The Effects of Waste Policy on Waste Production:
The Zero Waste Framework

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Introduction

Since countries began to industrialize beginning in the late 1700s and the production of goods consequently increased exponentially around the globe, nations currently face the increasingly pressing issue of waste build-up (Scheinberg, 2012). As countries become more industrialized, urbanized, and the general consumption of goods grows, trash production also continues to increase at an exponential level. A report released by the World Bank revealed that 2.01 billion tons of municipal solid waste was generated globally in 2016 with future predictions indicating these current quantities could increase by as much as 70 percent by 2050 (The world Bank, 2016). Along with the issues that have come about due to the sheer amount of waste that is produced, Kaza et al. (2018) has made it clear that the unethical management practices towards waste have exacerbated numerous environmental tragedies. Researchers studying the effects of waste build-up continue to emphasize the pressing need to address global waste production both at a government level through policy interventions and at the individual level in the household. Considering the differences in development among countries, effective solid waste management policy unique to individual locations is clearly necessary in order to create healthy, inclusive, and sustainable communities.

This present research examines the example and possible effects of one government implemented waste policy by asking the question: How has the Zero Waste Policy adopted in many large cities throughout the United States targeting waste production affected the quantity of waste produced? It will analyze the qualitative aspects of the Zero Waste Policy to provide a detailed overview of how the policy has been applied in each city. Further quantitative analysis on public city data for Los Angeles, California, and Austin, Texas, two of the largest cities that have pledged their commitments to zero waste will be conducted. Then, the public city data for Phoenix, Arizona will be analyzed as a control to examine for any significant changes in waste generation that may have occurred without any policy intervention. The paper will seek to use the analysis of pre/post waste generation policy implementation on the City of Los Angeles and the City of Austin as examples to observe the overall effectiveness of waste management policy on change in waste generation.

Background

Effects of Waste

While briefly mentioned in the introduction section of the paper, the effects of poor waste management can be seen in the contamination of oceans, flooding from clogged drains, transmission of disease, an influx of respiratory illnesses from airborne particles, physical harm to animals, and negative impacts in economic development (Kaza et al., 2018). Data estimate that around 1.6 billion tons of carbon dioxide gases-five percent of the total global emissions-was generated in 2016

(Kaza et al., 2018) from waste build-up in sources such as landfills. Not only has the excessive reliance on landfills created serious implications for carbon gas emissions, studies have shown that it is becoming increasingly difficult to contain wastes at the intended disposal sites (Przydatek & Kanownik, 2019). For example, analysis on groundwater and leachate-the liquid that drains from landfills-collected near the vicinity of a small municipal solid waste landfill site showed that there was a strong negative impact of leachate on the groundwater quality underneath the landfill; a deterioration of the chemical status in the quality of the groundwater was ultimately attributed to the lack of efficient drainage system in the landfill area (Przydatek & Kanownik, 2019). In addition, scientists studying Arctic sea ice located far away from major populated areas discovered remnants of discarded plastic (Przydatek & Kanownik, 2019), giving insight into the vast spread of and lack of control over proper waste disposal practices.

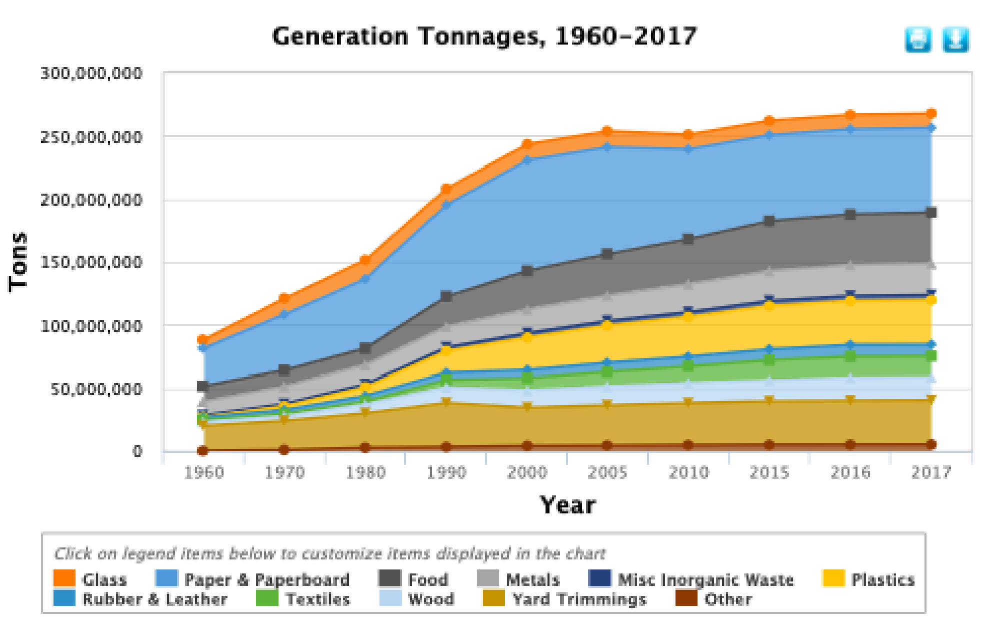
The global waste issue also reflects issues of environmental justice and disparate burdens. Of the total amount of waste produced in 2016, high-income countries generated more than 34 percent of the world's waste while only accounting for 16 percent of the world's population (Kaza et al., 2018). Overview of available data regarding waste facility locations such as incinerators, landfills, and hazardous waste sites, both legal and illegal consistently demonstrate that these facilities are most often located in areas that have more ethnical minority or deprived residents (Scheinberg, 2012). Results of such studies have concluded the difficulty in determining whether or not these disadvantaged social groups are more vulnerable. Moreover, public health officers and policy makers have been urged to implement waste management policies that both address waste production as a whole and the unequal distribution of the potential health impacts on communities (Martuzzi et al., 2010).

It is becoming increasingly evident that there is a positive correlation between a country's income level, migration rate, and municipal waste generation per capita (Wilson & Velis, 2014). The current trend sees people migrating to urban areas from rural areas. Although only about 30% of the total world population lived in urban areas in 1950, in 2014 approximately 54% of the world's population was found to live in urban cities-a calculation that is projected to grow to 66% percent by 2050 (UN DESA, 2014). Of this statistic, 80% of the population in the Americas already live in urban areas. Majority of the urban growth in the future is expected to be seen in Asia and Africa, with only 48% and 40% of the population in urban areas, respectively (Wilson & Velis, 2014). As migration to cities increases, Martuzzi et al. (2010) indicated that economies are also expected to grow along with per capita waste levels. Not only does this explain the high levels of waste generation in large populous cities such as Los Angeles, California and Austin, Texas in the United States, it also indicates that it is reasonable to predict that the waste generation for both growing cities in the United States and those in developing countries will increase as well.

Waste Generation in the United States

In 2017, the United States as a nation generated a total of 267.8 million tons of municipal solid waste (MSW) (US EPA, 2018). Applied to the individual, this is calculated as approximately 4.51 pounds of waste per person per day. Figure 1 below depicts the total MSW generated by material in 2017.

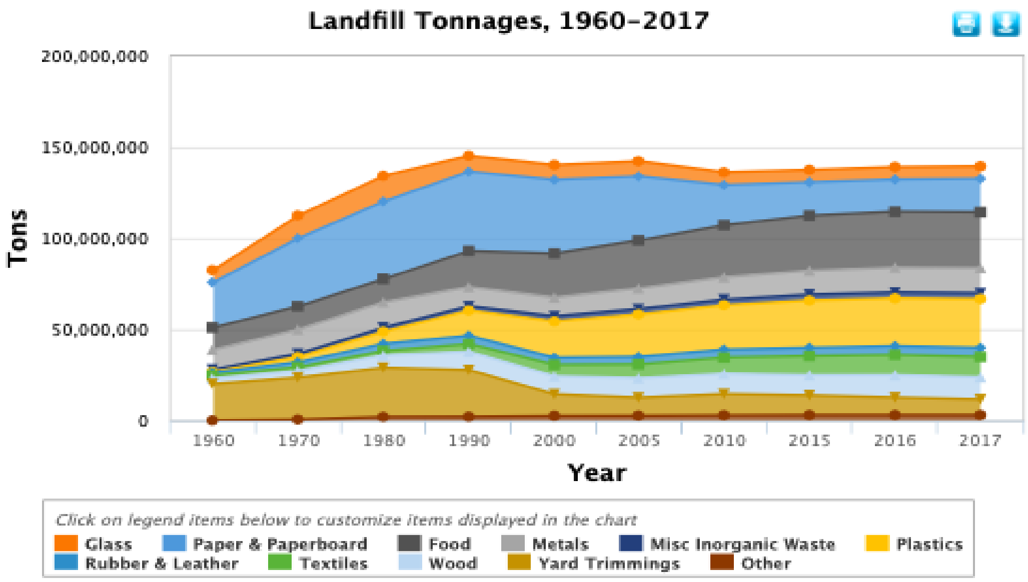
Figure 1. Total MSW Generated by Material in 2017



Source: US Environmental Protection Agency, 2017 (US EPA, 2018)

Of the total MSW generated, only around 67 million tons were recycled and 27 million tons were composted (US EPA, 2018). Compared to this, more than 139 million tons-52.1 percent-of MSW were sent to landfills (US EPA, 2018). Research shows that these quantities have continued to increase over recent years. Since 1980, total annual MSW generation has increased by 77% (Municipal Solid Waste Factsheet, 2018). Furthermore, in 2018, landfills were the third largest source of total methane emissions and accounted for 111 million metric tons of carbon dioxide emissions (US EPA, 2020). Figure 2 below shows the total MSW processed in landfills in 2017 by material and visualizes the proportion of wastes sent to landfills.

Figure 2. Total MSW in landfills by Material in 2017



Source: US Environmental Protection Agency, 2017 (US EPA, 2018)

Observation of Figures 1 makes it clear that the total tons of MSW produced in the United States has been increasing since the 1960s. More interestingly, Figure 2 shows that of the total tons of MSW produced, more than half of the waste is still being discarded into landfills, a quantity that has remained stable since the 1990s despite the efforts to decrease it.

Waste Generation in Los Angeles, California

When discussing the waste production of the United States as a country, it is essential to examine the contributions of large states and cities to these statistics. As previously mentioned, research indicates that areas with larger populations produce more amounts of waste. California is one such state. According to data provided by the U. S. Census Bureau, four of the eight cities among the top 15 fastest growing cities in 2013 to 2014 were in California (US Census Bureau, 2015).

More specifically, Los Angeles was ranked as the most populated city in the state and the second most populated city in the United States, with an estimated population of 3,979,576 people in 2019(United States Census Bureau, 2019). Based on these data and the understanding of the correlation between capita and waste production, it may be assumed that the amount of waste produced by the city reflects the vast population size.

According to the Los Angeles County Department of Public Works, residents and businesses throughout the county generated approximately 28.05 million tons of solid waste in 2017, which was calculated to average to about 89,900 tons a day (County of Los Angeles Department of Public Works, 2013). The city has also been observing an increasing trend of waste generation. In 2011, the City of Los Angeles Bureau of Sanitation reported that it collected approximately 1.4 million tons of waste from single and multifamily residences (CIty of Los Angeles, 2011). In that year alone, Los Angeles residents generated and disposed of approximately 2.379 million tons of solid waste at landfills (CIty of Los Angeles, 2011). According to an annual report released by the County of Los Angeles Department of Public Works in 2013, in 2012, residents and businesses throughout the city disposed of around 9 million tons of municipal solid waste (MSW), approximately 4.7 pounds of waste per individual per day (Solid Waste Information Management System, n.d.). After applying a 60 percent Countywide diversion rate, residents and businesses had generated 21.5 million tons of MSW, with an average of 58,987 tons every day (County of Los Angeles Department of Public Works, 2013).

