Analyzing the environmental effects of waste management in the city of Ottawa

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***Abstract*— This paper will analyze the ways garbage and waste collection changes the natural environment in landfills affecting marine life and beyond. Each ton of waste produced each year accumulates and causes concern for the Trail Road landfill in Ottawa. There are various impacts to be studied on the waste we produce as consumers including the circular economy, consumerism, and the impact on various weather events like flooding. Waste management is vital in all aspects of society and especially in terms of dealing with climate change. The City of Ottawa has developed a Solid Waste Master Plan for waste management as the Trail Road landfill is predicted to fill up by 2036 to 2038. Landfills produce methane, carbon dioxide, and other landfill gasses which contribute to greenhouse gas emissions affecting our environment. The city has a concern about accumulating waste and plastic pollution. As a result, this speeds up climate change through the land, water through leachate runoff and the air through the landfill gas. Solutions include using the green bin more and developing a circular economy approach to reduce waste in Ottawa. This paper will analyze waste in Ottawa from 2005 to 2016 to see if there are any changes in waste disposal. Some literature papers focused on smart technologies using smart waste bins as a proposed solution to managing waste in smart cities using IoT devices and machine learning to detect the volume of waste in waste bins.**

***Index Terms* — Garbage, Circular Economy, Waste Management, Landfills, Consumerism, Environmental Destruction**

II. Introduction and Background

Today, there is a lot of garbage that is dumped in our landfills. This leads to waste that can affect the environment leading to environmental destruction which adds to the pollution that can destroy the planet's ecosystems. In this study, we plan to analyze the environmental effects of waste management and garbage collection in the city of Ottawa to see the reality of our consumption and its impacts on the economy and climate, and health. The amount of landfill waste has increased substantially and needs to be reduced. Our study aims to help minimize the waste to help reduce carbon dioxide, methane gas, and various greenhouse gasses emitted into the atmosphere (Environmental Protection Agency, 2021). Waste reduction plays a key factor in our carbon footprint. We will be examining the relationship between how landfill waste can affect the economy. A lot of the waste that is thrown in the landfill such as plastics is not biodegradable and can end up in the oceans. This can harm wildlife and contributes to climate change as environmental destruction. Plastics in our oceans can affect our drinking water which can be detrimental to our well-being. This study can help residents in the city of Ottawa evaluate their purchasing habits and think about ways to protect the natural environment. We want to look at how the waste is being diverted in the landfills and whether there can be more efficient solutions to manage the waste. The issue of waste management is a pertinent contemporary issue as people are more aware of the effects of climate change.

We will further look at the relationship between waste management and the economy. The wants of people have increased especially into a more materialistic mindset which outweighs the needs of what is required for daily necessities. Therefore, it is important to know what to buy and what items to reduce throwing out. It is not only food waste that goes in the landfills but also electronic waste as people buy new phones and electronic devices every year. As a municipality, the city of Ottawa has its waste diversion program, a waste explorer, and a plan to tackle the challenges of waste management as well as raising awareness for residents to be mindful of their waste. We will analyze trends and compare the amount of waste for certain years to provide readers with some interesting facts about their waste. It is important to know how to regulate and manage all the waste that comes into the city of Ottawa's landfills because there needs to be room for new waste that comes into the landfill. The city of Ottawa has a master plan to change the way waste is diverted in landfills. As well, the city of Ottawa has several waste programs to promote good recycling habits.

By analyzing data from the city of Ottawa on waste management using data analysis, it can help plan the budget and reduce emissions. We will look at what other cities are doing for managing their waste in the landfills. Local businesses can encourage sustainable business practices for waste by recycling everything in the correct bins, so food does not go in the garbage but the compost. Food waste can lead to food shortages and can affect the economy and the environment because there are countries with a lower food supply (Ciccullo et al., 2020). Residents in the city pay taxes for garbage collection and waste management. So, the city needs to find ways to reduce landfill waste to make sure there is enough capacity. There is a lot of data generated from landfill waste so data analysis can be used to evaluate what should continue to be in the landfill and what could be avoided to dump in the landfill as solid waste. We want to look at sustainable ways to recycle, reuse, and reduce waste to avoid filling up the landfill which can affect the environment and the economy.

Furthermore, the natural resources on earth are limited, valuable, and costly. Consequently, we must look at the effects of overconsumption and only dispose of waste as required. Waste is produced in many settings and contexts in our daily lives so we must ensure that the waste is recycled properly to maintain the landfills and waste facilities. To protect the world's natural resources and the environment at stake, it is crucial that everyone looks at their consumption and reduce

their waste as much as possible. Data analysis can be used to inform and understand why there is particularly more waste disposed of in one neighbourhood, or what types of materials are being discarded. At the COP26 conference on climate change, the waste management industry has been neglected even though carbon dioxide or methane comes from solid household waste including food, electronic, and hazardous waste. The waste sector and waste management are key in solving climate change and reaching net-zero emissions. It has been overlooked at COP26 commented Adam Read, president of the Charted Institute of Waste Management (CIWM). There are concerns about methane emissions and black carbon from open burning waste (Nageler-Petritz, 2021).

We want to understand how waste can be reduced and protect the environment from toxic chemicals from the waste in landfills. We want to study if there is a correlation between consumption patterns and the amount of waste produced to avoid overcrowding the landfills. We will take a close look at the materials discarded, the effects of the landfills' pollution, and the amount of waste that has been recycled. Our study is unique in that it ties the environmental factors of landfill waste in the city of Ottawa and with the economy to investigate the overall consumption pattern of individuals. We will not only look at the environmental aspects but also the social, economic, and technological aspects of landfill waste. Technology can be utilized to sort, recycle, and prevent waste. Intelligent information systems can be used to track and monitor waste that is diverted to landfills. This study is useful for the city to allocate resources for waste diversion and benefits residents to understand where their waste is going. Many of us do not know the underlying effects of what happens when the waste is in the landfill and what that can do to the environment and the economy. We need to be conscious of our solid waste and the materials that go into landfills. Information technology and data analytics can be used to monitor levels of toxic pollution, the amount of solid waste in the landfills, and proper sorting before it goes to the landfill. Much of the landfill waste can be sorted and recycled before being dumped there. Because there are a lot of plastics in the oceans, e-waste, food waste, and other hazardous materials in the landfills, it is important to analyze data that is coming in the landfills and see which ones could have been recycled or reused to avoid severe environmental effects. According to O'Malley (2021), Ontario's landfills will need to create or expand at least 16 landfills by 2050 if there is no change in waste reduction techniques. For example, soil can be contaminated which makes it harder to grow crops. There can be acid rain which destroys and brings pollutions to the environment. Food waste can be turned into energy. There are certainly benefits to good waste management ranging from more jobs to better customer satisfaction and of course, environmental protection. Businesses, governments, and individuals all have a shared responsibility to reduce their waste and think about the environment.

I.I. MOTIVATION

The motivation behind this study is to comprehend the aftereffects of the waste we produce daily and the impact it is having on air pollution, hazardous materials like batteries, and the circular economy. Waste management in cities is ever-increasing at a higher rate each year. The city's Solid Waste Management Master Plan is a key factor in developing proposals to curb the overflowing waste in landfills for the next 30 years including the Trail Road Waste facility in Ottawa (*Solid waste master plan*, n.d.). These include green bins and composting. City councillors in Ottawa are producing a draft plan by 2022. Ottawa's landfills are predicted to be full sometime between 2036 and 2038 (Pringle, 2021). Once landfills fill up, there must be a sustainable way to better manage the garbage in cities rather than burning trash, incineration or dumping it in the sea.

Consumers must realize how it affects their daily life. For example, how much we spend on groceries is dependent on the trash we produce. We can lessen how much we buy. Another factor is the health of the people in Ottawa. The tonnes of waste thrown in landfills each year can make it harder to breathe if people must live nearby. There needs to be a more efficient manner to dispose and burn garbage as the landfills will run of space as the city's population expands. Studying waste management can help us and society realize the costs of what we produce. The cost to the economy is immense each year due to food waste before or after the food is expired. The city's budget might not be able to handle billions of dollars spent on waste management. The burden and cost of the garbage going to the landfills are what happens after it is left there to degrade for years. Consumerism must be explored as the clothes we buy and the things we shop for have a direct correlation to the economy in that there will be more jobs and economic growth with more goods and services bought and sold. Consumers love to buy more especially in developed countries. There is steady growth but also negative consequences particularly when it comes to the environment.

According to the Government of Canada (2021), the circular economy is the idea that there should be zero waste, and the item should be reduced, reused, or refurbished sustaining natural resources like water, air, etc. This is displayed in Figure 3. The raw materials do not go to waste. A circular economy is possible and reduces cost creating more jobs for lots of people. A linear economy differs from this in that the products are made, used, and disposed of without thinking about what happens to them after their lifecycle. This is indicated in Figure 2. According to Cairns and Whitaker (2021), the circular economy will reduce global emissions by 39%. The cycle of manufacturing, consuming, and discarding continues if we do not think about the circular economy. In our daily lives, we can use less plastic, reduce packaging on items and think critically about the delivery costs of shipping items when doing online shopping as well as the amount of packaging wrapped in the product. Most of what we do in our daily lives affects the landfills and in turn the environment and greater economy in terms of the costs of maintaining landfills. We can use green bins and educational programs to help inform consumers where their trash can go. It is easier to sort and

recycle and not lead to contaminated items. Developing technologies like automation is making it more accessible for researchers to study waste management and plastic pollutions in our oceans which cost the economy due to the billions of dollars in costs of repairing damaged ecosystems and marine life to our ever-growing amount of plastics in the oceans. It is estimated to cost the economy at least US$13 billion a year for marine ocean pollution (Carr, 2019).

I.II. HOW OUR STUDY IS USEFUL AND UNIQUE

The uniqueness and usefulness of good waste management practices benefit the environment. Everyone must be aware and each one of us has a role to play in what we do to our environment. We will analyze how consumerism related to the amount of waste produced along with its effects on the economy and the environment.

Shopping and eating habits are the key to this study in that we recognize how much we consume each day; how much waste is collected and what sort of waste is thrown out. Each household can look at their spending habits whether they eat out and discard more food or not during the COVID-19 pandemic as there is more strain on the global supply chain and production costs from panic buying. Households must be able to create and manage their budgets by looking at how much they spend on groceries weekly. Moreover, they should create a shopping list so they will not overspend on unnecessary items. Everyone has a responsibility in ensuring that landfills do not run out of space. Companies and local businesses are promoting less or even banning plastics because of the harm to the environment. For these reasons, we must think to protect the environment or care about people living in harsher conditions because they must deal with unsanitary water and severe climate events. Because waste has polluted the atmosphere, we need to adapt to renewable energy to have a cleaner and greener environment. Plastics can stay in the oceans for a long time because it is less biodegradable than other products. People's consumption keeps increasing which leads to more waste that is filling up quickly in our landfills. We all contribute to waste, so it is important to think about the environment as it has a vital role in sustaining the planet's climate and the overall well-being of people.

Proper waste management is important to educate others on as our actions affect others. It can lower production costs for businesses. Waste and the environment go hand in hand. Non-biodegradable waste is seen as a cause for concern if not disposed of correctly where the chemicals can impact the soil. This study is useful to understand how to reduce unwanted or unusable items and pollute the air. Governments are trying to find solutions as the population's garbage increases every year. Waste management can be seen as a huge problem to both the economy and the environment, and the effects are ongoing especially given recent events like the COP26 climate conference in Glasgow where waste must be a top priority in preventing climate change. World leaders must think of waste management as a principal factor in its climate goals. We must find ways to have sustainable practices with a circular economy. Waste management is important because it affects the environment, especially with an increased risk of severe weather events and climate change. Therefore, we must take proper action and manage our waste efficiently. We can use data analysis and data visualization to convert waste into valuable resources because certain materials that are discarded can be reused into new products. Ottawa is a growing large G7 city, and we need to show an example of how to manage our waste well.

