.39
50	$ 8,294,975.25	$ 8,742,409.93	$ 7,847,540.57	$ 7,400,105.89
51	$ 14,339,516.51	$ 14,396,080.55	$ 14,282,952.47	$ 14,226,388.43
52	$ 294,975.25	$ 742,409.93	$ (152,459.43)	$ (599,894.11)
53	$ 7,094,975.25	$ 7,542,409.93	$ 6,647,540.57	$ 6,200,105.89
54	$ 12,367,066.83	$ 12,370,360.14	$ 12,363,773.51	$ 12,360,480.19
55	$ 12,114,342.75	$ 12,182,608.14	$ 12,046,077.36	$ 11,977,811.97
56	$ 147,700,392.56	$ 147,775,245.35	$ 147,625,539.77	$ 147,550,686.98
57	$ 63,772,535.77	$ 63,791,847.09	$ 63,753,224.45	$ 63,733,913.13
58	$ 960,927.83	$ 964,835.05	$ 957,020.61	$ 953,113.39
59	$ 63,585,584.72	$ 63,587,026.25	$ 63,584,143.19	$ 63,582,701.66
60	$ 27,163,738.38	$ 27,247,302.26	$ 27,080,174.49	$ 26,996,610.60
61	$ 89,810,827.88	$ 89,829,745.09	$ 89,791,910.66	$ 89,772,993.45
62	$ 9,160,927.83	$ 9,164,835.05	$ 9,157,020.61	$ 9,153,113.39
63	$ 5,673,695.67	$ 5,693,006.99	$ 5,654,384.35	$ 5,635,073.03
64	$ 5,673,695.67	$ 5,693,006.99	$ 5,654,384.35	$ 5,635,073.03
65	$ 67,172,747.93	$ 67,255,410.86	$ 67,090,085.00	$ 67,007,422.06
66	$ 19,673,695.67	$ 19,693,006.99	$ 19,654,384.35	$ 19,635,073.03
67	$ 67,308,432.60	$ 67,377,527.06	$ 67,239,338.13	$ 67,170,243.67
68	$ 299,976,575.17	$ 299,978,917.65	$ 299,974,232.69	$ 299,971,890.20
69	$ 5,273,266.47	$ 5,336,455.52	$ 5,210,077.43	$ 5,146,888.39
70	$ 4,760,927.83	$ 4,764,835.05	$ 4,757,020.61	$ 4,753,113.39
71	$ 4,760,927.83	$ 4,764,835.05	$ 4,757,020.61	$ 4,753,113.39
72	$ 3,960,927.83	$ 3,964,835.05	$ 3,957,020.61	$ 3,953,113.39
73	$ 3,667,083.30	$ 3,673,708.30	$ 3,660,458.30	$ 3,653,833.29
74	$ 6,067,083.30	$ 6,073,708.30	$ 6,060,458.30	$ 6,053,833.29
75	$ 26,639,488.81	$ 26,642,206.59	$ 26,636,771.02	$ 26,634,053.23
76	$ 43,307,960.85	$ 43,365,818.44	$ 43,250,103.26	$ 43,192,245.66
77	$ 47,517,794.70	$ 47,561,694.58	$ 47,473,894.83	$ 47,429,994.95
78	$ 32,668,536.64	$ 32,806,718.76	$ 32,530,354.53	$ 32,392,172.41
79	$ 28,758,447.18	$ 28,866,935.48	$ 28,649,958.87	$ 28,541,470.57
80	$ 67,514,035.52	$ 67,558,311.32	$ 67,469,759.73	$ 67,425,483.94
81	$ 40,700,816.79	$ 40,710,735.11	$ 40,690,898.47	$ 40,680,980.15
82	$ 3,064,763.40	$ 3,149,645.75	$ 2,979,881.05	$ 2,894,998.70
83	$ 33,953,836.79	$ 34,027,106.79	$ 33,880,566.80	$ 33,807,296.80