An environmental impact analysis by Los Angeles City Planning (Environmental Impact Analysis, 2002) described that the collection and disposal network of the city' s solid wastes involve the efforts of over one hundred contractors collecting residential and commercial wastes. While the City of Los Angeles Bureau of Sanitation is mainly responsible for collecting the majority of the wastes from single-family residences and some multi-family residences, a small proportion of these wastes are also collected by private entities (Environmental Impact Analysis, 2002). On the other hand, while the Bureau of Sanitation only serves a small portion of commercial developments in the city, private collectors are mainly responsible for the collection of commercial wastes (City of Los Angeles, 2011). Collected wastes are then taken to one of twelve major permitted Class III landfills, six minor Class III landfills, two unclassified landfills or two transformation facilities (City of Los Angeles, 2011), where certain acceptable solid wastes can be destroyed to produce electrical power. The Los Angeles DPW Solid Waste Information Management System reported that in 2012, the city achieved an estimated 60% diversion rate from landfills and transformation facilities (Solid Waste Information Management System, n.d.).

Waste Generation in Austin, Texas

Similarly to the population trend of California, the state of Texas also boasts increasingly large populations within its cities. Between 2013 and 2014, half of the ten U. S. cities that saw the largest population gains were in Texas-Dallas, Fort Worth, Houston, San Antonio, and the state capitol of Austin (US Census Bureau, 2015). Moreover, Texas also had six of the 13 fastest growing cities calculated by percentage (US Census Bureau, 2015). In 2021, Austin is estimated to have a population of 1,011,790 people, a sharp 25.5% increase from the estimated population recorded in the 2010 Census (United States Census Bureau, 2019). Based on these data, it is also logical to estimate that waste generation in Austin will reflect population growth.

As a whole, the Texas Commission on environmental Quality revealed that Texans generated about 6.83 pounds of waste per person per day in 2016, which added up to approximately 34.73 million tons of waste diverted to landfills. A report released by the TexPIRG Education Fund and Frontier Group in 2018 revealed that the recycling rate of Texas was estimated to be 22%-well below the national average of 34% (Bradford et al., 2018). Austin, Texas, with the help of its Universal Recycling Ordinance (URO) is considered to be a leader of waste diversion, leading Texas with a 42% diversion rate (Bradford et al., 2018). However, through an independent study in 2015, Austin Resource Recovery found that more than 44% of residential trashes sent to landfills could have been recycled, with an additional 46% that could have been composted (“What’ s in Our Trash?” , 2015). Of the 44% of the trash stream that could be recycled, 23% was recyclable paper, 13% was recyclable plastic, and 8 % was recyclable metal and or glass (“What’ s in Our Trash?” , 2015). The study revealed that more recyclable materials are being sent to the landfill than being recycled, with an estimated 58,000 tons of recyclables ending up in a landfill annually (“What’ s in Our Trash?” , 2015).

The Zero Waste Framework

One such example of such a program is the Zero Waste framework. As many communities throughout not only the United States but also around the world have begun to work towards zero waste, the phrase “zero waste” has been defined in a multitude of different ways by various entities. For example, in the 2015 Adopted Resolution by the US Conference of Mayors, the concept of zero waste was defined as one that goes beyond just recycling and composting of discarded products at the end of its life cycle, but one that considers sustainability for the entire duration of the product’s life, beginning with initial product design (Welfley, 2017). Under this definition, materials and products would be created, used, and ultimately managed in ways that preserve value, minimize potentially harmful environmental effects, and conserve natural resources. In 2018, the Zero Waste International Alliance defined Zero Waste as the conservation of resources through responsible production methods, consumption habits, reuse and recovery of materials, products, and packaging. It discourages waste management methods such as burning in order to prevent pollution discharges to any aspect of the environment that could threaten both human health and the environment itself (US EPA, 2016). The Solid Waste Association of North America (SWANA) defined Zero Waste as the efforts to reduce solid waste generation to as close as nothing as possible through methods such as minimizing excessive consumption and maximizing solid waste recovery by increased recycling and composting (US EPA, 2016). At its core, the Product Policy Institute (PPI) describes “Zero Waste” as an approach that places a heavier emphasis on waste prevention that waste management and addresses potential waste generation through consideration of the entire cycle of a product from production to consumption (US EPA, 2016).

Applied to Los Angeles, California and the way the program was implemented, “Zero Waste” has been defined as the process of maximizing total rates of diversion from landfills and instead reducing waste generation at the source. The ultimate goal of Zero Waste in Los Angeles was stated as striving for more sustainable management practices towards solid wastes, reducing the total waste disposed in landfills by one million tons-around 90 percent-per year by 2025 (Jose, n.d.), and eventually achieving zero waste generation by 2050 (“City of L.A. Leads” , n.d., Murphy & Pincetl, 2013). In order to achieve this, the City of Los Angeles intended to radically alter three areas-the initial creation of a product including manufacturing and packaging processes, the use of products that are sustainable, recycled, and recyclable, and product disposal through resource recovery. The contracts and partnerships under the program are valid for a ten-year period.

The first Zero Waste Strategic Plan was formally adopted in Austin, Texas in 2009. In Austin, “Zero Waste” was defined as an ambitious goal to divert 90% of total waste generated in the city away from landfills and incinerators by the year 2040. The city intends to use a “whole system” approach in order to analyze, evaluate, and manage the entire flow of material resources and wastes in the communities. When officially approving the Zero Waste Strategic Plan in 2009, the Austin City Council set three main benchmark goals for the city. First, they intended to reduce the amount of solid wastes disposed of at landfills by 20 percent per capita by the year 2012. Second, they planned to divert 75 percent of solid wastes sent to landfills and incinerators by 2020. Lastly, they planned to divert 90 percent of solid wastes from landfills and incinerators by 2040 (US EPA, 2016). The following literature review section will clarify the historical context of waste management at the federal, state, and city levels. It will further provide an in-depth analysis of the provisions outlined in the Zero Waste frameworks in Los Angeles and

Austin and refer to studies and literature regarding existing strategies and/or policies regarding waste management to guide analysis on the potential effectiveness of the frameworks.

Literature Review

Historical Overview of Federal, State, and Local Environmental Legislation

Historically, solid waste law at the federal level is thought to have gone through four major phases (McCarthy & Tiemann, 2007). The first of these phases, the Solid Waste Disposal Act (SWDA) was passed in 1965 and was the first federal solid waste management law enacted. The SWDA was a broad attempt by the government to prioritize solving waste problems mainly through extensive research, training, and demonstrations when developing waste management plans and regulations (Solid Waste Disposal Act, 1965). The second phase is considered to have begun with the introduction of the Resource Recovery Act (RRA) in 1970, which shifted the focus of waste related regulation from one of disposal efficiency as outlined by its precedent the SWDA to one prioritizing waste management methods that reclaim energy and materials from solid wastes (McCarthy & Tiemann, 2007). To achieve this, the RRA authorized grants supporting new resource recovery technologies and required the EPA to generate annual reports highlighting the increase in recycling and overall reduction of total waste generation (McCarthy & Tiemann, 2007).

It was not until the third phase that the US federal government took a more active regulatory role in waste management. This role was outlined by the Resource Conservation and Recovery Act (RCRA) in 1976 and is considered as the first comprehensive federal policy that established federal programs for regulating solid and hazardous wastes (Aulston, 2010). This policy gave the Environmental Protection Agency the power to regulate and oversee the management of hazardous wastes and non-hazardous solid wastes. In addition, the RCRA further gave the US EPA the power to oversee the transportation, storage, and disposal methods of wastes throughout the country (Aulston, 2010). Today, wastes are categorized, defined and regulated under the criteria set by various sections of the RCRA. Both hazardous and non-hazardous wastes are generally categorized as solid wastes under the RCRA and many other state level regulations ("About the Solid Waste Program", 2021).

The fourth phase of federal solid waste law began with the passing of the Hazardous and Solid Waste Amendments (HSWA) in 1984 (Aulston, 2010). The HSWA amended the RCRA to include a focus on waste minimization, phase out land disposal of hazardous wastes, and describe corrective action for releases (Aulston, 2010). Further mandates included in this law introduced details of a new comprehensive underground waste storage tank program, allowed for greater policy enforcement authority of the EPA, and implemented stricter standards for managing untreated hazardous wastes (Aulston 2010). For example, land disposal of hazardous wastes was prohibited entirely, liner and leachate collection standards for land waste disposal facilities were created, and strict closure deadlines for facilities not meeting minimum standards were set, among many others (Aulston, 2010). With the initiation of this legislation, the federal government acknowledged the potential of future waste related problems. However, based on data regarding overall waste generation in the United States, it is clear that the RCRA and other federal policies at this time were limited in their ability to decrease waste generation and could not effectively address and implement effective waste management standards throughout the country. Instead, the abilities given to the federal government remained broad and there was an overemphasis of waste categorization standards.

Although significant legislation such as the RCRA reserves power for the federal government in the control of national waste management, due to the system of the United States government, there is a lack of consistency in waste control policies among individual states. The EPA is evidently a decentralized agency within the federal government and shares a degree of regulatory responsibility with other federal, state, and local level authorities. Moreover, the levels of government within each state has contributed to differences in ways waste management structures function. Due to this, implementing a single method of effective waste management or one-sided policy at the national level has been difficult to achieve. Many state and local governments have assumed responsibility for enforcing national level environmental laws and make decisions for issues that the federal government has failed to address such as land use. Essential services such as sewage treatment, water supply, and waste disposal are typically regulated at the local government level. Naturally with this hierarchical arrangement, services and standards relating to waste and the environment differ by state, city, and county and make it difficult to compare results and policy effectiveness. While federal legislations are necessary to help create and enforce programs and standards at the state and city level of waste management, state or local regulations are more effective in terms of achieving waste reduction due to the way that they are able to be specific in their policies and adapt to each area separately. As more and more states have begun to realize this and the severity of the issue of waste generation and management, it has become more common for individual states, cities, and municipalities throughout the country to enact their own regulations, partnerships and/or programs to address waste.

The Zero Waste LA Franchise

The Zero Waste LA Franchise is an example of a city-level waste policy unique to Los Angeles. When it was first passed, the Zero Waste LA program was described as "unprecedented", "far-reaching", "aggressive", and "innovative". The program was introduced as a motion in 2010 by Los Angeles Councilmembers Paul Koretz and Jose Huizar (Jose, n.d.). Before the Zero Waste LA franchise, the waste collection and disposal system was an "open-market" system (Royall, 2017) meaning any number of waste hauling companies were permitted to operate in any neighborhood in Los Angeles. Consequently, the city had little control over hauling company regulations and the implementation of waste diversion standards and establishing fair wages for disposal workers was significantly difficult to achieve (Royall, 2017). Moreover, Royall (2017) mentioned that due to this "open-market" system, the same neighborhoods could be serviced by different trucks from multiple hauling companies. This not only proved to be an inefficient use of resources, but the heavy wear-and-tear on the roads along with the increased air pollution also posed additional negative environmental effects in these neighborhoods. Some other limitations of the existing hauler permit system at the time the franchise was designed included the inability to meet Los Angeles' landfill reduction goals, the inability to comply with California state mandated recycling requirements, the lack of requirements for haulers to use and operate clean fuel vehicles, the inefficient vehicle routing process, and insufficient material processing infrastructure ("Los Angeles Approves" , n.d.). Prior to and at the time of program implementation, businesses, consumers, and residents living in Los Angeles generated approximately three million tons of waste annually ("L.A. City Council" , 2017). Of this, 70 percent of the total waste disposed was sourced from commercial and apartment buildings throughout the city (Jose, n.d.). In addition, the wastes of 65,000 commercial and multifamily customers were unregulated ("City of L.A. Leads" , n.d.).