III. LITERATURE SURVEY

There is an increase in global greenhouse gas emissions such as $C0_2$ and methane gas in the atmosphere contributing to climate change. Food waste and plastic pollution are key issues highlighted because waste contributes to greenhouse gas emissions. Waste management is an important problem that directly correlates with the environment. The economic growth and various living standards have contributed to an imbalance in waste management (Nižetić et al., 2019).

The research study presents some of the problems of plastic pollution and food waste that can impact sustainability. The researchers acknowledged that plastic waste, food waste and electronic waste are key issues that are correlated with the devastation of ecosystems. The research study proposed a smart waste management strategy using IoT technologies.

The researchers explained the use of smart cities and IoT but did not link what can be done better using these technologies towards waste management. There is little analysis of the environmental effects of waste management. The paper addressed a lot of research on green walls and smart cities using IoT technologies but did not link it enough when dealing with waste management.

The municipal governments are responsible for waste management in Canada. Pan et al. (2018) found landfills are the commonly used method for waste diversion in Canada. We can look at the diversion rate for waste to improve waste recycling efforts.

There were several statistical analysis techniques used to analyze solid waste management papers such as comparative analysis, ANOVA, and multiple regression. The researchers found GDP was a significant factor that correlated with waste management in the Western provinces of Canada where the study was conducted.

There were not many environmental effects of waste management on cities in Canada. The research paper did not examine some of the potential solutions in households but exclusively focused on waste management among businesses. The analysis mainly focused on the economics of waste management but could indicate what the implications of the waste diversion rate on selected cities are on the environment.

According to Dubey et al. (2020), the internet of things and machine learning is where an electronic device is connected to the internet by using an IP address. Machine learning and the internet of things can help smart cities maintain a smart waste management system. The research paper looked at managing household waste and using a smart dustbin to filter biodegradable waste.

The researchers identified that the majority of waste comes from household waste. The research study analyzed that

a growing population produces many biodegradable wastes. The improper management of waste can pose dangerous health effects and contributes to environmental pollution as there can be hazardous gasses leaking into the atmosphere.

There could be more discussion on what makes a smart city help manage household waste and contribute to a green environment. The researchers could elaborate more on the harmful effects of biodegradable and non-biodegradable waste on the environment.

E-waste is made up of many different metallic and non-metallic materials. These hazardous materials can include lead, cadmium, mercury, or nickel (Rautela et al., 2021). Rautela et al. (2021) explain that e-waste contributes to harmful effects on the environment and people's health because e-waste can emit toxic chemicals, smoke, oils and charcoal. Bioleaching is a method that can help reduce greenhouse gasses and leachates from landfills because of E-waste metals.

The authors were incredibly detailed and specific when explaining the harmful effects of e-waste on the environment and human health. E-waste can introduce potentially dangerous effects. Nevertheless, there is only roughly 17.4% of e-waste recycled and 82.6% are thrown in landfills.

The research study did not mention some of the solutions to counter the challenges of managing e-waste and what citizens can do to reduce e-waste going to landfills. The research study showed a lot of potential effects of e-waste but could examine how certain materials from electronic waste could be better recycled.

The increasing population growth and globalization have led to a gigantic amount of waste production. The researchers in this research study have found how landfilling technologies can aid in solid waste management techniques by filtering sanitary waste. Solid waste management is intrinsically interconnected with pollution to the water, soil, and air. Leachate is liquid waste from landfills, and it contaminates surface water, groundwater and the soil with various metals from landfills (Das et al., 2019).

This research paper lists some of the challenges when dealing with solid waste management such as waste treatment, waste logistics, and waste collection. There are several tools and technologies such as AI and RFID systems used to monitor waste management.

There could be more research on the environmental impacts and sustainable practices when dealing with waste management. The research study could benefit from more solutions to address the challenges or issues faced with solid waste management.

This paper describes the amount of waste disposal in Regina, a Canadian city during the COVID-19 pandemic. Buying habits have changed during the pandemic and so has waste distribution. Richter et al. (2021) found that the waste levels in that city have changed very little. There was only 450 tonnes/month during the pandemic summer in 2020. The pandemic affected the environment and in turn impacted the waste behaviour of people in Canadian cities. Those who work at home reduced waste, but there was the disposal of gloves and masks in municipal waste generation. Regina is a mid-sized city in Canada with a population of 215,000 and the population has remained stagnant over the years (Statistics Canada, 2017). That city's growth is still low compared to Ottawa's population of 1 million estimated to be 1,497,928 as of 2021 according to World Population Review, but the waste data and characteristic of being a mid-sized to a large city can be similar (*Ottawa population 2021*, n.d.).

The paper uses a violin plot to illustrate the skewness of the data and the different types of waste disposal such as Mixed Solid Waste, Construction and Demolition Waste, and grit waste. The graph showed the amount of waste disposed and it showed that there was a bimodal distribution in waste distribution. Sharma et al. (2020) analyzed that food waste decreased during the pandemic. There was a fewer solid waste disposal rate during the pandemic because fewer people were going outside to eat and travel.

This research paper does not analyze other types of waste like municipal solid waste and in other cities in Canada. There is a particular focus on one city and can expand to other cities to compare how the other cities did during Covid-19 and its waste disposal. There was less waste due to fewer people travelling around and about. It is interesting as Canada produces a lot of waste among the most in the world with 36.1 metric tons in 2019 per capita annually (Tiseo, 2021).

This paper is about food waste during the COVID-19 pandemic and how it has affected consumers. Fruits and vegetables have been thrown out more during the pandemic. It has affected the way we consume food and manage food waste. Online shopping has increased by 16% and pandemic restriction has caused strains in the global food supply chain. Staying home has greatly reduced the amount of food waste.

The research found that COVID-19 has reduced food waste in developed countries like the United States. It can be seen as a silver lining. Consumer spending habits at restaurants have dropped by 60% (Roe et al., 2020). The paper provides steps to reduce food waste like preparing food at home.

The study focused on panic buying and food shortage during the pandemic but could focus more on the prevention of food waste post-pandemic and the changes we can do to reduce overall food waste. It also did not have enough graphs and charts to back up food waste data, so it was hard to fully grasp the concepts.

This study analyzes waste management in terms of SWOT analysis through the circular economy. There are negative impacts to the environment such as pollution without the circular economy (Paes et al., 2019). The linear economy was key to the industrial revolution and its development, but things have changed and there is now too much waste to dispose of in the modern era with improper waste practices. Local governments are responsible for waste disposal subject to the financial resources they have. There is an approach in the circular economy called the value chain which includes product design, production, marketing, consumption, and recycling.

It includes tables for SWOT analysis. Researchers found research articles for organic waste and the circular economy approach. A strength they found in the circular economy approach is the reduce, reuse, and recycle approach reduces costs.

What this paper can further improve in its research is

to explain more specifically the connection between the circular economy and the environment. A weakness the researcher found is the complexity of supply chain management on organic food waste. The paper can be clearer on how a circular economy is useful.

This research paper uses a model called fuzzy logic-based model to analyze greenhouse gas emissions and landfill gas from solid waste landfills in Ontario (Mohsen and Abbassi, 2019). The model represents vague information and is used to develop methane rates from landfills. Landfill gas is one of the largest emitters of methane. The amount of gas is due to the depth of the landfill, age, temperature, etc. The process to determine methane rate is complicated in landfills because it is hard to estimate the amount of gas generated. Landfills in four Ontario cities including Ottawa recorded the highest levels of methane at 20 million m^3/year.

The researcher points out the environmental effects of landfills in particular their use of methane in polluting our planet with a graph. Waste composition or what the waste is comprised of is important for understanding the gas from landfills. Methane generation rate is an important variable in determining greenhouse gas emissions in landfills.

What they can do better is explain the fuzzy model process in other cities besides Ontario for comparison. They can also provide the reader with any alternatives to this fuzzy model to better estimate methane gas rates in landfills. The paper is quite shorter than the other reviewed papers. It can be better to provide more details on the functions of a fuzzy model.

This research paper aims at studying the effects of greenhouse gas emissions from municipal solid waste management in Turkey and advise governments about waste management, but it applies to Ottawa and Canada as well because climate change is a global issue and the effects of waste on the environment (Yaman, 2020). GHG emissions were calculated from a model by the French. A reduction in greenhouse gas emissions was implemented from the Paris Climate Agreement in 2015. There are three scenarios in Kocaeli, Turkey from 2018-2028. LandGEM is another method to calculate method emission rates from landfills.

What was done well is defining key terms and including multiple scenarios including landfill gas, composting, and incineration. There is a chart explaining the different scenarios including transforming landfill gas to energy and heating homes to avoid greenhouse gas reductions. The second scenario is turning composting into land use and the final scenario is to heat homes from incineration.

They can expand on other geographical regions like developed countries and compare the difference in waste management. The authors do not go beyond the geographic boundary of this study because the Minister of Environment in Turkey has new guidelines for limiting emissions in Turkey. It is small sample size for this study as it is limited in that geographic area only.

The paper talks about organic waste and its effects on the circular economy in Canada. The researchers focused on Quebec (Perger, 2019). North America has a huge responsibility as a large consumer of products and consequently, of waste as well. A four-step framework to eliminate waste is to eliminate, reduce, raise the importance of food waste, and create. Food waste is a growing problem worldwide. Methane is a potent greenhouse gas that is 25 times greater than carbon dioxide and its impact on the climate contributes to this sort of waste. Diverting organics from landfills reduces leachates and other odours causing pollution to the surrounding community.

The paper highlights key areas that can be applied to every city including Ottawa, province or federally in Canada using a circular economy approach to organic food waste. With a block diagram highlighting what needs to be done to have a circular economy. There must be 4 main areas including reducing food waste, reusing for consumption again, recycling for soil quality and composting and recovery for energy.

What the paper should focus more on is solutions as Canada has the world's worst food waste problem and the researchers found that no solution has been feasibly implanted yet. The research must be done by the different municipalities in Canada. There is still not enough data on food waste in Canada.

COVID-19 has interrupted municipal waste management in multiple cities (Roy et al., 2021). PPE has presented a challenge to the way dispose of those types of waste. There is an increase in single-use plastics from ordering take out. Countries have tried incineration because of the lack of landfill space. The World Health Organization recommends collecting waste in black bags. The waste generation rate is the highest in Canada. A 70% increase in waste generation is expected worldwide by 2050. Canada needs to meet this challenge as it has the highest waste generated worldwide. There needs to be a demand in reducing single-use plastics.

The paper has a hierarchy of waste management from best use to worst use which is useful including reducing and reusing items. It also includes a high-level summary image of municipal waste management's cycle towards sustainability and the circular economy. The paper does not explain clearly how technology can help mitigate the problem of municipal waste.

II.I Comparative Analysis

Based on Table 1 and Appendix A below, we found many qualitative and qualitative data that researched the environmental and health effects of waste management. From each research paper we reviewed, we looked at the method, results, limitations, data identification, sample size, data type, and test. The research papers looked at using smart technologies, IoT, machine learning and AI to tackle waste management issues such as food waste, e-waste, landfill capacity, and pollution to the environment. There were also papers on how COVID-19 impacted food waste, buying, and eating habits and municipal waste management. What we can conclude from the table is that technology such as AI has changed the way we dispose of different wastes like food and solid municipal waste especially during the COVID-19

pandemic as the effects of staying home reduce waste and pollute the environment. Smart cities can help cities reduce waste by using smart bins, the cloud, and sensors as a method to control the number of trashes in landfills. Smart bins use sensors in the garbage bins to detect how full the trash bin is, and by using IoT, it can use data in the cloud to monitor trash and lower emissions in the air.