84	$ 42,855,518.72	$ 42,903,300.18	$ 42,807,737.26	$ 42,759,955.80
85	$ 1,294,205.21	$ 1,298,118.02	$ 1,290,292.39	$ 1,286,379.58
86	$ 39,390,291.98	$ 39,444,237.12	$ 39,336,346.85	$ 39,282,401.72
87	$ (404,822.98)	$ (142,427.04)	$ (667,218.91)	$ (929,614.85)
88	$ 4,008,010.18	$ 4,112,908.44	$ 3,903,111.91	$ 3,798,213.64
89	$ 139,145,540.70	$ 139,231,407.42	$ 139,059,673.97	$ 138,973,807.24
90	$ 7,815,486.55	$ 7,944,578.58	$ 7,686,394.52	$ 7,557,302.49
91	$ (271,681.03)	$ (182,923.12)	$ (360,438.93)	$ (449,196.84)
92	$ 30,638,998.98	$ 30,761,223.61	$ 30,516,774.34	$ 30,394,549.71
93	$ 9,893,712.56	$ 10,081,648.66	$ 9,705,776.47	$ 9,517,840.37
94	$ 3,924,221.73	$ 3,931,799.56	$ 3,916,643.90	$ 3,909,066.07
95	$ 921,640.66	$ 1,035,104.60	$ 808,176.72	$ 694,712.78
96	$ 62,717,777.27	$ 62,830,332.56	$ 62,605,221.97	$ 62,492,666.68
97	$ 33,889,772.99	$ 33,900,795.69	$ 33,878,750.29	$ 33,867,727.59
98	$ 6,557,404.02	$ 6,617,006.86	$ 6,497,801.18	$ 6,438,198.34
99	$ (448,816.87)	$ (313,124.76)	$ (584,508.99)	$ (720,201.11)
100	$ 18,713,481.93	$ 18,821,970.23	$ 18,604,993.62	$ 18,496,505.32
101	$ 93,002,937.63	$ 93,028,951.53	$ 92,976,923.73	$ 92,950,909.83
102	$ 11,810,221.24	$ 11,829,199.12	$ 11,791,243.37	$ 11,772,265.49
103	$ 14,521,704.49	$ 14,593,277.31	$ 14,450,131.67	$ 14,378,558.85
104	$ 78,848,550.96	$ 79,020,808.52	$ 78,676,293.39	$ 78,504,035.82
105	$ 8,222,676.43	$ 8,364,219.19	$ 8,081,133.67	$ 7,939,590.91
106	$ 9,709,983.33	$ 9,892,161.04	$ 9,527,805.62	$ 9,345,627.92
107	$ 1,486,251.04	$ 1,634,933.29	$ 1,337,568.79	$ 1,188,886.55
108	$ 27,921,316.55	$ 28,080,027.75	$ 27,762,605.34	$ 27,603,894.13
109	$ 46,926,031.96	$ 47,022,082.44	$ 46,829,981.48	$ 46,733,931.01
110	$ 15,233,043.03	$ 15,306,760.90	$ 15,159,325.16	$ 15,085,607.28
111	$ 25,941,207.25	$ 25,947,086.53	$ 25,935,327.98	$ 25,929,448.70
112	$ 110,285,376.77	$ 110,442,679.98	$ 110,128,073.57	$ 109,970,770.36
113	$ 18,848,136.47	$ 18,951,930.91	$ 18,744,342.03	$ 18,640,547.59
114	$ 78,604,844.20	$ 78,733,258.38	$ 78,476,430.02	$ 78,348,015.84
115	$ 181,242,114.09	$ 181,422,719.92	$ 181,061,508.26	$ 180,880,902.44
116	$ 6,461,517.22	$ 6,535,495.78	$ 6,387,538.66	$ 6,313,560.10
117	$ 28,194,898.91	$ 28,305,929.56	$ 28,083,868.26	$ 27,972,837.62
118	$ 64,217,353.33	$ 64,224,189.43	$ 64,210,517.24	$ 64,203,681.14
119	$ 35,136,740.60	$ 35,220,088.72	$ 35,053,392.49	$ 34,970,044.37
120	$ 185,371,621.78	$ 185,481,181.19	$ 185,262,062.37	$ 185,152,502.96
121	$ 3,952,651.55	$ 3,957,386.39	$ 3,947,916.70	$ 3,943,181.86
122	$ 13,617,970.76	$ 13,630,173.69	$ 13,605,767.84	$ 13,593,564.92
123	$ 7,225,688.81	$ 7,303,250.21	$ 7,148,127.41	$ 7,070,566.01
124	$ (115,790.05)	$ (27,806.73)	$ (203,773.37)	$ (291,756.69)
125	$ 23,963,309.89	$ 23,966,978.90	$ 23,959,640.88	$ 23,955,971.87
126	$ 15,963,309.89	$ 15,966,978.90	$ 15,959,640.88	$ 15,955,971.87
127	$ 85,992,902.83	$ 86,026,586.88	$ 85,959,218.79	$ 85,925,534.74
128	$ 7,135,078.26	$ 7,289,368.14	$ 6,980,788.39	$ 6,826,498.51

129	$ 1,967,066.83	$ 1,970,360.14	$ 1,963,773.51	$ 1,960,480.19
130	$ 17,923,869.38	$ 17,931,482.44	$ 17,916,256.31	$ 17,908,643.25
131	$ 14,288,592.48	$ 14,357,158.50	$ 14,220,026.46	$ 14,151,460.44
132	$ 7,905,378.84	$ 7,914,840.95	$ 7,895,916.72	$ 7,886,454.61
133	$ 17,656,526.95	$ 17,732,402.31	$ 17,580,651.59	$ 17,504,776.22
134	$ 2,542,275.15	$ 2,667,390.63	$ 2,417,159.68	$ 2,292,044.21
135	$ 1,267,083.30	$ 1,273,708.30	$ 1,260,458.30	$ 1,253,833.29
136	$ 11,133,749.97	$ 11,140,374.97	$ 11,127,124.96	$ 11,120,499.96
137	$ 4,733,749.97	$ 4,740,374.97	$ 4,727,124.96	$ 4,720,499.96
138	$ 15,894,677.80	$ 15,905,210.02	$ 15,884,145.57	$ 15,873,613.35
139	$ 4,652,251.39	$ 4,653,692.92	$ 4,650,809.86	$ 4,649,368.33

Appendix F. Capital Cost Sensitivity Analysis

VITA AUCTORIS

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