According to the City of Los Angeles (2016), Zero Waste LA is a public private partnership franchise that expands the most current residential waste and recycling services to every business, commercial, industrial, and large multifamily customer in the city starting in July 2017. Under the program, eleven-zone commercial and multifamily franchise systems were created to collect and process wastes, including recyclables (City of Los Angeles, 2016). Each zone is served by a single waste hauler and is held responsible for meeting the environmental, community, customer service and rate standards (City of Los Angeles, 2016). The exclusive franchise aimed to streamline the waste disposal system that serves the neighborhoods in order to mitigate the detrimental impacts that have arisen. Under the program, every apartment and business in the city receives waste and recycling bins at no extra cost and aims for recycling at 100 percent of customer sites (City of Los Angeles, 2016). A separate compost bin was also made available, eventually bringing the total to three waste bins per building/residence. The system also intended to stabilize and provide equitable, transparent service rates by limiting the number of cost increases in a year, reducing the financial burden for smaller businesses and apartments while granting access to 24-hour customer service. The monthly rate for a three-cubic yard solid waste bin collected once a week including unlimited recycling was capped at $216.72 per week (City of Los Angeles, 2016). New, clean fuel trucks (City of Los Angeles, 2016) were introduced to collect waste in resource-efficient routes that were designed to reduce the number of vehicles on the street while decreasing air pollution and road damage (Royall, 2017).

Ron Herrera, the Secretary Treasurer of Teamsters Local 396, the union representing UPS, Sanitation, and Genesis Logistic workers (Teamsters Local 396, n.d.) indicated how the system also included considerations for solid waste workers. With more proper waste separation at the source, the program ideally protects the health and safety of workers from hazardous waste exposure while also creating more jobs for Los Angeles residents through opportunities in recycling and remanufacturing of reusable materials. Furthermore, less waste would be processed to landfills which would also provide significant contributions to the fight against climate change (Royall, 2017). Robert Nothoff, the Director of Don’t Waste LA, a coalition of various community and labor organizations working to increase recycling and composting in Los Angeles (Dugger, n.d.) has stated that achieving the franchise’s goal of reducing one million tons of waste per year disposed at landfills (City of Los Angeles, 2016) would allow for the reduction of greenhouse gases across the city by 2.6 million tons (“Los Angeles Becomes”, 2016). Additional benefits of the partnership included food rescue assistance and support, $200 million financial investment in new recycling infrastructure with special emphasis on facilities and upgrades in low-income communities, facility inspections and certifications to ensure health and safety of workers, annual cleaning of waste, recycling, and compost bins-including possible graffiti removal-, material tracking, and assistance and support for used item donation (City of Los Angeles, 2016).

The Zero Waste Strategic Plan in Austin, Texas

The Zero Waste Strategic Plan in Austin is another example of a city level policy. Although it shares the same general Zero Waste conceptualizations as the Zero Waste LA Program, the Zero Waste Strategic Plan in Austin and the Zero Waste LA Program are separate legislations and have different goals and methods of achieving those goals. The Zero Waste Strategic Plan in Austin was officially implemented in 2009-earlier than the program in Los Angeles. When Zero Waste was first drafted as a policy design principle in Austin in late 2008, it was estimated that the city was losing over $40 million dollars annually by sending recyclable and/or reusable materials to landfills (Liss, 2008). Under the Zero Waste system, the city will strive to recover the economic loss and eliminate as much waste as possible. As mentioned earlier in this paper, the City of Austin set a goal to divert 90% of its generated wastes from incinerators and landfills by the year 2040. In order to achieve these goals, the city’s Zero Waste Plan proposed to build on past residential recycling, commercial recycling, and producer responsibility policies. Specifically, some policies that were introduced in the Zero Waste Plan included the intention to improve local and regional recycling, composting, and reuse programs, the adoption and implementation of incentives to reward individuals for their commitment to the goal, and the development of Zero Waste infrastructure such as new Green Campuses and Resource Recovery Parks (Liss, 2008). Liss (2008) also stated the Zero Waste Plan would further advocate for increased producer and retailer responsibility-especially as they pertain to wastes that stem from products and packaging materials and place an outright ban on certain problem materials. In addition to producer and retailer responsibility, the Plan also acknowledged the importance of consumer responsibility and targeted interventions at the consumer level through community collaboration, partnerships, and involvement. The Plan was also designed to educate and advocate for the Zero Waste framework as a solid part of future sustainability and climate change policies (Liss, 2008).

At the time of program implementation, the City of Austin’s Solid Waste Services Department was solely responsible for litter collection, solid waste collection, and provided customers with curbside recycling. Although the City was responsible for collecting the wastes for single-family residents, multi-family residents, businesses, and institutions were required to utilize private waste haulers to collect and process their wastes (Liss, 2008). The City did not have the direct authority to control the waste flow in the commercial streams like it did towards the residential streams, however was able to implement necessary ordinances, policies, and/or programs necessary to influence the commercial waste streams. Texas State Law gave cities the power to oversee sold waste service providers in their neighborhoods. Under this provision, Austin issued licenses to commercial solid waste haulers in order to regulate the wastes they are transferring within the city limits. The fee was calculated based on a variety of variables including but not limited to the number and size of the operating trucks (Liss, 2008). The City of Austin, like many other cities in Texas is part of regional landfill station, transfer station, and citizen collection station systems (Liss, 2008) and therefore is influenced by wastes from other neighboring cities.

The policy options described in the Zero Waste Plan are organized into four categories: 1) upstream, 2) downstream, 3) green business, green building and jobs, and 4) residuals management and regional coordination. Upstream policies advocated for more Extended Producer Responsibility (EPR) legislation (Liss, 2008) and pushed for the producers of products to take back their wastes. Downstream policies referred to programs that increased the recycling, reusing, and composting rate on all discarded materials. An important provision in this category is the consideration of garbage rate and permitting fee structures as tools to encourage less waste generation. This kind of waste prevention strategy will be explored in more depth in the literature review section of this paper. The third category targeted businesses and the local economy by reinvesting discarded resources, creating incentives, support and new green collar jobs. Finally, the policies in the fourth category intended to control the influence of wastes coming into Austin from outside sources (Liss, 2008). Zero Waste Plan policies were also organized into three different categories: 1) voluntary, education, and incentives, 2) new rules and advocacy, and 3) new city programs based on cost of funding for implementation.

Based on examination of the Zero Waste frameworks implemented in both Los Angeles and Austin, it is clear that the cities are relying on a variety of strategies and sub-policies to help them achieve their goals. To summarize, while both programs adopt similar ideals of zero waste, due to their nature as city level legislations, they are able to employ different and more specific regulations. Some of the more prominent policies include waste, recycling, and compost bin provision, new and improved recycling infrastructure, education and incentives, increased waste separation at the source, food rescue assistance, EPR legislations and the implementation of fees and licenses. It seems as though the Zero Waste LA program placed a heavier focus on situational factors such as bin provisions and infrastructure while Austin’s Zero Waste Strategic Plan more strongly emphasized economic strategies. In order to determine the potential effectiveness of these policies, the following section of the literature review will consider existing studies and results regarding these strategies with regards to waste reduction.

Permits, Subsidies, and Fees

Under the authority given by laws such as the RCRA, the federal government, through the EPA, has been able to enact a wide variety of different policy tools at various levels to address the diverse nature of solid wastes. One such policy tool has been the use of permits, especially with regards to the management of hazardous wastes. All treatment, storage and disposal facilities (TSDFs) that manage hazardous wastes are required to obtain a RCRA permit establishing the administrative and technological standards that wastes in the facilities must be managed (US EPA, 2015). The permit includes provisions such as facility design and operation outlines, safety standards, and clarifies acceptable facility performance activities (US EPA, 2015). Permits also require facilities to prepare emergency plans and can mandate requirements specific to the facility such as groundwater monitoring. The authority to issue and/or deny permits is reserved for the permitting agency only, whether it is the state department or the federal EPA (US EPA, 2015). In California, all recycling facilities are required to obtain permits from the local enforcement agency which, in turn, regulates solid waste facilities on behalf of the California Department of Resources Recycling and Recover (CalRecycle). The federal government also uses performance standards to dictate maximum emission levels that are allowed to be released during the waste management and disposal process and are applied to every state once set by the federal government. However, states have the ability to implement more stringent standards. While permits and performance standards do not seem to directly affect the amount of waste produced, they are, to an extent, useful in limiting the effects of waste treatment on the surrounding environment, promoting interagency coordination, and encouraging more public participation in waste reduction activities.

A paper by Palmer, Sigman, and Walls completed in 1997 (Palmer et al., 1997) analyzed various types of public policies and strategies aimed at reducing municipal solid waste generation that may prove to be useful when examining the possible effectiveness of the Zero Waste policies that have been implemented in Los Angeles and Austin. Especially prominent in the sub-policies for the Zero Waste Plan in Austin, policies targeting economic incentives and/or fees are commonly discussed as methods with strong performance potentials to prevent waste generation. Palmer et al. (1997), analyzed waste reduction that occurred in response to three kinds of public policies-deposits/refunds, advance disposal fees (ADFs), and recycling subsidies. Under a deposit/refund program, the deposit acts as a tax on the final material (recyclable material) priced at the amount of the deposit. Those who recycle the material are returned the full deposit-a refund-resulting in no net increase in the price paid for the material. An advance disposal fee is described as an extra charge on all material consumption. The advance disposal fee sees an increase in the price of the material for consumers, like in a deposit/refund program. Ultimately, the ADF affects the recycled material market by reducing the amount of the material or goods available to be recycled. In actuality, ADFs vary across the country and are much more complex in policy. For example, in California individuals are refunded the partial amount of the ADF when a container is returned for recycling. In Florida, the ADF, which then cost a penny per recyclable container, was repealed automatically if and every time the aggregate recycling rate for the specific material collected exceeded fifty percent. Finally, a recycling subsidy affects the demand price and the price received by suppliers of recycled goods. In addition, the subsidy would decrease the official price individuals who recycle pay for the recyclable material (Palmer et al., 1997).

The research discovered that a significant difference in each intervention level was necessary to achieve waste reduction through each policy. Due to the differences in each policy and their reliance on source reduction and recycling, the policy intervention levels needed for each policy to achieve waste reduction also differ. For example, while the deposit/refund system increases both source reduction and recycling, the recycling subsidy was found to increase recycling and recyclable material consumption due to the lowering effect it had on the price of the recyclable material for consumers who recycle. On the other hand, while the ADF was revealed to reduce the total consumption of goods, it also decreased the total amount of recyclable material and recycling. Due to this, ADFs require additional considerations to result in tangible waste reduction overall (Palmer et al., 1997).

Policy effectiveness was also found to be reliant on the type of material to be discarded. Plastics and aluminum disposal was achieved at a much lower cost through reducing total consumption rather than increasing recycling amount because a large proportion of plastics cannot be recycled. Therefore, while a deposit/refund policy could decrease the consumption of these materials, it can see significantly little effects on recycling efforts. In addition, a recycling subsidy would also result in a negligible amount of waste reduction as it would rely on recycling only (Palmer et al., 1997).

Some additional intervention methods that have been proposed to encourage waste reduction behaviors have been financial measures. For example, some cities have implemented "pay-per-bin" systems, in which residents and/or households are charged a monetary fee for each refuse bin that is filled and collected (Whitmarsh et al., 2017). As a comparison, charging a fee on single-use carrier bags has found that after introducing the fee, the increase in use of single-use carrier bags was smaller in areas that had implemented the fee compared to that seen in areas that did not have the fee. Poortinga, Witmarsh, and Suffolk (2013) compared Wales, the first country in the United Kingdom to have introduced the fee on single-use carrier bags, to England, where there was no such policy. Although the results showed that there were increases in single-use bag uses in both countries, the rate of increase that was observed in Wales was much less than that of England (Poortinga et al., 2013), indicating the effectiveness of the fee. It was concluded that implementing financial measures through a carrier bag fee overall reduced the use of single-use bags and influenced the existing consumption habits in Wales (Poortinga et al., 2013). Furthermore, after the study, support for the single-use bag fee as a waste minimization method increased throughout other countries.