IV. Problem Identification and Gap Analysis

We found the research papers have extensive research of modern technologies including IoT, AI, and machine learning to manage waste but there are not enough findings on the potential causes or solutions to waste management using these technologies. All the research papers included either quantitative analysis, qualitative analysis or both quantitative and qualitative analysis.

- There is a gap between the solid waste management affecting severe weather events and how household waste can contribute to environmental pollution or deforestation.
- We can consider how food waste is affecting developed or underdeveloped countries with the global supply chain and the economy. We can look at how sustainable waste management practices such as proper recycling methods and composting.
- There is a potential gap between how to convert waste into energy or resource that can enhance more sustainable options for waste management (Slootweg, 2020).

High-level Plan:

We can look at how much people are spending on materials they do not need. There is a global climate crisis that can be solved by our actions. Food waste, household hazardous waste, e-waste, and plastic waste are harming the environment, so we must think about what is needed before purchasing the materials. We will examine our food and shopping habits to see what materials are contributing to waste and how we can do better as a city to ensure that less waste is diverted to landfills and harming the environment.

We will conduct a survey for our data collection as well as observe other people's waste habits in our neighbourhood and ward. By doing a survey, we will be able to find out if people realize how to recycle well and how it impacts the environment.

Problem Statement:

Landfill gas has a role in the environment, and it has increased methane emissions from landfills to pollute the environment contributing to climate change, making it harder to breathe for humans as well as the surrounding wildlife nearby. Gas emissions from landfills continue to contribute detrimental effects on the environment and human health (Duan et al. 2020).

This research paper aims to study and analyze the environmental effects that come from household solid waste. We want to know some answers to the following questions: 1) How much solid waste is disposed of in landfills and what types of materials are discarded the most? 2) What types of extreme weather events are linked with the pollution caused by landfills? 3) Why are people focused on buying too many materials for their wants over needs? 4) How many people are recycling and using the green bin?

Hypothesis:

Using green bins and applying the 3 R's (Reduce, Reuse, Recycle) will reduce the waste in landfills and turn, reduce greenhouse gas emissions that contribute to climate change.

Main Objective:

1. To determine the amount of solid household waste (food waste, e-waste, hazardous waste) and the types of materials from residents in the City of Ottawa

Sub-objectives:

1. To examine the correlation between consumer spending habits and how it affects the number of goods or services purchased which increases household waste
2. To explore the types of severe weather events occurring due to hazardous chemicals leaking from landfills and the connection with climate change and waste
3. To find out why people are spending too much on materials they do not need that go to the landfills
4. To figure out how many people recycle, throw out food, compost and/or use the green bin in the city of Ottawa

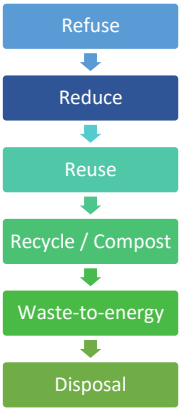


Fig. 1. This block diagram figure shows ways to reduce waste from the most to least desired methods similar to a waste hierarchy.

Fig. 2. This graphic shows a linear economy approach with the standard "take-make-use-dispose" model. Adapted from Hi-Cone (2020).

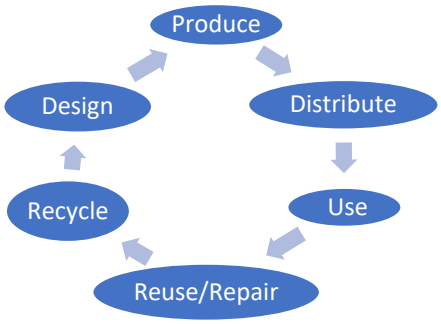


Fig. 3. This chart shows a circular economy approach with zero-waste. Adapted from the City of Ottawa's Solid Waste Master Plan (n.d.).

Table II.
WASTE MANAGEMENT CHALLENGES AND SOLUTIONS

Challenges	Solutions
• People are spending too much on materials they do not need that end up in the landfills	• Think about what materials are necessary and needed before buying them • IoT, Machine Learning and AI can be used in smart cities that use sensors to monitor waste levels. Smart waste bins are useful with sensors to detect the amount of waste in the bin and see if it is full or not. To measure the level of waste, we use an ultrasonic sensor on the waste bin (Abuga & Raghava, 2021).
• Plastics are polluting the oceans and trees are clear-cut for paper and other materials like plastic water bottles, cutlery, etc.	• Try to reduce or refuse the use of single-use plastics and recycle used paper. • In fact, the Canadian government is banning single-use plastics by the end of 2021 and proposed to end all plastic waste by 2030 (Environment and Climate Change Canada, 2021).
• Food waste is discarded and is linked to the inadequate food supply in undeveloped countries	• Eat all the food that is bought and use the compost green bin for spoiled food • Change consumerism mentality and adopt better lifestyles in eating habits by eating out less
• Severe weather events are increasing such as flooding, forest fires, and hurricanes linked to carbon and methane emissions from waste	• Reduce carbon footprint (i.e., driving less, walking more) and use renewable energy
• Households have too many bags with trash	• Cities can limit the number of bags for waste with the partial Pay-As-You-Throw (PAYT) meaning you pay a fee for additional garbage bags at the curb, limiting the number of bags allowed or having clear garbage bags (Solid Waste Master Plan, n. d.). • Adopt a circular economy approach rather than a linear approach to reduce waste • Educate the public about their waste habits and recycling habits in schools by implementing a waste curriculum in school, and through promotion posters in the workplace

	(*Awareness-raising.* Awareness-raising, n.d.). • Put recycling bins in public places like parks (Pringle, 2021).
• E-waste ends up in landfills which can have harmful effects on the environment and human health	• Recycle electronics and their parts • Spend a lot less on useless products or keep up with the latest products if not necessary.

This table examines some of the challenges and solutions associated with waste management.

V. DATA COLLECTION PROCEDURES AND SAMPLING

Data Collection and Sampling:

We first identified an area of interest in waste management such as how it is affecting the environment. Then we created research questions and formulated objectives. In our survey questionnaire, we generated both quantitative and qualitative questions. The questions are open and close-ended. There will be 50 entries and instances in total and we will have a final question for any comments or thoughts at the end of the questionnaire.

For the sampling process, we will use stratified random sampling and quota sampling methods. In the stratified random sampling method, we looked at dividing individuals into a stratum such as the geographical location of a ward in the city of Ottawa. We selected two people from the Kitchissippi ward, one person from the Innes ward, one person from Gloucester-Southgate ward and one person from Alta Vista ward. We found that people in the Kitchissippi ward and Alta Vista wards tend to have more people in their homes whereas there were fewer people in households for the Innes ward. For the quota sampling method, we used a certain quota or criteria such as the age group and how many times they went shopping. For this non-random data sampling technique, we found at least one respondent who went shopping daily who was between the ages of 18-24. Two more potential methods of data sampling include snowball and cluster sampling. This is because, for snowball sampling, we can expand our network in how we ask people about their waste habits and many people can help us gather our data this way when we do not know the whole city population. For clustered sampling, we could look at geographically dividing the population into their distinct wards and form a cluster of 50 people in each ward with one-stage sampling. According to Table 2, we listed the variables with their name, data type, format, and example to help us identify which variables to use in our data collection process.

Table III.
IDENTIFYING VARIABLES

Name	Data Type	Format	Example
Independent	Integer	Numeric	300,000 tonnes of waste
Dependent	Integer	Numeric	Household size (e.g., 6)
Intervening	String	Text	Number of times one goes shopping (e.g., many times a week)
Extraneous	Float	Numeric	GDP per capita (e.g., $43,242)
Active	Integer	Numeric	Number of cans thrown into the blue bin
Attribute	String	Text	Osgoode
Quantitative	Integer	Numeric	10 households
Qualitative	String	Text	Quality of environmental effects of waste management (e.g., soil contamination)
Continuous	Float	Numeric	Income (e.g., $55,000)
Categorical /Discrete	String	Text	Solid household waste type (e.g., paper)
Constraints	Integer	Numeric	Age > 19
Dichotomies	String	Text	Sex (e.g., male)
Polytomies	String	Text	Education level (e.g., university)

This table lists the variables with their name, data type, format, and example.

Primary Quantitative and Qualitative Data:

We will be using synthetic (imaginary) data for our dataset as primary data to fill in our proposed online questionnaire. The data will be synthetic data for this project for learning purposes. The link to the questionnaire is attached in Appendix B.

As a part of our non-participant observation method for primary data, we observed our own neighbourhood and ward. We found that many people (approximately 50 homes on our street) have used green bins for composting and throw out on average two to three garbage bags although the green bin use can still be better because Williams (2021) found that the green

bin use in Ottawa has increased only by 8% since 2018.

Secondary Quantitative Data:

The city of Ottawa's open dataset is a useful dataset for quantitative data analysis. The link to the dataset is provided in Appendix B and the attached zip file. This dataset shows the recycling and waste tonnages in tonnes by month from 2009 to 2016 in Ottawa. Through observing the dataset, we can see that garbage has decreased since 2010 because of the implementation of the green bin program and collecting garbage bi-weekly. GMP has increased, fibre and SSO decreased from 2009 to 2016. There are four listed types of waste including GMP (glass-metal-plastic), fibre, garbage, and SSO (source-separated organics). In this dataset, there are 145 instances or rows and seven columns including FID for the total number of rows.

Total residential waste has remained steady since 2005 (*Ottawa Community Foundation*, 2020). In 2010, the Green Bin program was introduced, and garbage declined by 12% compared to the previous year. In 2013, in the first year of bi-weekly garbage collection, it declined by another 18% compared to 2011 as shown in Figure 4.

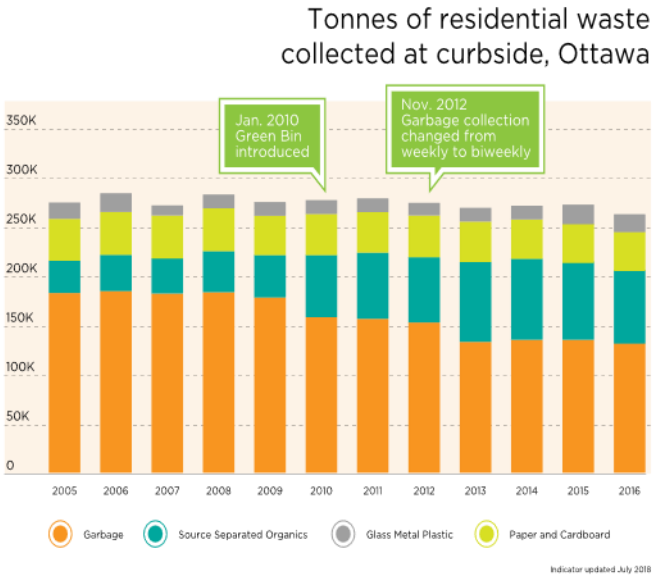


Fig. 4. Tonnes of residential waste at curbside in Ottawa from 2005 to 2016. This figure shows the tonnes of residential waste at the curbside in Ottawa from 2005 to 2016 with a range from approximately 260,000 to 280,000 tonnes. Adapted from Capital Current.

Another dataset we found pertaining to waste management is hazardous household waste and e-waste in Canada in Appendix B and the attached zip file. In this dataset, an example of the data from the respondents indicated whether they put medical sharps in the garbage or a drop-off centre. It also listed if they returned the computer parts to a recycling center or disposed of them in the garbage. The columns or features of this dataset are the dates, geographic location, the presence of several types of household hazardous waste and electronic waste (e-waste), disposal methods used in the previous 12 months, the Units of Measurement, the Units of Measurement_ID, the Scalar_Factor, the Scalar_Factor_ID, Vector, Coordinate, and Value. The link to the dataset is provided in Appendix B and the attached zip file. There are 18, 370 instances or rows.

("What a Waste", 2018) found that 5 % of global greenhouse gas emissions came from solid waste management except for transportation. A global trend the article highlighted was the region with the most waste is East Asia and the Pacific region which generates 23% of waste globally ("What a Waste", 2018).

Food waste is correlated with the number of extreme weather events occurring. There are more than 80% of the world's starving population are living in places susceptible to extreme weather events (World Food Program USA, 2021).

According to Doyle et. al, (2020), Ottawa, is one of Canada's largest cities by land area with 126 trucks travelling across 5600 kilometres every week to collect waste from 294,000 single-family homes and 1700 multi-residential buildings. These homes generated 272,692 tonnes of waste in 2018. Around 42% of waste is garbage and 58% could be diverted from landfills through the recycling and green bin programs. The percentage is from the 2018-2019 City of Ottawa Curbside Residential Waste Audit Study. The City of Ottawa 2020 waste report from the Solid Waste Master Plan also finds that about 50% of Ottawans and 33% of multi-residential buildings use the green bin.

Secondary Qualitative Data:

According to the City of Ottawa (2021), a user, Stew Watson with his username @stewart03204358, on August 11 wrote on Twitter that garbage collection should go back to once per week like before 2010 in response to a tweet by the City of Ottawa. Another user, Laskinator, wrote to expand recycling capabilities to include recyclable plastics including if it has 3 arrows on it, it can go in the blue bin. John Benjamin wrote partial pay-as-you-throw, reduce item limits with limits to garbage bags, clear garbage bags with recycling and organic bins like green bins as a comment to the Twitter post.

Another area of qualitative data is in response to this question: What are the ways you would like to be engaged on the Solid Waste Master Plan? Some responses include making recycling bins available at city parks and waste incineration like in Europe and the U.S. (*What are the ways you*, n.d.).

According to Ravenhall (2021), domestic waste is any waste that is produced at home. Some examples of qualitative data for recyclable waste include plastics, paper, cardboard, aluminum, and glass bottles. Furthermore, domestic hazardous waste includes medical waste, batteries, and refrigerators.

A Facebook post shared by the Ottawa Citizen (2021), shows that a user, Lynn Parrington, commented on incineration as a solution, and she lives in Florida near an incinerator where there was little smell and no exhaust. Another user, Andrew Cooper, disagreed saying incinerators are a solution is equal to

sweeping things under the rug. There is disagreement in a user named Rosemary O'Shaughnessy saying it contributes to air pollution. Another user, Randy Stocker, wrote that property tax in the city of Ottawa is the highest in the country. One user Helen Pichard says that she does not like clear bags as a proposed solution. Most people do not recycle or use the green bin enough. There are a variety of answers to this Facebook post.

On Reddit, a user named StuSee says blue bins are for cans and plastics, black bins for paper and cardboard, green bins for compostable items and garbage bags for everything else (I_equals_sqrt-1, n.d.).

VI. Quantitative and Qualitative Data Analysis

A. Quantitative data analysis

Primary Quantitative Data Analysis:

For the basic descriptive statistical analysis of question 28 of the self-created dataset in Excel: the min is 0 and the max is 6. The mean is 3 plastic items per week and the median is 3 as well. The question is about the plastic use of Ottawa users. The standard deviation is as shown in Figure 5 is 1.4982 standard deviations away from the mean. The graphs below are created with Microsoft Excel and Python Jupyter Notebooks.

$$\sigma = \sqrt{\frac{\sum(X-\mu)^2}{n}}$$

where,

σ = population standard deviation
$\sum$ = sum of...
μ = population mean
n = number of scores in sample.

$$\sigma = \frac{\sqrt{(0-3)^2 + (1-3)^2 + \cdots (4-3)^2}}{50}$$
$$= 110/50$$
$$= 2.2$$
$$\sigma = \sqrt{2.2}$$
$$= 1.48$$

Fig. 5. The standard deviation of question 28 in Primary Dataset

How many plastic items (straws, bags, bottles, etc.) do you use weekly? This formula calculates the standard deviation of question 28 in the primary dataset. Adapted from Rajabi, R. (2019, August 15). Using Standard Deviation in Python | by Reza Rajabi | Towards Data Science. Towards Data Science. https://towardsdatascience.com/using-standard-deviation-in-python-77872c32ba9b

Furthermore, another question we can analyze is question 29: How many garbage bags do you throw out bi-weekly? The mean for question 29 in the primary dataset as calculated in Figure 6 shown below, gives the number 3.08.

$$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) = \frac{x_1 + x_2 + \cdots + x_n}{n}$$
$$\bar{x} = \frac{1+2\ldots+2}{50} = 3.08 \approx 3$$

Fig. 6. *Mean of question 29 in primary dataset How many garbage bags do you throw out bi-weekly (every two weeks)?*

This formula calculates the mean of question 29 in the primary dataset. From Hazarika, N. (2013, June 18). *MajesticSEO Beginners Guide to Correlation: Part 3 -Majestic Blog*. Majestic Blog; https://blog.majestic.com/case-studies/majesticseo-beginners-guide-to-correlation-part-3/

Therefore, there are approximately 3 garbage bags thrown out each bi-weekly. The min for question 29 is 1 and the max number of garbage bags is 6. The greatest number of garbage bags thrown out is 6 bags and the least is 1 bag. This indicates the residents in the city of Ottawa tend to throw out 3 garbage bags on average every two weeks. To reduce the number of garbage bags thrown out every two weeks, the city could impose a fee for every garbage bag thrown out. These garbage bags from solid household waste ends up in landfills and could pollute the environment. The median number of garbage bags thrown out bi-weekly is 3. The analysis shows that many people use 3 plastic items per week and throw out on average 3 garbage bags bi-weekly. The mode for the number of garbage bags is also 3 which means there 3 bags are the most thrown out bi-weekly in this dataset. The standard deviation is 1.1577. The summary statistics are displayed in Table 4.

Table IV.
DESCRIPTIVE STATISTICS FOR QUANTITATIVE DATA ANALYSIS FOR QUESTIONS 28 AND 29 IN THE PRIMARY DATASET

Statistics for question 28: *How many plastic items (straws, bags, bottles, etc.) do you use weekly?*	**Statistics for question 29 *How many garbage bags do you throw out bi-weekly (every two weeks)?***
Count: 50	Count: 50
Median: 3	Median: 3
Min: 0	Min: 0
Max: 6	Max: 6
Mean: 3	Mean: 3
Standard Deviation: 1.4982	Standard Deviation: 1.1577

This table calculates the basic summary descriptive statistics for questions 28 and 29: "How many plastic items (straws, bags, bottles, etc.) do you use weekly?" and "How many garbage bags do you throw out bi-weekly (every two weeks)?"

	Household Size	Electronics	Electronics Recycled	Plastics	Garbage Thrown Bi-weekly
count	50.000000	50.000000	50.000000	50.000000	50.00000
mean	3.500000	3.700000	2.640000	3.000000	3.08000
std	1.644409	1.474269	1.613211	1.498298	1.15776
min	1.000000	1.000000	0.000000	0.000000	1.00000
25%	2.000000	3.000000	1.000000	2.000000	2.00000
50%	3.000000	4.000000	3.000000	3.000000	3.00000
75%	5.000000	5.000000	4.000000	4.000000	4.00000
max	6.000000	6.000000	6.000000	6.000000	6.00000

Fig. 7. Descriptive statistics of variables in the primary dataset. This figure shows the descriptive statistics of various quantitative data in the primary dataset.

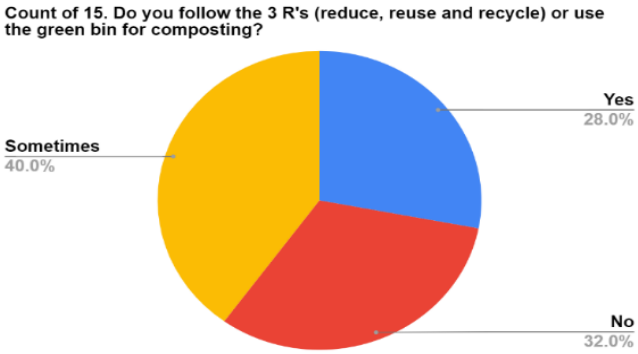


Fig. 8. *3 R's of Recycling and Composting question 15 in primary dataset Do you follow the 3 R's (reduce, reuse, and recycle) or use the green bin for composting?* This figure displays the count of the question: "Do you follow the 3 R's (Reduce, reuse, recycle) or use the green bin for composting?

Out of 50 responses, there were 14 people (28%) that said Yes, 16 people (32%) said No and 20 people (40%) said Sometimes. More people said they did not know how to reduce, reuse, recycle or use the green bin. This shows that more education and emphasis are needed on enforcing more use of the green bin and recycling in Ottawa. The pie chart shows that a lot of people said sometimes which means we still have work to do to improve Ottawan's recycling habits and green bin use.

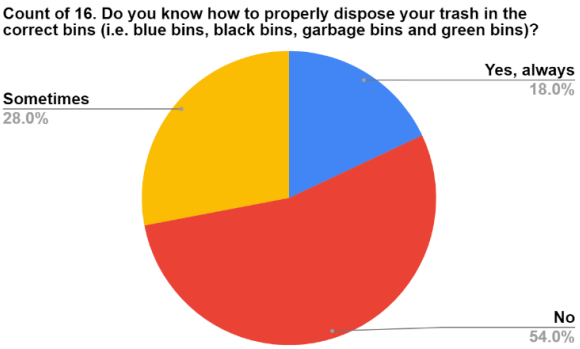


Fig. 9. *Number of people who know how to dispose of trash question 16 of the primary dataset.* This figure displays the count of the question: "Do you know how to properly dispose of your trash in the correct bins (i.e., blue bins, black bins, garbage bins and green bins)?

Out of 50 responses, there were 9 people (18%) that said Yes, always, 27 people (54%) said No and 14 people (28%) said Sometimes. This shows that more people are not able to properly dispose of items in the correct bin due to reasons like lack of knowledge or inattentiveness.

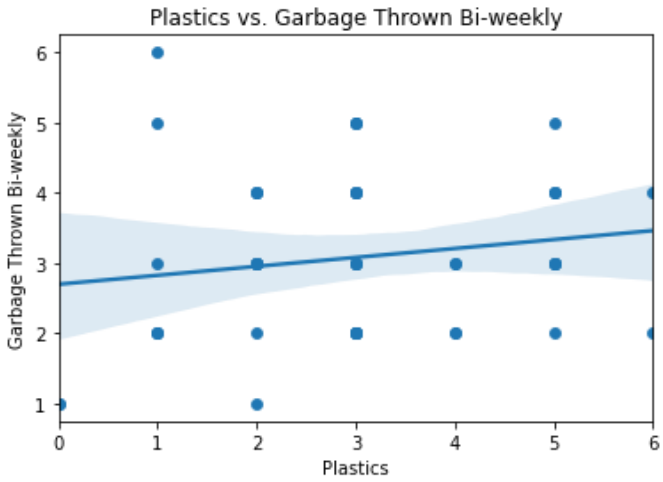


Fig. 10. *Scatterplot of Plastic Waste vs. Garbage Thrown Bi-weekly for questions 28 and 29 in primary dataset comparing the number of plastics versus the number of garbage bags thrown out weekly. Note.* This scatterplot shows the amount of plastic waste thrown out versus the number of garbage bags thrown out bi-weekly.