Unit-based pricing (UBP) of residential solid wastes have been widely implemented in many countries throughout the world, including the countries of the European Union, Japan, South Korea, and even certain municipalities in the United States. Bel and Gradus (2016) analyzed the effects of three different types of UBP systems of waste management-the bin (subscription based) system mentioned in the study by Poortinga et al. (2013), the volume-based program in which residents purchased specific bags and/or labels to discard of their wastes, and the weight-based system, in which the resident is charged for the total weight of wastes they produce each time the collection vehicle collects the trash. The results showed that the weight-based pricing system was the most effective in influencing waste quantities and impacting environmental conditions as they are more specific and are most refined in terms of measuring the waste amounts (Bel & Gradus, 2016). Upon surveying pay-as-you-throw (PAYT) type UBP programs for municipal solid waste production in four municipalities in Japan, Sakai et al. (2008) found that the implementation of PAYT programs reduced total residual waste generation from 20% to 30%. Based on the results, it was concluded that when combined with other policies, regulations, and strategies, PAYT programs have the potential to dramatically reduce waste production, especially for containers and packaging materials (Sakai et al., 2008). Results of these studies indicate that adopting similar policies that demand a fixed fee per unit of waste in large cities throughout the United States may be effective in either slowing down or decreasing waste production at the source.

Influencing Societal Norms and Knowledge

Understanding various ways of promoting sustainable, waste reduction behaviors in multiple situations is also necessary to achieve overall waste reduction. Recycling has been arguably the most thoroughly studied waste reduction behavior. Many studies have shown how attitudes, norms, habits, and situational factors such as the frequency waste is collected and recycling bin provisions can accurately predict recycling behavior. However, even with the abundance of threads regarding potential influences of waste prevention behaviors and habits, there is little consensus on what kinds of strategies or policies most effectively change behaviors. This may be due to the complex relationships that exist among these strategies-whether they are situation-based, individual behavioral determinants, related to socio-technical systems or any combination of these factors (Thomas & Sharp, 2013).

Knowledge about environmental issues-more specifically about how recyclable products, recycling programs, and recycling facilities relate to these environmental issues has also been found to predict recycling behavior. Barr (2007), after reviewing existing literature regarding the effects of waste minimization and recycling on the environment, suggested that individual action was a result of their beliefs towards the environment. The beliefs and intentions towards environmentally friendly habits-in this case, waste minimizing actions-is set into action by the modifying effects of both situational and psychological factors (Barr, 2007). Contrary to this, the strongest predictors of recycling behavior have been found to be contextual factors such as whether or not the individual has access to a curbside recycling collection service or are in the presence of a recycling facility (Barr, 2007). Martin et al (2006) supported this and argued that situational factors hold a larger role in determining an individuals' waste production behavior. In their study, analysis of quantitative and qualitative survey results regarding householders' attitudes towards recycling revealed that although many of the surveyed householders were very willing to adopt recycling and waste minimizing behaviors, they claimed the local services they were provided were unreliable and inconvenient to allow them to do so (Matin et al., 2006). Many of the waste related policies that have been implemented throughout cities in the US including the Zero Waste frameworks in Los Angeles and Austin seem to understand this relationship. For example, the Zero Waste LA program attempts to strengthen contextual factors by providing every resident in each of the eleven service zones access to three separate bins for waste. Based on this information, it can be assumed that adopting policies that address social environments and individual beliefs can have positive outcomes for overall waste reduction.

Further studies have indicated the strong relationships between social norms and recycling rates. For instance, a study completed by Thomas and Sharp (2013) concluded that both injunctive social norms and descriptive norms such as what one believes they should do and perceptions of what other people are doing, respectively, have not only increased in many societies recently but also have positive influences in recycling uptake behaviors. However, research has shown that descriptive norms have a stronger influence on individual actions. Through surveys of Hampshire residents in England, Thomas (2006) showed that the levels of which people believed their neighbors were recycling were gradually increasing by the year, indicating that recycling was becoming a more descriptive social norm. In 2005, 57% of the residents thought recycling was a regular habit in other households, which was an increase from the 48% calculated from the year prior (C, 2006). Considering the way that descriptive norms can influence waste reduction behaviors, encouraging waste minimizing behaviors by increasing the strength of the descriptive norms people are exposed to in their everyday lives may be considered as a potential strategy to implement in general waste policies that target source reduction.

Many different conceptual theories and their significant roles in shaping frameworks to understand the social and psychological effects that influence people's behaviors with regards to waste production have also been discussed. A few prominent examples are Stern's Value-Belief-Norm Theory (VBN), Ajzen's Theory of Planned Behavior (TBP), and the Attitude-Behavior-Context (ABC) model. According to Stern's VBN Theory, environmentally friendly behaviors and habits are more likely to occur when a causal series of variables-for example, values, personal norms and beliefs-are present. In this theory, the relationships between individual beliefs, norms, and behaviors are organized in a causal relationship (Stern et al., 1999). Supporting this theory, Ghazali et al. (2019) also described that personal norms were successful antecedents of pro-environmental behaviors among other constructs of the VBN model (Ghazali et al., 2019). Interestingly, this study observed the similarities and differences between Malays and Chinese cultures and their behaviors. Results showed that the Chinese were more engaged in pro-environmental behaviors compared to their Malay peers. The researchers credited factors such as the more well established public transportation system available in

China, accessibility to eco-friendly products, and promotion frequency of pro-environmental behaviors by non-profit organizations and potential reasons for this discrepancy (Ghazali et al., 2019). These situational factors further contributed to individual values and personal norms. Overall, the study results indicated that certain social norms unique to culture, environment, and therefore the individual may predict different kinds of pro-environmental behaviors. Such relationships should be considered when drafting waste policies targeting behavioral changes.

Like the VBN model, the Theory of Planned Behavior first introduced by Azjen (1991), provides a theoretical framework of analyzing factors that influence behavioral choices and will be insightful in determining waste reduction strategies. The theory assumes that peoples' behaviors are supported by their rational basis, meaning they consider the implications of the actions they make. The theory also argues that an individual's intention to perform or not perform a certain behavior is influenced by their attitude, the subjective norm, and their perceived control over their ability to perform the behavior (Davis & Morgan, 2008). In a case study of Bristol City, UK, researchers used a questionnaire inquiring about the householder's personal recycling behavior, attitudes, norms, and situational factors in their environment to determine strong indicators of waste minimization behaviors. Based on the results, it was concluded that situational factors such as access to recycling facilities or other forms of waste prevention were the strongest predictors of recycling intentions. Moreover, it also determined that both perceived behavioral control and attitudes towards waste minimization were also significant predictors of recycling intentions (Davis & Morgan, 2008). Under this theory, when new policies or programs such as the Zero Waste frameworks of Los Angeles and Austin targeting improved waste management systems and waste minimization are implemented, situational factors that address individual's access to pro-environmental decisions should be prioritized.

Waste Separation and Source Reduction

The Environmental Protection Agency previously released a "hierarchy of waste management" (U.S, Environmental Protection Agency, 1989) which stated that strict adherence to the hierarchy was crucial for effective waste reduction at national, state, municipal, and local levels. A visual diagram of the hierarchy is shown below in Figure 4.

Figure 4. Waste Management Hierarchy

Source: US Environmental Protection Agency (1989)

The hierarchy describes source reduction as the method most preferred to reduce waste through designing and manufacturing goods with the minimum amount of toxic content and volume of material while maximizing usefulness. Source reduction can be practiced through household buying and reusing habits of recyclable goods. Recycling is the next optimal method in the hierarchy, and includes compost. Energy recovery through options such as waste combustion, while a more recommended management method that treatment, disposal, and landfilling, is listed as a less favorable option for waste management (US EPA, 2015). Under this hierarchy, source reduction method should always be prioritized over recycling and recycling should be prioritized over landfilling and incineration. Data suggest that there are more effective collaborations of waste management methods including combinations of source reduction and recycling dependent on the type of material that can reduce waste production.

When discussing the Zero Waste LA franchise system with the Waste Management Hierarchy in mind, it seems that the Zero Waste LA system is targeting the second tier of the hierarchy-recycling and composting. The Zero Waste LA program, while allocating significant intervention efforts through 100% customer site recycling, organic recycling, and food rescue, makes little mention of source reduction. According to the United States EPA (2015), this may indicate less efficient management results from the franchise system. The Zero Waste LA may require additional thought to source reduction interventions.

Among the literature regarding effective strategies for waste reduction behaviors, those discussing source reduction behaviors such as waste prevention and product reuse are less common. Existing studies exploring these topics mainly suggest that both contextual factors and psychological factors play a role in whether or not an individual chooses to display source reduction behaviors. Research conducted by Witmarsh et al (2017) found that in the United Kingdom, individuals with higher education attainment, pro-environmental identities, and altruistic values were more likely to purchase and use products with less packaging materials. Furthermore, younger, lower income, and educated individuals were more likely than their older counterparts to avoid buying new products (Whitmarsh et al., 2017). Exemplar behavior such as avoiding buying new products and buying products with less packaging were found to be much less common than more archetypal behaviors such as recycling. The need for supporting factors at personal levels through behaviors and norm exposure and structural levels through societal provisions and frameworks were highlighted in producing certain material consumption behaviors (Whitmarsh et al., 2017).

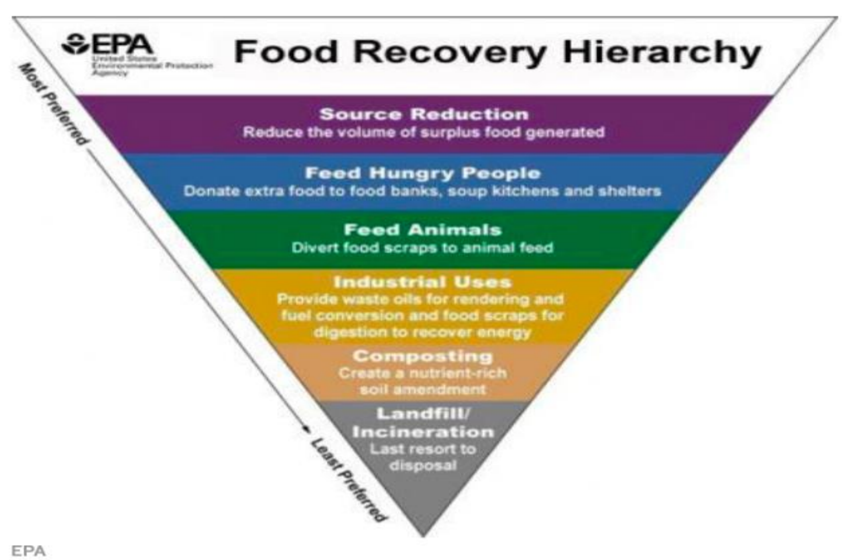
Food Rescue Assistance

The impact of food wastes on the overall total amount of waste generated and the benefits of targeting food rescue have become increasingly clear in recent years. Globally, the Food and Agricultural Organization of the United Nations reported that roughly around a third-1.3 billion tons) of all edible produced foods produced for human consumption is lost and/or wasted annually (Ishangulyyev et al., 2019). Food lost and waste (FLW) is credited as a significant threat to food security, the economy, and the environment. The financial worth of FLW annually is estimated to be worth around $936 billion in US dollars, excluding any social and environmental costs. In addition, FLW are both indirectly and directly associated with serious environmental impacts such as soil erosion, water and air pollution, deforestation, and greenhouse gas emissions. They are indirectly involved due to the resource intensive production requirements-of food that lead to such negative outcomes (Mourad, 2016). FLW is also directly involved with outcomes such as increased greenhouse gas emissions, as when food waste is sent to landfills, much of the waste is converted into greenhouse gas and methane. Moreover, food waste has a faster decomposing time compared to other wastes that may be sent to landfills and yield higher methane emissions (Whitmarsh et al., 2017). In New York, food waste makes up 18 percent of the state’s waste stream, with around 3.9 million tons of discarded food being discarded into landfills (O’Connor, 2017). In order to address the significant impact that food waste poses on total MSW production, the state of New York recently experienced the passing of a landmark food waste bill called the Food Donation and Food Scrap Recycling Act (the Act).

Under this law, businesses in the State of New York that generate an average of two tons of wasted food per week annually are required to donate all excess edible food and recycle all remaining food scraps if they are located within 25 miles of an organics recycling facility (Food Donation and Food Scrap Recycling Act, 2019). Some examples of businesses this law would impact are restaurants, grocery stores, hotels, colleges and universities, event centers, and shopping malls. Furthermore, this law mandates all designated food scraps generators to separate their excess edible food for donation for human consumption and separate remaining food scraps from other solid wastes for organic recycling. Such food scraps must be properly stored in qualified storage bins until a transporter delivers the scraps to an organic recycler (O’Connor, 2017). This portion of the policy is similar to that outlined in Zero Waste LA-in particular the service that intends to provide food recuse assistance and support along with organic collection and recycling services for customers within the city.

Interestingly, this legislation establishes what it calls a food scraps recovery hierarchy for the state of New York acknowledging the impact of food scraps on the environment, economy, and worker’ s health and is similar to the waste hierarchy provided by the EPA for solid wastes. This hierarchy also reveals potential targets and goals that should be considered when adopting policies that address food waste reduction specifically. The first tier of the hierarchy is source reduction, or reducing the amount of surplus food created at the source. The second tier is recovery, or providing those who need it the wholesome food. The third tier is repurposing, or reusing such as by feeding animals. Fourth is recycling, or processing any leftover food wastes through compost or anaerobic digestion (O’ Connor, 2017). Figure 4 below visually depicts this hierarchy.

Figure 5. Food Recovery Hierarchy



Source: US Environmental Protection Agency (2020)

The inclusion of this food hierarchy in the Act codifies it as part of New York State law, allowing the issue of food waste to be addressed formally across the state in government discussion. Although the Food Donation and Food Scrap Recycling Act does not come into effect until January 1st, 2022, it is already being considered a monumental step towards helping New York prevent food waste, preserve wholesome food, and recycle food scraps. The Zero Waste Plan for the city of Austin does not set aside specific policy efforts pertaining to food wastes, however, the Zero Waste LA framework does reserve specific commitments to food rescue assistance in its communities. Considering the reduction benefits that are predicted to result from policy targeting food wastes such as Food Donation and Food Scrap Recycling Act, Zero Waste LA may also be predicted to result in similar waste reduction benefits throughout the city.

Methods

In order to determine any possible benefits the Zero Waste LA program may have had on the total waste generation in Los Angeles, quantitative analysis was conducted on the waste generation data before and after program implementation. Quantitative data on total waste generation will be accessed through publicly accessible datasets from the Los Angeles open data portal. Special focus and analysis was conducted on the data provided by LA Sanitation (LASAN) regarding monthly solid resource tonnages including bulky items, E-wastes, and white goods. The dataset was created on November 30, 2015 and was last updated on October 2, 2020, which provides relatively equal data before and after the Zero Waste LA policy was implemented available to analyze. For further consideration of waste generation before policy implementation, data detailing LA Sanitation information on abandoned waste requests-including illegal dumping, illegal E-Waste, and illegal bulky wastes-will be considered. For the purposes of this analysis, the date of policy implementation will be set as the year of 2017. Therefore, any and all waste generation data pertaining to a time before that date was generalized as “before policy implementation” while data pertaining to a time after that date will be considered as “after policy implementation”.

Upon completing a general cleaning of the dataset, not limited to but including filtering relevant/irrelevant data, duplicates, and syntax errors, average waste generation amounts in years prior to policy implementation was compared to those from the years post policy implementation in order to observe for any significant reduction in total waste generation. In addition, further analysis will be conducted to determine which waste category (MSW, recyclables, hazardous, compostable, etc.) saw the most prominent influence from the Zero Waste LA franchise.

In addition to the analysis of Los Angeles data, waste data for the city of Austin, Texas which not only had a longer period of program implementation but also more strongly emphasized the importance of EPR regulations and economic strategies as opposed to Los Angeles’ focus on policies influencing societal and environmental norms was analyzed for comparison purposes. Waste data for Austin was obtained from the city’s open data portal and will be analyzed in a way similar to Los Angeles data. However, data for Austin was made available through a different set of categories and waste commodities. Therefore, prior to quantitative analysis of Austin data, each commodity will be considered separately and organized into fewer groups similar to those pre-provided in the Los Angeles dataset. For Austin, the date of policy implementation will be set to the year of 2009. The City of Austin public data portal offers waste data beginning in January 2003. However, due to the large amount of data that seems to be missing from 2003 to 2008, data prior to 2009 will not be considered in the analysis. Any trends in the data beginning and after 2009 will be observed as post-policy implementation. As dividing the areas throughout the city into eleven different service zones is unique to the Los Angeles Zero Waste policy, data for Austin does include any area categories. Therefore, no particular analysis will be conducted on waste generation based on specific areas or zones throughout the city.

In order to rule out the possibility of any situational factor other than the policy itself as significant contributors to changes in waste generation, the waste generation of another city in the United States without any recent waste reduction policy implementation will also be analyzed. In this study, the case example of waste generation amounts in the City of Phoenix, Arizona will be observed as a control variable. The waste data for Phoenix will be accessed through the open data online website, made public by the city. The earliest available dataset for the City of Phoenix is that of the transfer station loads gathered in 2014. The Phoenix data was most recently updated in May of 2020. The time period for which Phoenix data is made available is similar to that of Los Angeles, which will be helpful in conducting accurate analysis of the two cities. As Phoenix did not implement any specific policy targeting waste reduction like Los Angeles or Austin had, waste generation amounts will not be compared under a pre-and post-policy implementation context. However, waste generation throughout the years since 2014 will be compared to observe for any trends in the data.

Upon the conclusion of analysis on Los Angeles, Austin, and Phoenix waste data, changes in total waste generation among the three cities will be compared to understand any possible trends, differences, and/or similarities. In the case that the data for the City of Phoenix shows a similar change in waste generation over the years without any waste reduction policy to that of Los Angeles with waste reduction policy, further analysis that delves deeper into any other external situational factors that could have influenced waste generation rates should be considered. On the other hand, if analysis of both data sets results in considerable differences, it may be reasonable to credit the waste reduction policy as the main influence behind the changes in waste reduction. Furthermore, discussion will seek to understand specific aspects of the policies enacted in each city that may have contributed to the changes or lack of changes.

Data and Findings

Los Angeles, California

Data on tonnages of waste collected in Los Angeles were obtained through the dataset made public by LA Sanitation and are available for public view on lacity.org. The original data were presented as daily measurements of total tonnages per district, route, site and commodity. Data were available beginning January 1, 2016 to December 28, 2020. For the purposes of this study and analysis, particular focus will be placed on the tons of waste produced, the date and district from which they were collected from, and the commodity of waste that was collected.

Descriptive Statistics of Total Tons of Waste Collected in Los Angeles

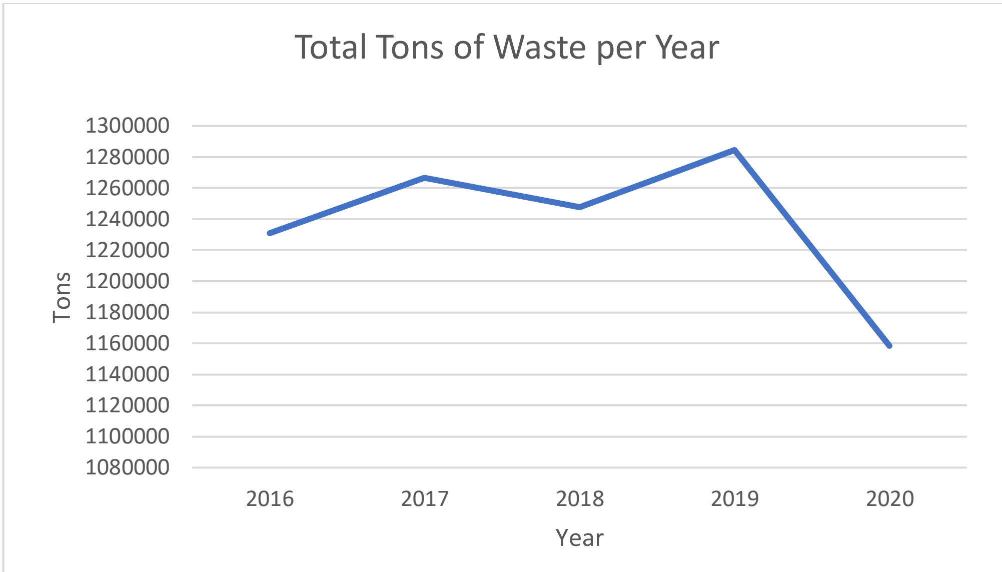
Table 1 below depicts the total tons of waste collected throughout all the districts in Los Angeles by year.

Table 1: Total Tons of Waste Collected in Los Angeles per Year

Year	Total Tons of Waste Collected
2016	1,230,786.19
2017	1,226,488.15
2018	1,247,905,87
2019	1,284,472.43
2020	1,158,416,89

Based on **Table 1**, it is evident that total tonnages of collected waste in 2020 decreased compared to the totals collected in 2016. The average amount of waste collected over the five-year period was 1,237,613.906 tons and the median was 1,230,786.19 tons. The standard deviation was 43,483.682. The year 2020 saw the minimum of total tons collected, at the amount of 1,158,416,89 tons while 2019 had the maximum of 1,284,472.43 tons. The mean for total waste tonnages was greater than the median, which indicated that the data had a positive skew. This meant that several years of data reported waste tonnages that were higher than the median and skewed the average towards the right. The data are also visually presented in the line graph in Graph **1** below.

Graph 1: Total Tons of Waste Collected per Year



Source: LA Sanitation Public Data Portal

As seen in the Chart 1 above, data show a general decrease in total waste from 2016 to 2020, however total tonnages varied in between the four-year period.

As aforementioned, waste tonnages for Los Angeles were also reported by district. Los Angeles was organized into a total of 12 districts: CSLA DCT, CSLA Harbor, CSLA Lopez Canyon, CSLA San Fernando, CSLA Washington, East Valley, Harbor, North Central, South Central, West Los Angeles, West Valley, and Receptacles. However, in the dataset provided by LA Sanitation, there was a significant amount of missing data for the districts CSLA DCT, CSLA Harbor, CSLA Lopez Canyon, and CSLA San Fernando from 2016 to 2018, Receptacles from 2016 to 2017, and West Valley from 2016 to 2019. Therefore, for the purposes of this study and analysis, only data from districts with data available for the entire 2016-

2020 period will be used. Those six districts are CSLA Washington, East Valley, Harbor, North Central, South Central, and West Los Angeles.

Data and Descriptive Statistics of Total Tons of Waste Collected by District per Year

Table 2 below depicts the tons of waste collected from each district by year.

Table 2: Total Tons of Waste Collected by District

Year	CSLA Washington	East Valley	Harbor	North Central	South Central	West Los Angeles
2016	10,355	51,098	11,556	45,950	41,984	37,860
2017	17,249	51,823	12,012	43,977	43,702	37,886
2018	19,277	50,385	11,017	44,867	42,999	37,789
2019	22,571	50,224	11,544	44,426	43,180	37,319
2020	17,678	52,144	12,116	46,479	44,621	1,545

Table 3 presents the descriptive statistics for each district.