According to Figure 10, the scatterplot shows the correlation between the number of plastic wastes thrown out versus the number of garbage bags thrown out bi-weekly. There is a positive and weak linear correlation shown from the scatterplot. This means the more plastic that is thrown, there are slightly more garbage bags thrown out every two weeks.

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

$$r = \frac{\left(476 - \frac{(150)(154)}{50}\right)}{\sqrt{560 - \frac{22500}{50}}\sqrt{540 - \frac{23716}{50}}}$$

$$r = \frac{(476 - 462)}{(10.4880)(8.1043)}$$

r = 0.16470

Fig. 11. *Pearson correlation coefficient of question 29 in primary dataset. How many garbage bags do you throw out bi-weekly (every two weeks)?* This figure calculates the Pearson's r correlation coefficient. From Coleman, D. (2016, January 12). *Correlation Coefficient with Minitab - Lean Sigma Corporation*. Lean Sigma Corporation; https://www.leansigmacorporation.com/correlation-coefficient-minitab/

As shown in Figure 11, the Pearson correlation is 0.16470. The p-value is 0.2530. Because the p-value is less than 0.05, this means we should reject the null hypothesis and conclude the correlation is statistically significant. Therefore, it indicates there is a weak, positive linear correlation between the number of plastics and the number of garbage bags. For example, at a restaurant dinner or birthday party, people may use more plastic forks and spoons which can result in more

garbage because they would likely use dispose of more solid household waste.

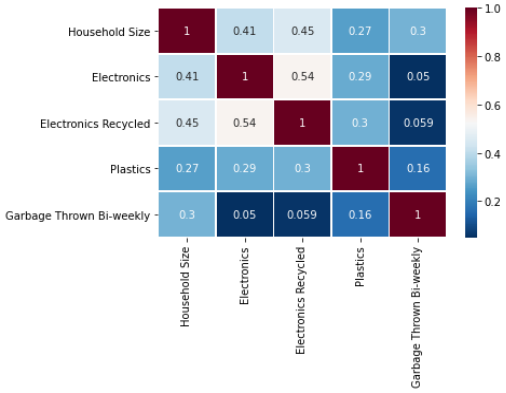


Fig. 12. *Pearson correlation heatmap.* This figure shows a Pearson correlation heatmap.

A Pearson correlation heatmap in Figure 12 shows a coefficient close to 1 meaning there is a very strong positive correlation between the two variables. The variables Household Size, Electronics, Electronics Recycled, Plastics and Garbage Thrown Bi-weekly correlate equally at 1 meaning they are all strongly correlated. Electronics and Garbage Thrown Bi-weekly have the weakest correlation at 0.05 meaning they are not correlated strongly.

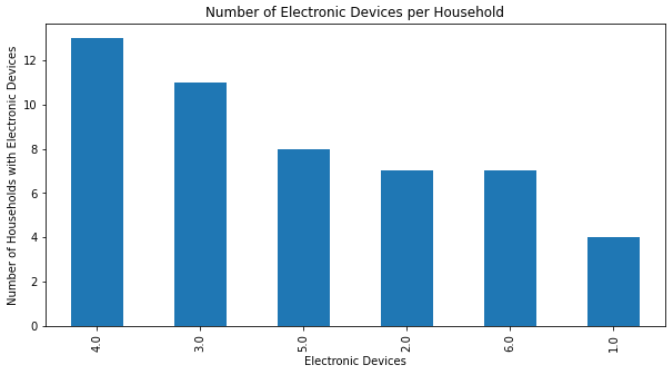


Fig. 13. *Number of electronics per household question 9 in primary dataset. How many electronic devices (TVs, radio, phones, tablets, etc.) do you have in your household?* This figure shows the frequency of the number of electronic devices per household.

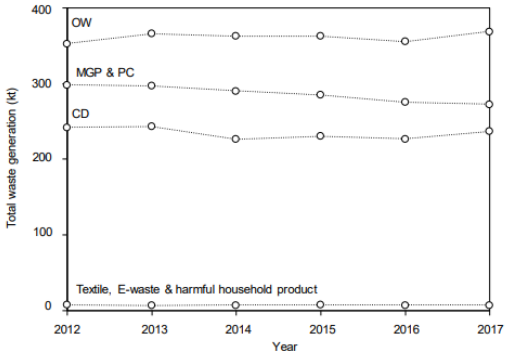
In Figure 13, we can see the frequency of the number of electronic devices per household in the histogram. The greatest number of electronic devices in a household is 5 devices and the least number of electronic devices is 1 device. There are as many as 13 households that have 4 electronic devices 4 households have 1 electronic device. Therefore, many households have between 1 to 5 electronic devices. The number of electronic devices could depend on whether they can afford the device or if they tend to recycle their electronic devices rather than throwing them into the landfill.

Waste management affects cities in under-developing and developing countries such as Jordan, Pakistan, and Bangladesh. According to Abu Qdais et al. (2019), in Jordan, the greenhouse gas emissions include 3.365 million Mg disposed of municipal solid waste that is collected yearly. Food waste affects the environment and by producing greenhouse gas emissions such as carbon dioxide, methane, and other greenhouse gasses. In Bangladesh, food waste accounts for 68.3-81.1% of solid municipal waste (Ananno et al., 2021). Furthermore, in Bahawalpur, Pakistan, the streets are filled with 95% of solid municipal waste which affects people's health and the environment by contributing pollution to the atmosphere (Safar et al., 2021). Throughout these studies, we have found waste management is a concern for the health and environment of many cities worldwide. It is therefore imperative to take action with waste management as it is correlated with the climate change crisis.

Table V.
COMPARING CITES IN CANADA

Regina	Ottawa	Montreal
The article "Waste disposal characteristics and data variability in a mid-sized Canadian city during COVID-19" (Richter et. al, 2020) explains how waste disposal of COVID-19 varied during the pandemic as shown in Figure 15 (Richter et. al, 2020). Regina's waste generation decreased from 800 tonnes in 2019 to 400 to 500 tonnes in 2020 because of COVID-19.	Ottawa's waste data shows that the tonnes of waste increased from 2005 to 2016 from 276432 to 283022 as shown in the attached curbside recycling 2005 to 2016 secondary dataset.	In Montreal, total waste generation decreased from 970 kilotons in 2012 to 931 kilotons in 2017 as shown in Figure 14 (Malmir et. al, 2020).

Note. This table compares the amount of solid household waste in Canadian cities.



All of the cities have decreased waste from their respective years. Interestingly, Montreal has the most amount of waste generation with 970 kilotons or 970,000 tonnes due to its population size, but Ottawa comes in close with 276,432.

tonnes. Regina's waste generation decreased from 800 tonnes in 2019 to 400 to 500 tonnes in 2020 because of COVID-19.

Fig. 14. *Waste in tonnes in Montreal from 2012 to 2017.*

This figure shows the waste in tonnes in Montreal from 2012 to 2017 according to the types including OW: organic waste, PC: paper and cardboard, MGP: metal, glass, plastic, CD: construction and demolition waste, and E-waste: electronic product. In Montreal, total waste generation decreased from 970 kilotons in 2012 to 931 kilotons in 2017. The average amount of OW, MGP and PC, CD, and textile, E-waste & harmful household products was 361 kilotons, 286 kilotons, 234 kilotons, and 8 kilotons, respectively. Many factors may have affected the decrease in waste like digital instead of paper waste, reduction of consumption and packaging material.

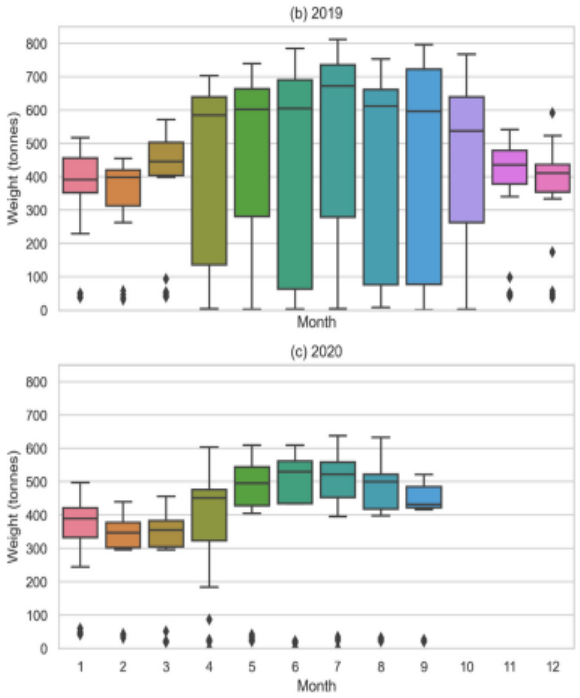


Fig. 15. *Comparison of waste generation in tonnes in Regina from 2019 versus 2020 by month.*

Comparison of waste generation in tonnes in Regina from 2019 versus 2020 by month. The colour represents each month. Regina's waste decreased in 2020 starting in January with around 400 to 500 tonnes because of the COVID-19 pandemic especially in the summer months where fewer people were travelling compared to 2020 and thus not harming the environment and generating more waste.

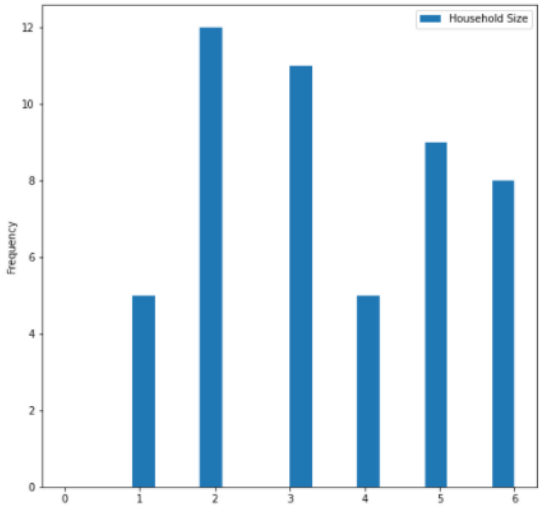


Fig. 16. *Histogram of average household size*. The histogram shows that the average household size or most frequent household size is 2 people per household with a frequency count of 11.

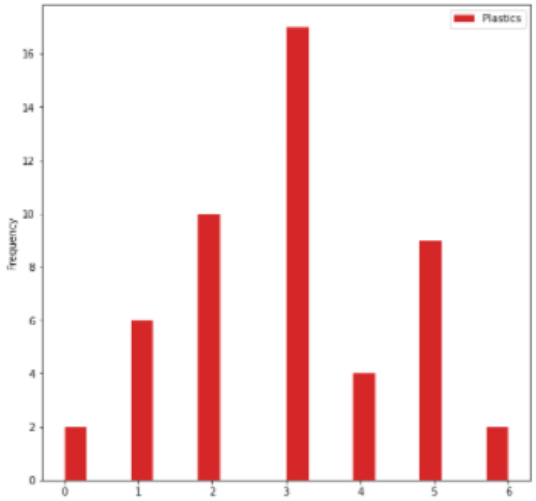


Fig. 17. *Frequency of plastics thrown out per week*

This figure shows that the frequency of plastics thrown per week is 17 and 3 plastic items are the most in terms of frequency counts. More plastic is being thrown out because people are eating out, shopping and not eating at home.