Table 3: Descriptive Statistics of Total Waste Collected by District

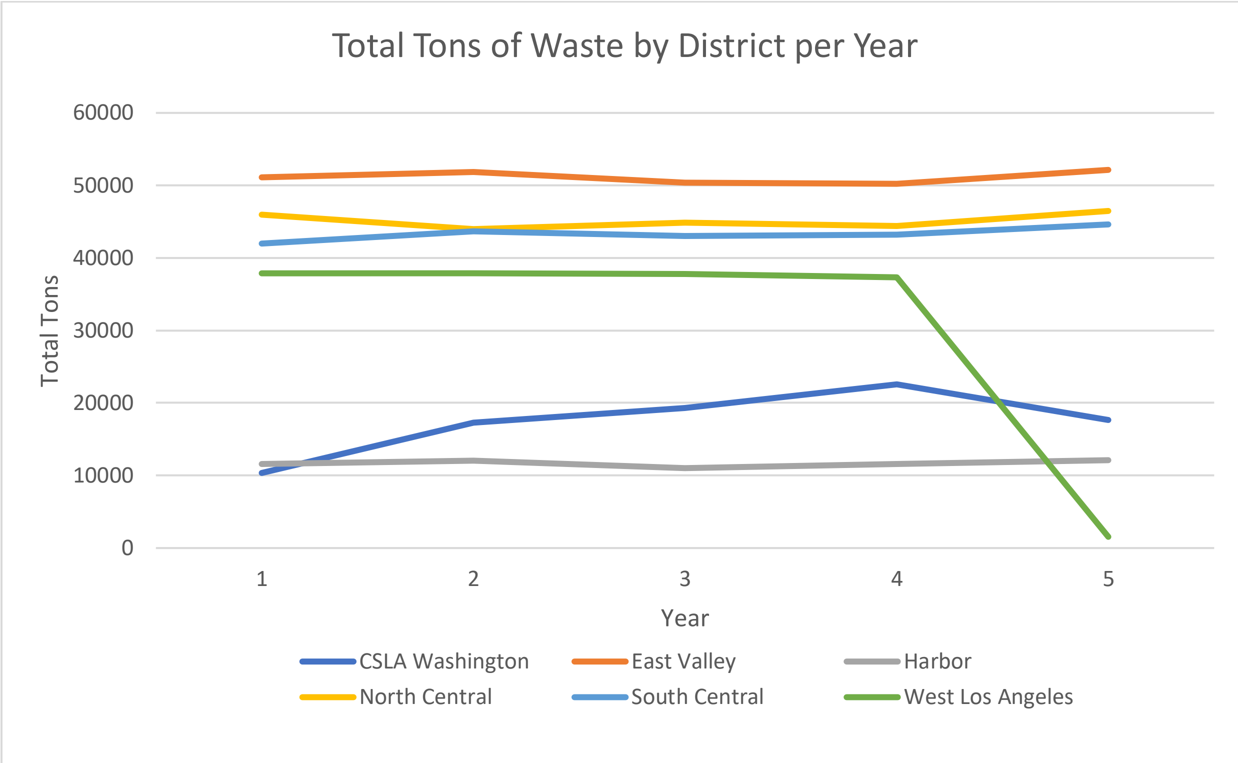
	CSLA Washington	East Valley	Harbor	North Central	South Central	West Los Angeles
Mean	17426	51134.8	11649	45139.8	43297.2	30479.8
Median	17678	51098	11556	44867	43180	37789

Std. Deviation	4471.89	849.3	438.45	1047.13	967.4	16176.69
Minimum	10355	50224	11017	43977	41984	1545
Maximum	22571	52144	12116	46479	44621	37886

The descriptive statistics presented above were calculated from yearly tonnages, and due to the lack of sufficient data statistical information such as mode were not considered. The chart below visualizes the total tonnages of waste collected from each district each year. The CSLA Washington and West Los Angeles districts were the only districts that had mean values less than the median. This indicated a negative skew in the data and meant that much of the waste tonnages collected for these two districts were less than the median value. On the other hand, East Valley, Harbor, North Central, and South Central all had mean values higher than the median, indicating a positive skew of data. Especially pertaining to the North Central district with the largest discrepancy between the mean and the median, this meant much of the reported waste amounts were greater than the median, which shifted the mean to the right.

Graph 2 presents a visualization of the total tons of waste collected by district per year in Los Angeles.

Graph 2: Line Graph of Tons of Waste by District per Year



Source: LA Sanitation Public Data Portal

The information presented in the chart indicates that most districts in Los Angeles did not experience any significant change in the total amount of waste collected per year. While CSLA Washington did see some visual changes in the total tons of waste collected over the five-year period, there was no resulting overall decrease in waste production when compared to the first year of data collection in 2016. However, West Los Angeles was the only district in the city that had a substantial decrease in tons collected in 2020 compared to previous years. This decrease of more than half of the previous reported amount of collected waste tonnages occurred in the 2019, the fourth year of data collection.

Data and Descriptive Statistics for Total Waste Collected by Commodity per Year

Table 4 below presents the total tons of waste collected by commodity each year. Commodity categories were divided into bulky, recycling, refuse, and yard trimmings. **Appendix A** defines and elaborates on the meanings and standards for these categories.

Table 4: Total Tons of Waste by Commodity

Year	Bulky	Recycling	Refuse	Yard Trimmings
2016	50,078.72	169,915.55	721,578.65	289,213.27
2017	55,619.77	166,652.42	738,627.91	305,588.05
2018	58,863.16	153,141.50	742,179.94	293,721.27
2019	63,385.26	156,536.47	756,178.83	308,371.87
2020	65,595.60	159,357.41	666,651.65	266,812.23

Table 5 presents the descriptive statistics for each commodity.

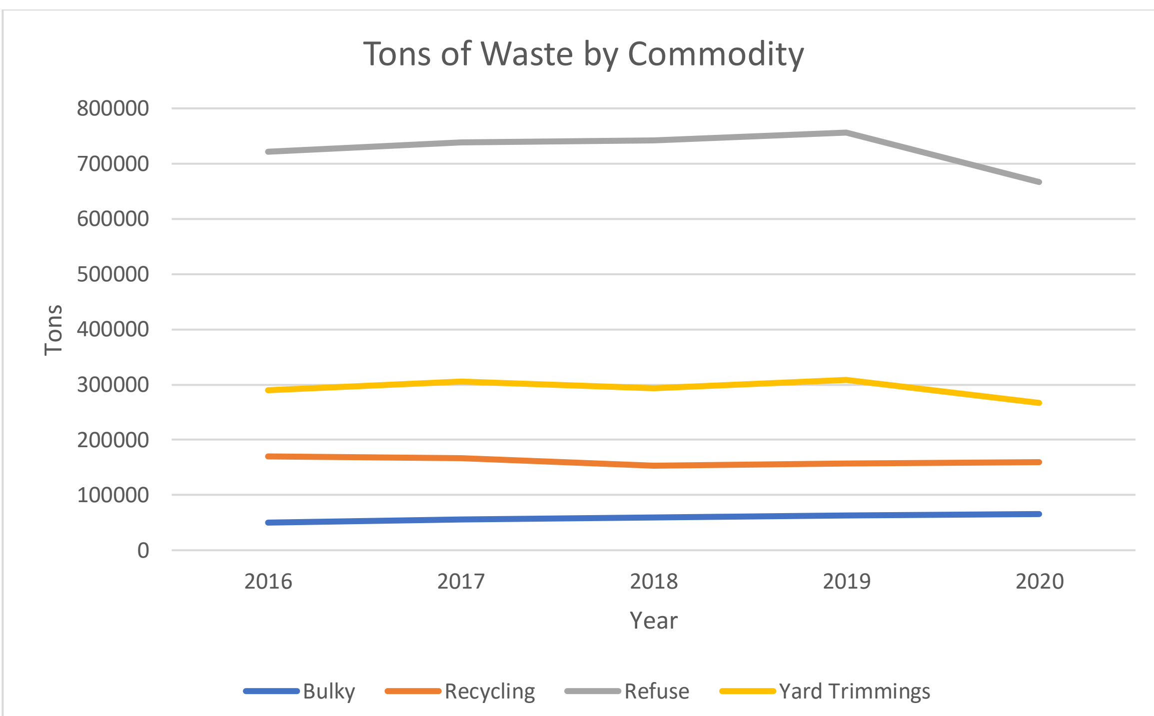
Table 5: Descriptive Statistics of Total Tons of Waste Collected by Commodity

	Bulky	Recycling	Refuse	Yard Trimmings
Mean	58,708.5	161,120.67	725,043.4	292,741.34
Median	58,863.16	159,357.41	738,627.91	293,721.27
Std. Deviation	6,191.56	6,995.38	34,889.88	16,545.98
Minimum	50,078.72	153,141.5	666,651.65	266,812.23
Maximum	65,595.6	169,915.55	756,178.83	308,371.87

As with the data for tons of waste by district, the data for waste collected by commodity was also analyzed by yearly increments therefore statistics such as mode were not considered. The chart below visualizes the tons of waste by commodity per year. Under these categories, bulky, refuse, and yard trimming waste categories all had mean values smaller than the median, indicating a negative skew of data. This meant that much of the collected data for each of these three districts were smaller than the mean. On the contrary, recycling wastes was the only category that had a mean value higher than the median, indicating a positive skew of data.

Graph 3 below visually depicts the total tons of waste collected by commodity per year.

Graph 3: Tons of Waste by Commodity per Year



Source: LA Sanitation Public Data Portal

The information in the chart indicates that refuse was the only waste commodity that saw a substantial decrease in total tons collected. While careful observation of the visual data shows that total tons of yard trimmings collected also seem to have slightly decreased in 2020 compared to 2016, overall, tons of bulky, recycling, and yard trimming waste materials collected over the five-year period generally seem to have remained stagnant. The chart also makes it clear that refuse wastes are collected in much greater quantities compared to recycling, bulky, and recycling wastes, which are closer together in quantity collected. This indicates that refuse wastes are the most abundantly produced waste type in Los Angeles.

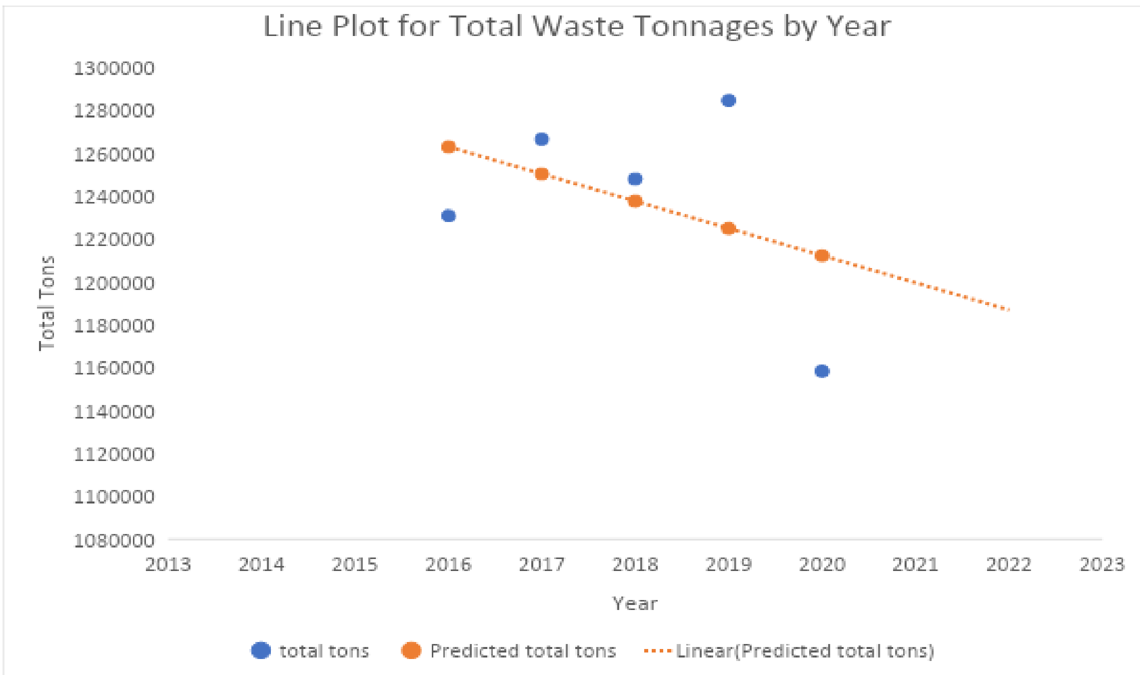
Analysis of Los Angeles Data

Correlation Analysis

Analysis of the data indicates that there seems to be a negative relationship between year and the total tons of waste collected in Los Angeles. The year 2020 saw an approximately 5.88% decrease in waste tonnages compared to 2016 and a 9.81% decrease in waste tonnages since the previous year, 2019. A correlation matrix showed that although there was a negative relationship between the two variables, the Pearson's r was -0.527 meaning the relationship was not statistically significant at any level with a p-value of 0.361. The correlation matrix is included in

Appendix B. This negative linear relationship between year and the total tons of waste collected is given in the scatterplot below.

Graph 4: Scatterplot with Fit Line of Year and Total Tons of Waste per Year



Another correlation matrix was used to examine the data for any statistically significant correlations between year and the tonal tons of waste collected by commodity. This correlation matrix is included in **Appendix B.** Similar to the results found with the correlation matrix for the variables year and total tons, the correlation matrix for year and commodity of waste showed that while there are negative relationships between year and recycling, year and refuse, and year and yard trimmings, none of these relationships are significant at any statistical level. Interestingly, however, there was a positive correlation between year and bulky wastes, meaning that as the year increased, the amount of bulky wastes collected in

Los Angeles also increased. Furthermore, at a Pearson’s r of 0.991, the p-value was 0.001 and the relationship between year and tons bulky wastes was significantly significant at a p level of 0.05.

Finally, a correlation analysis between the year and the total tons of waste collected per district in Los Angeles was conducted. This correlation output is included in **Appendix B**. When observing the correlational relationships between the year and waste tonnages by district, the only district that had a negative relationship with year was West Los Angeles. Pearson's r was -0.715 with a p-value of 0.714, meaning that as the year increased, the total amount of wastes collected from the West Los Angeles district decreased in value. However, this relationship is not statistically significant at a p level of 0.05. Interestingly, the Pearson’s r values for the other districts in the city and tonnages were calculated to be positive, indicating a positive correlation. This meant that as the year increased, the total tons of waste collected from each district also increased in value. However, the correlation coefficient did not have any statistical significance at any level.

Regression Analysis

A regression analysis was conducted to examine if and how the date of waste collection could predict changes in total waste tonnages over time. Results returned that the F-value was 0.614 and the $r^2 = 0.17$. The p-value was calculated as 0.49, and therefore did not indicate significance at $p < 0.05$. From this result, it can be concluded that this regression model could explain 17% of the fitted data. The B-coefficient was returned as -12,675.432 in this regression model, meaning every increase in year would be associated with a 12,675.432 decrease in total waste tonnages.

Austin, Texas

Waste quantity datasets for Austin, Texas was made public by the City of Austin through the official open data portal. Unlike the relatively simple and organized data for Los Angeles, dataset for the city of Austin was larger and more descriptive. Data on waste quantities were collected beginning January of 2003. Collected data were categorized by load type, total load weight, drop-off site, and route type. Total amount of waste was collected as total pounds, as opposed to tons seen in the Los Angeles dataset. For the purposes of this current analysis, data collected before 2009 will not be considered due to the abundance of missing values and statistics. In addition, special focus will be placed on the date of waste collection, total load weight, and load type.

Data and Descriptive Statistics of Total Pounds of Waste Collected in Austin

Table 6 below presents the total pounds of waste collected in yearly increments.

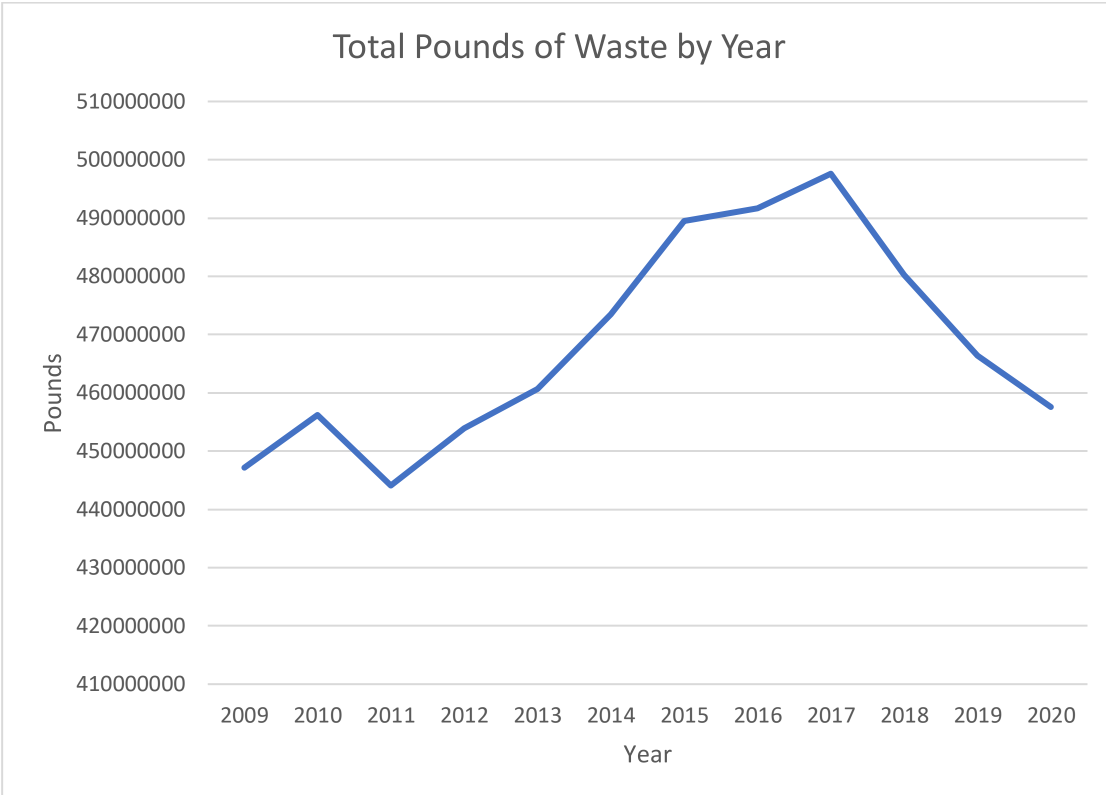
Table 6: Total Pounds of Waste Collected by Year

Year	Total Pounds of Waste
2009	447,175,354
2010	456,221,447
2011	444,089,467
2012	453,900,347

2013	460,709,366
2014	473,445,725
2015	489,434,223
2016	491,616,355
2017	497,602,543
2018	480,235,196
2019	466,388,138
2020	457,516,835

Based on **Table 6**, it seems evident that the total pounds of waste collected both increased and decreased over the years. However, overall compared to 2009, there was an increase in total pounds of waste collected in 2020. The average amount of waste collected over the eleven-year period was 468,194,583 pounds. The median was 463,548,752, which was less than the average. This indicates that the data had a positive skew, meaning much of the waste amounts collected were greater than the median, shifting the mean to the right of the distribution. The standard deviation was 18,042,708.1. The minimum of total pounds was collected in 2011, at the amount of 444,089,467 pounds while the maximum amount was collected in 2017 at the amount of 497,602,543 pounds. The data and the positive skew are visualized in **Graph 5** below.

Graph 5: Total Pounds of Waste by Year



Source: City of Austin Public Data Portal

As visible in **Graph 5**, total pounds of waste in 2020 although have decreased drastically from 2015-2017 levels, have increased slightly from 2009.

Waste amounts were also reported by waste type. However, unlike the Los Angeles dataset that had organized the data into four concise categories, the Austin dataset presented more diverse categories of waste. Pounds of waste were collected and organized as bagged litter, brush, bulk, contaminated recycling, contaminated yard trimmings, dead animal, garbage collections, litter, mattress, mixed litter, mulch, organics, recycled metal, recycling- single stream, sweepings, tires, yard trimmings, and yard trimming-x-mas trees. For this particular analysis and purposes of comparison with the results of Los Angeles data analysis, the waste types were organized into four categories: refuse, recycling, yard trimmings, and bulky. Refuse included garbage, dead animals, and litters, recycling included recycling and recycled metals, yard trimmings included brush and yard trimmings, and bulky included bulk and tires. Data for bagged litter, contaminated recycling, contaminated yard trimmings, mattress, mulch, organics, and yard trimmings-x-mas trees were omitted entirely and not considered in the analysis as the missing values were significant and could potentially alter the results. **Table 6** depicts the total pounds of waste collected by year categorized by the type of waste.

Data and Descriptive Statistics for Total Pounds of Waste by Type in Austin

Table 6: Total Pounds of Waste by Type

Year	Refuse	Recycling	Yard Trimmings	Bulky
2009	257,091,447	104,280,210	69,978,726	15,920,211
2010	260,494,220	104,997,669	75,299,082	15,476,196
2011	249,374,200	105,353,117	73,500,114	15,924,676
2012	256,674,430	107,913,231	73,133,780	16,227,056
2013	251,581,206	108,809,956	76,911,811	23,406,893
2014	259,220,073	111,144,510	83,961,733	19,279,569
2015	265,565,231	116,081,451	85,960,781	22,509,860
2016	263090,728	116,815,871	90,776,613	21,557,343
2017	264,291,319	118,136,363	93,063,223	22,697,458

2018	260,111,146	119,686,999	79,307,314	21,648,997
2019	258,897,921	117,285,133	68,234,542	22,601,542
2020	282,259,154	130,650,560	34,049,320	11,354,621

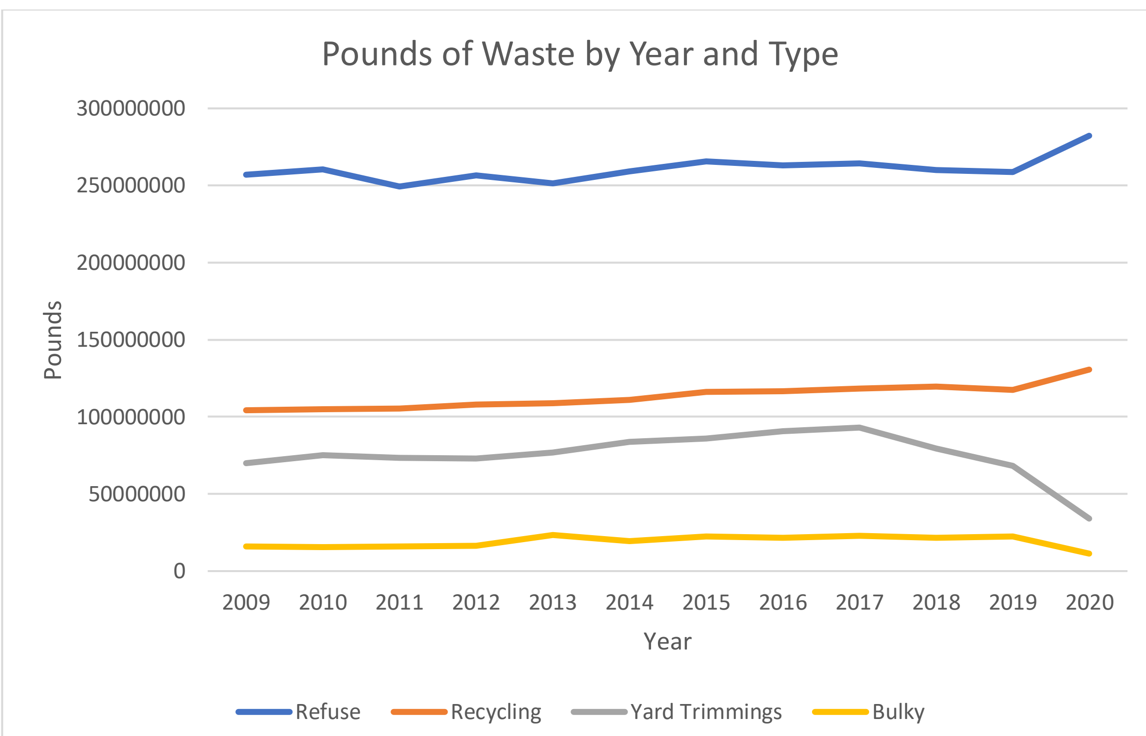
Table 7 presents the descriptive statistics for the amount of waste collected by type.