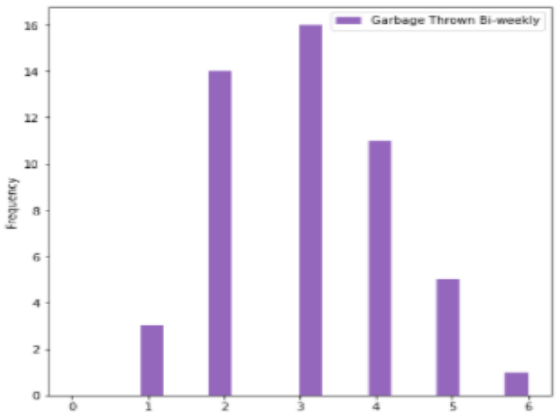


Fig. 18. *Garbage Thrown Bi-weekly.* This figure shows the frequency of garbage bags thrown bi-weekly in Ottawa.

The highest frequency is 16 and 3 bags. Therefore, we can conclude that the average and the maximum number of garbage bags thrown biweekly is 3 bags in Ottawa. Most residents do not surpass this number as the maximum is 6 garbage bags per household. Most households throw out three garbage bags because they have fewer family members.

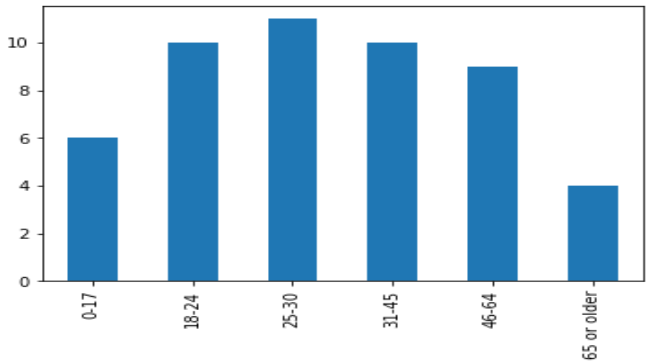


Fig. 19. Bar Graph of Age Groups**.** This figure shows the different age groups. There are more 25–30-year-olds with a frequency count of 11 out of 50. This can be because this is the age where maturity is most developed to know how to recycle and figure out waste management strategies.

B. Secondary Primary Data Analysis

Our secondary dataset on Ottawa's household waste tonnage levels from 2009 to 2016 shows the average for the year 2005 is 14995.3333 for garbage in tonnes with a count of 12 and a standard deviation of 1522.9162 and the average for the year 2016 for garbage is 11066.4615 with a count of 12 and a standard deviation of 1053.4911. The mean and standard deviation has decreased from 2005 to 2016 by around 3929 tonnes and 492 tonnes respectively. The summary statistics are displayed in Table 6.

Table VI.
DESCRIPTIVE STATISTICS FOR QUANTITATIVE DATA ANALYSIS

Statistics for 2005	Statistics for 2016
Count: 12	Count: 12
Mean: 14995.3333	Mean: 11066.4615
Standard Deviation: 1522.9162	Standard Deviation: 1053.4911

This table shows the descriptive statistics for 2005 and 2016 respectively.

	Year	GMP	Fibre	Garbage	SSO	Total Rows
count	145.000000	143.000000	143.000000	143.000000	143.000000	145.000000
mean	2010.537931	1385.167832	3608.125874	13372.615385	4835.538462	73.000000
std	3.482138	188.366551	443.478851	2232.327362	3273.946500	42.001984
min	2005.000000	1017.000000	2564.000000	8277.000000	21.000000	1.000000
25%	2008.000000	1221.500000	3291.500000	11730.000000	2361.000000	37.000000
50%	2011.000000	1391.000000	3624.000000	13615.000000	4246.000000	73.000000
75%	2014.000000	1530.500000	3910.000000	15169.000000	7330.500000	109.000000
max	2016.000000	1941.000000	4644.000000	17610.000000	13914.000000	145.000000

Fig. 20. *Descriptive statistics for the secondary quantitative dataset.* This figure describes the various descriptive statistics for the secondary quantitative dataset.

Figure 21 and 22 shows the waste tonnages and recycling levels from 2005 and 2016 by month to compare the waste tonnages over time. In 2005, there was more garbage and SSO (source-separated organics) than in 2016.

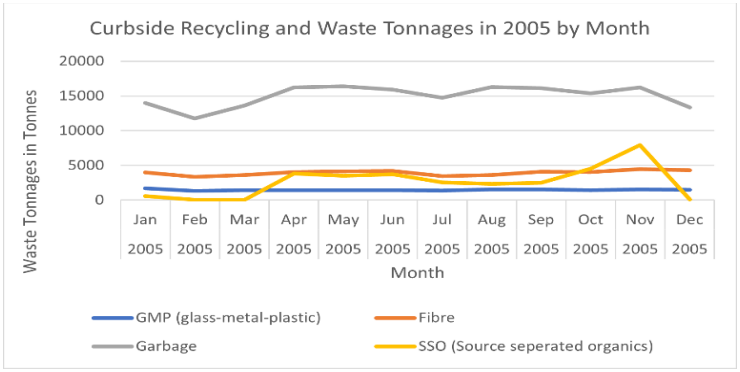


Fig. 21. *Curbside recycling and waste tonnages in 2005 by month.* This chart shows the number of waste tonnages in curbside recycling in 2005 by month.

The curbside recycling and waste tonnages for 2005 varied. GMP was a steady amount, Garbage and Fibre were also consistent, but SSO increased and had a sharp decrease by the end of the year. Landfill gas from the landfills and other factors like the number of garbage bags have caused the waste tonnages to increase over the years.

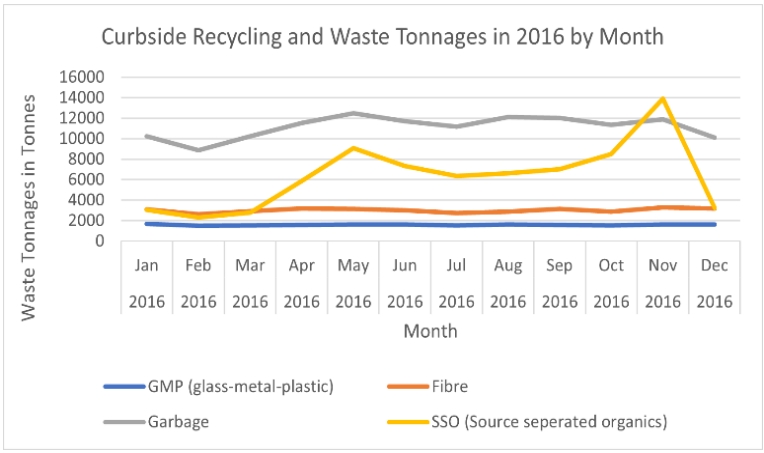


Fig. 22. *Curbside recycling and waste tonnages in 2016 by month***.** This chart shows the number of waste tonnages in curbside recycling in 2016 by month.

The curbside recycling and waste tonnages for 2016 varied again. GMP was a steady amount, Fibre was also consistent, Garbage had a slight decrease and SSO increased by a wider amount than 2005 and had a sharp decrease by the end of the year. Source separated organics increased in 2016 because more people are using the green bin to compost, but the amount is still insignificant.

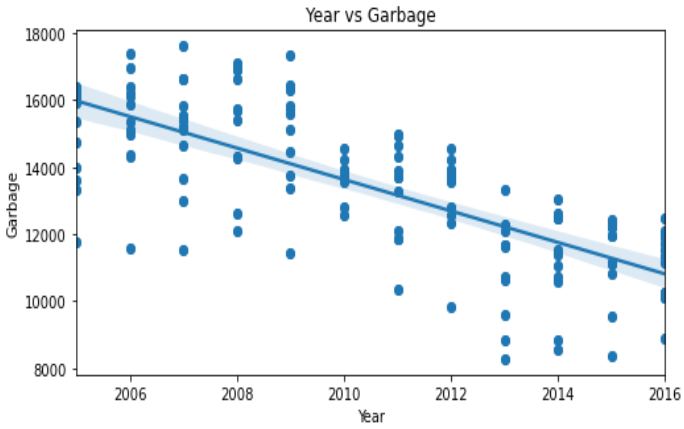


Fig. 23. *Scatterplot of the year versus garbage.* This scatterplot shows a strong, negative correlation between the number of years and garbage.

This scatterplot compares year versus garbage. It is a weak negative correlation because the placement of the points is not all close to the line of best fit. As the years go by from 2005 to 2016, the tonne of garbage decreases from 17610 to 8277 tonnes because garbage collection changed from being collected weekly to bi-weekly. More people are using the green bin and recycling and over time, garbage has decreased. The value of r is -0.7378 implying a strong negative correlation.

C. Market Basket Analysis

For market basket analysis of the primary quantitative data, we can use household size and garbage bags thrown bi-weekly as shown in Table 7. The minimum support is 3 and we count the frequency for household size and garbage thrown bi-weekly removing the second itemset. The frequent itemset is {3, 4, 5, 6}.

Table VII.
MARKET BASKET ANALYSIS FOR PRIMARY QUANTITATIVE DATA

Itemset for Household Size	**Count**	**Itemset for Garbage Thrown Bi-weekly**	**Count**
~~2~~	~~12~~	~~2~~	~~14~~
3	11	3	16
4	5	4	11
5	9	5	5
6	8	6	1

Itemset for Household Size	**Count**	**Itemset for Garbage Thrown Bi-weekly**	**Count**
3	11	3	16
4	5	4	11
5	9	5	5
6	8	6	1

D. Primary Qualitative Data Analysis

Question 2 of the questionnaire says, "How can we reduce our spending habits"? Some responses are buy what we need, think before we buy, drive less, travel less, etc. To do an affinity diagram, we sort it into categories like Buying habits, Budget preparation, Carbon footprint activities, and Transportation methods.

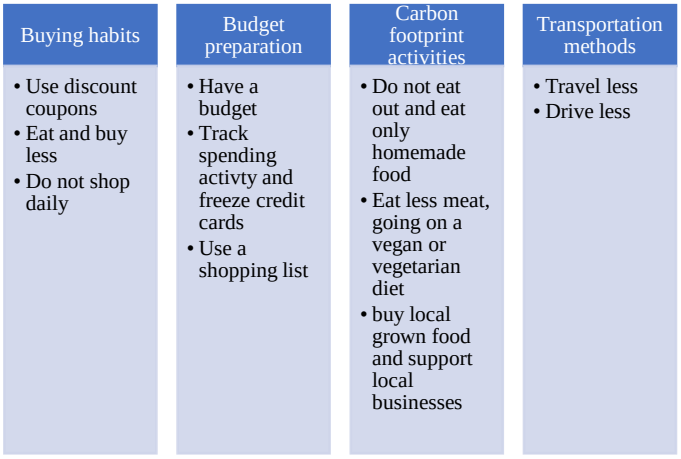


Fig. 24. *Affinity diagram for question 2 of primary dataset "How can we reduce our spending habits?"* Affinity diagram for question 2 of primary dataset

For Question 11 of the primary dataset, "Why is recycling important for waste management?", we want to answer the following questions after doing qualitative data analysis:

1. What does help reduce, save, and conserve waste management practices and environmental protection?
2. Why should we recycle to help waste management and landfills?

Table VIII.
QUALITATIVE DATA ANALYSIS FOR QUESTION 11 IN PRIMARY DATASET "WHY IS RECYCLING IMPORTANT FOR WASTE MANAGEMENT?"

Respondent's answers to question 11: Why is recycling important for waste management?	**Added Codes**
helps the environment **[ENV]**, helps reduce waste going into the landfills **[REDUCE]**, so we can reuse materials and reduce our waste **[REUSE, REDUCE POLLUT]**, helps us reuse materials instead of throwing them out **[REUSE]**, reduces pollution **[REDUCE POLLUT]**, saving energy and helping sustain natural resources **[ENERGY]**, saving	*Why should we recycle to help waste management and landfills?* **[ENV]** – Helps the environment (5) **[REUSE]** – Reuse materials (3) **[REDUCE POLLUT]** – Waste reduction and reduces pollution (7) **[DIVERTS]** – Diverts waste from landfills (6)

energy **[ENERGY]**, preserving natural resources **[NAT RESOURCES]**, saves energy **[ENERGY]**, conserves trees **[TREES]**, saves energy **[ENERGY]**, diverts waste from landfills **[DIVERTS]**, helps businesses save lots of money on waste management **[MONEY]**, because it helps reduce waste in landfills and they can last longer **[REDUCE POLLUT]**, conserves out natural resources and saves energy **[ENERGY, NATURAL RESOURCES]**, saves money **[MONEY]**, helps the environment by not having organics go to landfills **[ENV]**, recycling is to reduce energy usage **[ENERGY]**, reduce the volume of landfills **[REDUCES LANDFILLS]**, reduce air and water pollution **[AIR, WATER]**, reduce greenhouse gas emissions **[GHGs]**, and preserve natural resources for future use **[NAT RESOURCES]**, reduces food waste **[FOOD]**, save energy **[ENERGY]**, creates jobs **[ECONOMY]** and reduces pollution **[REDUCE POLLUT]**, saves energy **[ENERGY]**, saves diversion from landfills **[DIVERTS]**, helps waste diversion **[DIVERTS]**, creates jobs **[ECONOMY]**, makes less work for workers to sort items **[SORT]**, divert waste from landfills **[DIVERTS]**, makes people think of where their waste goes **[THINK]**, reduces cost to landfills and it's cheaper **[PRICE]**, helps divert waste from landfills **[DIVERTS]**, helps reduce methane **[GHGs]**, improve waste diversion **[DIVERTS]**	**[REDUCES LANDFILLS]** –Reduces waste going into the landfills (10) **[CLEAN AIR]** – Creates cleaner air (2) *What does help reduce, save, and conserve waste management practices and environmental protection?* **[ENERGY]** – Saves energy (8) **[LAND]** – Reduces land pollution (1) **[NAT RESORUCES] –** Preserves natural resources (2) **[MONEY]** – Saves money (3) **[SOIL]** – Reduces soil pollution (1) **[TREES]** – Conserves trees (1) **[AIR]** – Reduces air pollution (3) **[WATER]** – Reduces water pollution and contamination (2) **[GHGs]** – Reduces greenhouse gas emissions (3) **[FOOD]** – Reduces food waste (1) **[ECONOMY]** – Creates jobs (2) **[SORT]** – Creates less work for people to sort the materials (3) **[THINK]** – Helps people think about where specific items should go (1) **[PRICE]** – Reduces cost to landfills (1)
Recycling reduces waste and reuses materials **[REDUCE LANDFILLS, REUSE]**. Recycling helps reduce waste **[REDUCES LANDFILLS]**. Recycling helps the environment by reducing pollution **[ENV, REDUCE POLLUT]**. Recycling helps reduce waste and greenhouse gas emissions **[REDUCES LANDFILLS, GHGs]**. Recycling helps reduce waste **[REDUCES LANDFILLS]**. It reduces air and land pollution **[AIR, LAND]**. It helps reduce waste **[REDUCE LANDFILLS]**. Recycling keeps the air clean **[CLEAN AIR]**. Recycling helps the environment **[ENV]** and is important in sorting materials for waste management **[SORT]**. Recycling helps reduce pollution **[REDUCE POLLUT]**. Recycling reduces air, water, and soil pollution **[AIR, WATER, SOIL]**. Recycling reduces waste and pollution **[REDUCE POLLUT]**. Recycling reduces waste and helps the environment **[REDUCES LANDFILLS, ENV]**. Recycling helps create greener air **[CLEAN AIR]**. Recycling helps reduce waste and sort materials efficiently **[REDUCES LANDFILLS, SORT]**. Recycling is important to reduce waste **[REDUCES LANDFILLS]**. Recycling is important to reduce waste. [**REDUCES LANDFILLS]**.	

Qualitative data analysis using open coding for question 11 "Why is recycling important for waste management?"

In the primary dataset, we used open coding for qualitative data analysis and found that for the majority of the data, 10 people say recycling reduces landfills and 8 people say it helps save energy. Recycling helps the environment by reducing waste and pollution. It saves money and creates jobs to help the economy and environment.

For systematic coding, we can the following codes for qualitative data analysis for question 13 of our primary dataset "What are some ways to reduce household waste in Ottawa? ": Recycling (R), Thinking (T), Trees (Tr), Electricity (E), Education (Ed), Composting (Com), Green bin (Gb), Local (Lo), Garbage (G), Lifestyle (L), Plastics (P), Reuse (Re), Food (F), Consumerism (C), and Environment (En).

1. Recycling (R)
2. Buy only materials that we need so there will be fewer materials thrown out. (L), (C)
3. Spend less and buy less to reduce our household waste. (C)
4. Donate or sell materials to secondhand stores or friends/family. (Lo)

5. Spend less on materials you do not need. (C)
6. Recycle and reuse materials. (R), (Re)
7. Change our lifestyle and carbon footprint (i.e., walk more, drive less, public transportation, support local businesses, etc.) (L)
8. Spend less on materials we do not need to consume less. (C)
9. Avoid using plastic straws, bags, and wrapped materials. (P)
10. Think before throwing out/disposing of materials. (T)
11. Recycle batteries and bring paint to household waste disposal. (R)
12. Think before buying or spending materials. (T)
13. Reuse and recycle paper to prevent deforestation. (Tr), (Re), (R)
14. Buy second-hand and donate used items. (Lo)
15. Ban single-use plastics and plastic water bottles. (P)
16. Repair and fix materials, use less electricity when not needed. (L), (E)
17. Reuse and recycle materials. (Re), (R)
18. Use a reusable water bottle. (Re)
19. Plant more trees. (Tr)
20. Avoid buying packaged materials. (L), (C)
21. Recycling more and use the green bin. (R)
22. Reduce electrical consumption. (E)
23. Do not buy materials we do not need in the first place. (C)
24. household waste can be reduced in Ottawa by reusing reusable bags. (Re)
25. Avoid plastic-wrapped and single-use items. (P)
26. Use renewable energy. (E), (En)
27. You can reduce waste by recycling and composting. (R), (Com)
28. You can reduce waste by recycling and composting. (R), (C)
29. Pay-as-you-throw with a fee for additional garbage bags. (G)
30. Pay-as-you-throw fee, limit number of bags, clear bags, and more education needed in all sectors and industries. (Ed)
31. Need to educate more people about the benefits of a recycling program, and more funding from the government about composting and recycling programs. (Com), (R), (Ed)
32. When it comes to reducing waste, such options are but are not limited to: - limiting the number of waste bags allowed per household – encouraging the use of recycling bins. (G), (R)
33. Separating mattresses and furniture for better recycling. (L)
34. Banning green bin organics from the garbage. (Gb)
35. Refuse items not necessary to buy. (L), (C)
36. Avoid unnecessary packaging and individually wrapped items. (C)
37. Repurpose items (L), (Lo)
38. Choose to go paperless for your bills, receipts & documents, for example, your water bill or property taxes. (C)
39. Use old documents as scrap paper to write notes or lists. (R)
40. Closing garbage chutes in multi-residential buildings. (G)
41. Limiting the number of bins curbside. (G)
42. Buy local (Lo), (Com)
43. Recycling in parks (R)
44. Do not eat preprocessed and packaged food a lot daily. (F)
45. Reduce meat consumption. (F), (C)
46. Eat less outside. (F)
47. Extend product's lifecycle (L), (En)
48. Eat less packaged and canned food. (F)
49. Do not waste food. (F), (E)
50. Eat less at restaurants. (F)
51. Reuse paper. (R)
52. Throw out less garbage. (G), (C)

From the list we can record the frequency of each code:
Recycling (R): 11
Thinking (T): 1
Trees (Tr): 2
Electricity (E): 4
Education (Ed): 2
Composting (Com): 2
Green bin (Gb): 1
Local (Lo): 4
Garbage (G): 3
Lifestyle (L): 8
Plastics (P): 3
Reuse (Re): 5
Food (F): 6
Consumerism (C): 12
Environment (En): 2

We can see several factors that influence how we can reduce our waste and help the environment. The most crucial factor is to reduce consumerism and consumption of materials followed by recycling which is the response with the second-highest frequency. This is important because a lot of solid household waste comes from consuming too many materials.

D. *Secondary Qualitative Data Analysis*

We can use open coding from this Facebook comment from the Ottawa Citizen (2021). Lynn Parrington commented on incineration as a solution, and she lives in Florida near an incinerator where there was little smell and no exhaust. The question to ask is What are some solutions to add to the Solid Waste Master Plan in Ottawa to deal with the growing amounts of waste? We can categorize it as IN [1], FL [1], SM [1], LIT EXH [1], LAND [1], C [1], SM [1], LRT [1].

Table IX.
QUALITATIVE DATA ANALYSIS FOR SECONDARY DATASET

Answer to Facebook comment	**Added Codes**
I'm shocked the city has never invested in an incinerator **[INCINERATOR]**. I lived near one in Florida **[FLORIDA]** - there was no smell **[SMELL]**	IN [1], FL [1], SM [1], LIT EXH [1], LAND [1], C [1], SM [1], LRT [1].

and very little exhaust **[LITTLE EXHAUST]**. Significantly less than what comes off the landfill **[LANDFILL]** on Carp Road **[CARP]**. Let us be forward-thinking people-this would be a smart investment **[SMART]**. Perhaps better than the LRT **[LRT]**?	

Open coding of a secondary dataset.

For systematic coding, we can put pre-defined codes for another comment. Stew Watson with his username @stewart03204358, on August 11, 2020, wrote on Twitter that garbage collection should go back to once per week like before 2010 in response to a tweet by the City of Ottawa.

The pre-defined codes are

1. Recyclable plastics [RP],
2. Blue bin [B].

Another user, Laskinator, wrote to expand recycling capabilities to include recyclable plastics including if it has 3 arrows on it, it can go in the blue bin. John Benjamin wrote partial pay-as-you-throw, reduce item limits with limits to garbage bags, clear garbage bags with recycling and organic bins like green bins as a comment to the Twitter post by the City of Ottawa (2021).

The pre-defined codes are

1. Partial pay-as-you-throw [PPAYT],
2. Limit [L],
3. Recycling [R],
4. Clear garbage bags [C],
5. Organic bins [O].

Table X.
QUALITATIVE DATA ANALYSIS FOR SECONDARY DATASET

A question to ask is: "What are some solutions for Ottawa's Solid Waste Master plan?"

Answer to tweet	Pre-defined Codes
Answer to tweet:" We need to expand our recycling capabilities to include all [**RECYCLABLE PLASTICS**]. If it has got a 3-arrow logo on it, I want to be able to toss it in the [**BLUE BIN**]. Limiting what I buy can only go so far."	1. **RECYCLABLE PLASTICS** - [RP] – (1), 2. **BLUE BIN** - [B] (1)
Another tweet by John Benjamin: "As a person with 3 disabilities, I prefer: •**PARTIAL PAY-AS-YOU-THROW**: Households would be allowed to place a set number of garbage items out for collection. Households with more than this **LIMIT** would purchase garbage tags for each additional item. **RECYCLING**, organics, and … The City of Ottawa is considering choosing one of three possibilities: **Partial PAY-AS-YOU THROW**: Reduced item limits: **CLEAR GARBAGE BAGS** with **RECYCLING** and **ORGANIC BINS**: have your say."	1. **PARTIAL PAY-AS-YOU-THROW** - [PPAYT] - (2), 2. **LIMIT** - [L] - (1), 3. **RECYCLING** – [R] – (2), 4. **CLEAR GARBAGE BAGS** - [C] – (1), 5. **ORGANIC BINS** - [O] – (1)

Systematic coding of a secondary dataset.

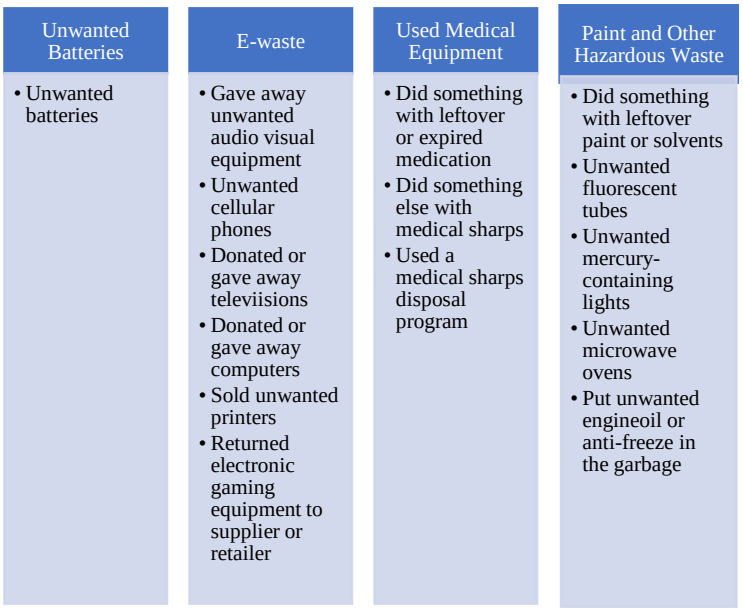


Fig. 25. *Affinity diagram for the hazardous household waste secondary dataset*. Affinity diagram for hazardous household waste of secondary dataset.

In Figure 25, the affinity diagram for hazardous waste, we found many people sold or throw out e-waste, medical equipment, batteries, and paint among many other types of household hazardous waste. However, there are many recycling programs for medical equipment/needles, batteries, and e-waste instead of throwing them into the garbage.

VII. Discussion and Results

Through our detailed and in-depth data analysis of the datasets and data, we found that solid household waste management affects the environment and contributes to greenhouse gas emissions through methane, landfill gas. Green bin needs to increase, and it has helped in reducing garbage since 2010 when the green bin program was introduced from 17610 to 8277 tonnes of garbage by diverting waste away from landfills. Our literature found that methane is 25 times more potent than carbon dioxide, a contributing factor to climate change. In our literature survey and review, we found that food

waste is a contributor to methane, a more harmful greenhouse gas than carbon dioxide. Therefore, there needs to be a reduction in food waste because there are many cities where food security is a concern as inflation rises for food prices. Furthermore, food waste can be reduced by using the composting bin and buying food that you will not throw out because you bought too much food.

The implications of our results through the data analysis are that there needs to be more recycling and Ottawa can do a lot more to improve waste going to landfills. The green bin has helped, but it can still be used more. The results are relevant and useful because they can help inform residents in Ottawa where they can improve in managing their waste and areas that are lacking like if they recycle often or use the green bin.

E. SWOT Analysis

For SWOT analysis, we can focus on waste management in Ottawa.

Strengths:

- Green bins divert waste away from landfills.
- Recycling programs help reduce greenhouse gas emissions that speed up climate change

Weaknesses:

- Lack of education on waste management
- Lack of recycling in the city

Opportunities:

- Job opportunities in waste reduction
- Economic spending in the waste management industry to deal with climate change

Threats

- Climate change as a result of landfills and its pollution in the atmosphere
- Lifestyle, consumerism, and overconsumption means people buy too many materials they do not need
- Food waste, e-waste, and hazardous waste emit air, land, and soil pollution
- Growth of population

VIII. Further Research

For further research, we could do a study on the effects of waste in Ottawa on the economy with similar impacts because the economy is also a key factor in Ottawa's goals of mitigating the waste diversion rate from landfills. The cost to the economy is no small figure and it would be worthwhile to investigate the cost.

IX. Conclusion

In this paper, we have studied and analyzed the environmental effects of waste management and presented a detailed analysis of the ways to reduce solid household waste. We have found that waste management is affecting the environment and contributes to climate change because landfills produce greenhouse gas emissions such as methane and carbon dioxide. Smart cities and IoT technology have been used to help the waste management industry be more efficient in sorting their waste. Lifestyle and consumerism are factors that can influence a person's buying behaviour that correlates with the number of materials purchased which eventually ends up in the landfills. Through our hypothesis question and literature, we can conclude that we need to do more to reduce waste in Ottawa by having more effective waste programs like the green bin by enforcing or educating the population. Residents in the city of Ottawa could be more educated and aware of the green bin program as well as the recycling program to reduce waste and contribute to the sustainability of ecosystems. There are lax recycling rules and regulations, and it needs to be stricter to improve recycling rates in Ottawa. Landfills pose potential harm to human health and the surrounding environment and waste generated in landfills must be reduced. This research paper has helped us analyze our waste habits and reflect on how we can help reduce our waste to preserve the lifespan of the landfills in Ottawa and especially in solving climate change at climate change conferences like COP26.

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Appendix A

Table I.
COMPARATIVE ANALYSIS OF WASTE MANAGEMENT TECHNOLOGIES AND IMPACT ON LANDFILLS

References (Name and Year)	Method	Results	Limitations	Data Identification	Sample Size	Data Type	Test
Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management (Nižetić et al., 2019)	Renewable energy technologies, IoT technologies	The results revealed a cloud-based model could be more efficient productive at monitoring crop levels with an accuracy of 94%.	Electricity generation techniques and transmission of electricity	Number of Internet-connected devices and electronic vehicles	Global food waste of 115 kg/consumer in developed countries	Quantitative	Linear Regression
Household waste management system using IoT and machine learning (Dubey et al., 2020)	IoT, Machine Learning, Smart City	A machine learning model uses the KNN approach with 93.3% accuracy to detect alert messages of hazardous waste.	There may be errors in sending an alert message when the sensors fail to detect data from the dustbin.	Biodegradable and non-biodegradable waste	100 samples	Quantitative	Supervised machine learning, KNN for classification
The use of waste diversion indices on the analysis of Canadian waste management models (Pan et al., 2018)	GDP, Waste diversion rate, MSW generation	BC's waste diversion rate was the highest with 32% and SK with the lowest average diversion rate with 13.8%.	Only non-hazardous waste was analyzed	GDP on the waste management output index (WMOI)	25 million tonnes of non-hazardous waste in 2014 with a daily per capita rate of 2.63 kg/cap	Quantitative	ANOVA, Comparative Analysis, and Multiple Regression

Organic Waste Management in Canada: Building a Sustainable Circular Economy (Perger, 2019)	Observation of behaviour of methods of people in Quebec	Decrease landfill life to preserve impacts on the surrounding community	There is no ideal path or an ideal cycle of sustainability and there is also not enough data about organic food waste in Canada	Data over four years using the observation method	Municipality groups in Quebec	Qualitative	Linear regression between fuzzy model and actual data.
Investigation of greenhouse gas emissions and energy practices. Environmental Development (Yaman, 2020)	Three methods were used: landfilling recovery with LFG recovery, composting and incineration	Total GHG emissions for each scenario was estimated subtracting the avoided GHG emissions from the generated GHG emissions	There is a limit of cities in Turkey for analyzing the data	Amount of methane greenhouse gas emissions from landfills in tonnes	Those living in Kocaeli, Turkey and other surrounding cities	Quantitative and qualitative	The process of blue ocean strategy created
Impacts of COVID-19 Outbreak on the Municipal Solid Waste Management: Now and beyond the Pandemic (Roy et al, 2020)	Search engines like Google Scholar and news articles to look at the literature of municipal waste management before and during the COVID-19 pandemic	Increase in MSW waste due to the pandemic	Emission limit and composition of waste in different regions and countries	Solid waste management data and number of COVID-19 cases	Municipalities around the world	Quantitative and qualitative	Compositional Bayesian regression to predict waste generation
Waste disposal characteristics and data variability in a mid-sized Canadian city during COVID-19 (Richter et al., 2021)	Data visualization techniques and data from Regina's landfill from 2013-2020	Increase in MSW waste during the pandemic	Emission limits in different regions and countries around the world	Solid waste disposal in tonnes	Those living in Regina during the pandemic	Quantitative	Laboratory testing of COVID-19 versus the biomedical waste disposed of with a bimodal relationship

The Impact of COVID-19 on Consumer Food Waste. *Applied Economic Perspectives and Policy* (Roe et al., 2020)	Distribution of household food waste during the pandemic	Increase in homemade food	No data between front-of-house and back-of-house sources	Amount of food waste by consumers	500 US consumers during the pandemic	Quantitative	Employment rate and food waste disposal rate
Solid waste management: Scope and challenge of sustainability (Das et al., 2019)	Solid Waste Management, Environmental Issues, RFID	The amount of global waste generation was 40% in developed countries whereas it was 37% in developing countries and 23% in undeveloped countries.	Lack of skilled labour for working with sanitary landfills	Solid Waste Management	18 cities in various countries	Quantitative and Qualitative	Sampling, Z-score, Correlation Analysis
Prediction of greenhouse gas emissions from Ontario's solid waste landfills using a fuzzy logic-based model (Mohsen and Abbassi, 2019)	Fuzzy based programming with seven parameters: total waste, the content of waste, temperature, annual precipitation, age, depth, and cover of the landfill	The fuzzy model was verified with and compared with a measured gas flow rate. The coefficient of determination (R^2) measured the accuracy of the prediction of the fuzzy logic model	Lack of data to fuzzy model to be predicted accurately	Measured gas flow rate	30 landfills in Ontario	Quantitative	Linear regression between fuzzy model and actual data.
E-waste management and its effects on the environment and human health (Rautela et al., 2021)	E-waste, Pollution	There was 17.4% of e-waste collected and 82.6% abandoned.	The policies for effective waste management will depend on several parts such as the financial support of the government, the growth of the economy, and the involvement of the community.	E-waste in select countries	The concentration of heavy metals from improper recycling	Quantitative and Qualitative	Rate of e-waste collected

Appendix B: Links to Questionnaire and Datasets

Link to the questionnaire:
https://docs.google.com/forms/d/e/1FAIpQLSeCmllFK27KtVMGfyndF67cWOa1svJT2U0kMuQkNSIdNM5qqQ/viewform?usp=pp_url

Link to the hazardous e-waste secondary dataset:
https://www150.statcan.gc.ca/n1/tbl/csv/38100126-fra.zip

Link to the curbside recycling 2005 to 2016 secondary dataset:
https://open.ottawa.ca/datasets/ottawa::curbside-recycling-and-waste-tonnages-2005-2016/about

The Python codes and libraries are attached in a zip file as both CSV and Excel XLSX files and Jupyter Notebook IPYNB files.