Table 7: Descriptive Statistics of Total Pounds of Waste Collected by Type

	Refuse	**Recycling**	**Yard Trimmings**	**Bulky**
Mean	260,718,673	113,429,594	75,348,086.6	19,050,368.5
Median	259,665,610	113,612,981	76,105,446.5	20,418,456
Standard Deviation	8,280,144.21	7,794,315.43	15,226,029.2	3,925,302.28
Minimum	249,347,200	104,280,210	34,049,320	11,354,621
Maximum	282,259,154	130,650,560	93,063,223	23,406,893

As with the data for Los Angeles, the data for waste collected by commodity was also analyzed by yearly increments therefore statistics such as mode were not considered. Of the four categories of waste, refuse waste was the only category that had a mean value greater than the median, indicating a positive skew of data. On the other hand, recycling, yard trimmings, and bulky wastes all had a mean value less than the median, indicating a negative skew. This meant that much of the reported waste amounts were less than the median, shifting the mean to the left of the distribution. **Graph 6** below visualizes the pounds of waste by type per year.

Graph 6: Pounds of Waste by Type per Year



Source: City of Austin Public Data Portal

The information visualized in the chart indicates that the only waste categories that experienced a decrease in total pounds was bulky waste and yard trimmings. Counter to this, pounds of recycling and refuse increased slightly in 2020 compared to 2009. Like in the case of the Los Angeles data, the quantity of refuse wastes collected seems to be much greater than the quantity of wastes collected in the other three commodities.

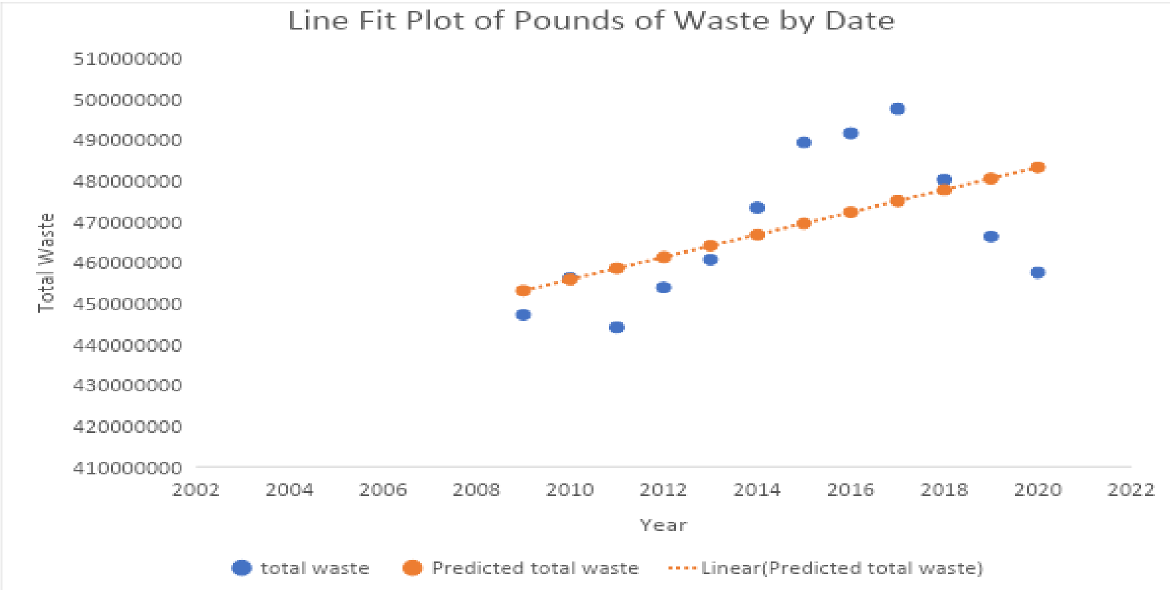
Analysis of Austin Data

Overview of the data seems to indicate that the City of Austin experienced an increase in total pounds of waste collected from 2009 to 2020. There was approximately a 2.31% increase in total pounds of waste collected in 2020 than that collected in 2009. However, there was a 1.9% decrease in total pounds of waste collected in 2020 compared to the previous year, 2019. Furthermore, there was an 8.06% decrease in total pounds of waste collected in 2020 compared to 2017, the year that saw the maximum amount of waste collected. These results indicate a decreasing trend in the amount of waste collected annually since 2016.

Correlation Analysis

Although analysis of the data from 2009 to 2020 seems to indicate a generally positive relationship between year and total pounds of waste collected, there was no significant correlation with a Pearson’s r of 0.549 and a p-value of 0.065. This meant that as the year increased, the total pounds of waste that was collected also increased. The correlation matrix is included in **Appendix C**. This positive linear relationship between year and the total pounds of waste collected is depicted in the scatterplot below.

Graph 7: Scatterplot with Fit Line of Pounds of Waste by Year



Another correlation analysis was conducted to examine the data for any statistically significant correlations between year and the total pounds of waste collected by type. The correlation matrix is included in **Appendix C**. Analysis of the total pounds of waste by type and year indicates that there were significant positive correlations between the year and total pounds of refuse and recycling. Refuse was determined to be statistically significant at a p level of 0.05 with a Pearson's r of 0.635 and a p-value of 0.027. Recycling was also determined to be statistically significant, however at a p level of 0.001 with a Pearson's r of 0.940 and a p-value of 0.477. This meant that for both refuse wastes and recycling wastes, as the year increased, the total amount of waste collected in each category also increased at a statistically significant level. Interestingly, there was only one negative correlation among the four types of waste and year. Yard trimmings had a Pearson's r of -

0.228, indicating a negative relationship, however this was not statistically significant at any p level.

Regression Analysis

A regression analysis was conducted to examine if and how the date/time of waste collection could predict changes in total pounds of waste collected over time. Results returned that the F-value was 4.310 and the $r^2 = 0.301$. This meant that the regression model could explain 30.1% of the fitted data. The p-value was calculated as 0.065, and therefore did not indicate significance at $p < 0.05$. The B coefficient was returned as 2,746,493.21 in this regression model, meaning every increase in year would be associated with a 2,746,493.21 increase in total pounds of waste.

Phoenix, Arizona

As with the case for Los Angeles and Austin data, data for the waste tonnages of Phoenix, Arizona was obtained from those made public through the city's official open data portal. Unlike with the other two cities, waste data for Phoenix were made available in several different csv files, and did not report any data for the year 2017. Data were made available beginning in January 2014 to December 2020. The categories in which the data were presented varied by year and month, however for the purposes of effective comparison with Los Angeles and Austin, this analysis will focus on yearly total tonnages, and yearly tonnages based on commodity.

Table 8 below presents the total tonnages of waste collected in Phoenix per year.

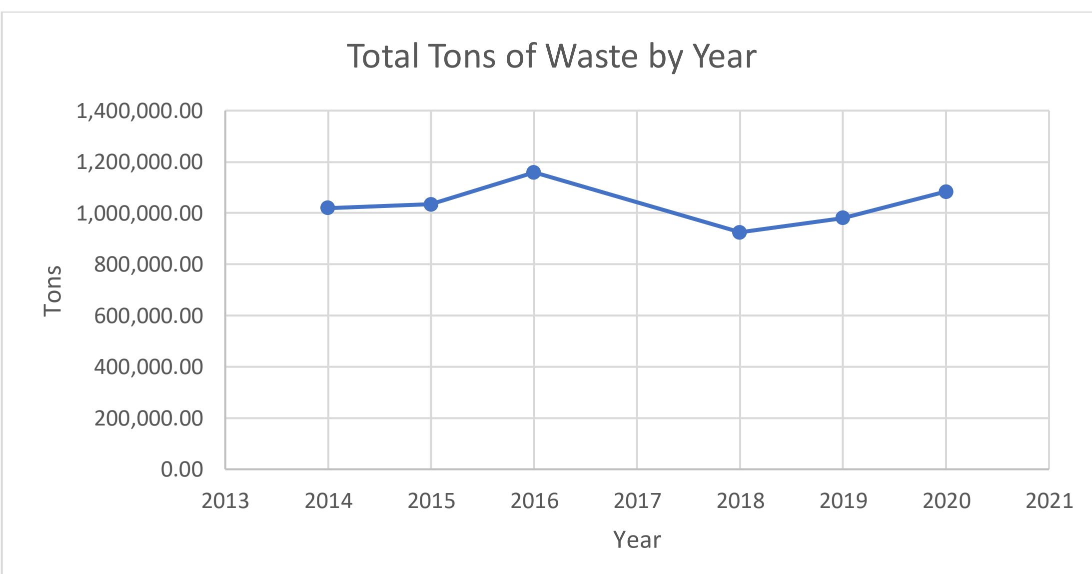
Data and Descriptive Statistics of Total Tons of Waste Collected in Phoenix

Table 8: Total Tons of Waste per Year

Year	**Total Tons of Waste**
2014	1,019,925.38
2015	1,034,501.75
2016	1,158,920.32
2018	925,143.94
2019	980,896.4
2020	1,084,027.35

Based on **Table 8**, it is evident that there was an increase in total tons of waste collected in 2020 from 2014. The average tons of waste was 1,033,902.52 tons. The standard deviation was calculated as 81,210.52 tons. The minimum amount of waste was collected in 2018, with a total of 925,143.94 tons while the maximum amount of waste was collected in 2016, with a total of 1,158,920.32 tons of waste collected that year. The data are visualized in **Graph 8** below.

Graph 8: Total Tons of Waste per Year



Source: City of Phoenix Public Data Portal

The information from the chart seems to indicate that although there were changes in the amount of waste collected, there were no substantially large fluctuations of total waste tonnages that were collected annually. Additionally, there was a slight increase in tons collected in 2020 compared to the total tons collected in 2014.

Like the data for Austin, Phoenix data did not categorize tonnages by any district. The datasets for waste tonnages in 2014, 2015, and 2016 reported waste tonnages in a number of different categories including but not limited to food scrap, rejected recycling, tires, and water waste. However, much of the data values for these categories were missing. In addition, beginning in the 2018 dataset, waste tonnages were reported three categories: refuse, green, and recycling. Therefore, for the purposes of this analysis, the data from the 2014, 2015, and 2016 datasets were also simplified into the three categories of refuse, green, and recycling and categories with significant missing values were excluded from consideration.

Data and Descriptive Statistics for Total Waste Tonnages by Commodity in Phoenix

Table 9 below depicts the total waste tonnages each year by commodity.

Table 9: Total Tons of Waste by Commodity per Year

Year	Refuse	Green	Recycling
2014	855,396.07	34,872,14	129,657.17
2015	876,865.17	26,420.49	131,216.09
2016	992,210.71	19,054.06	147,655.55
2018	713,859.89	48,565.88	162,718.17
2019	772,169.08	51,057.44	157,669.88
2020	860,296.4	42,628.45	181,102.5

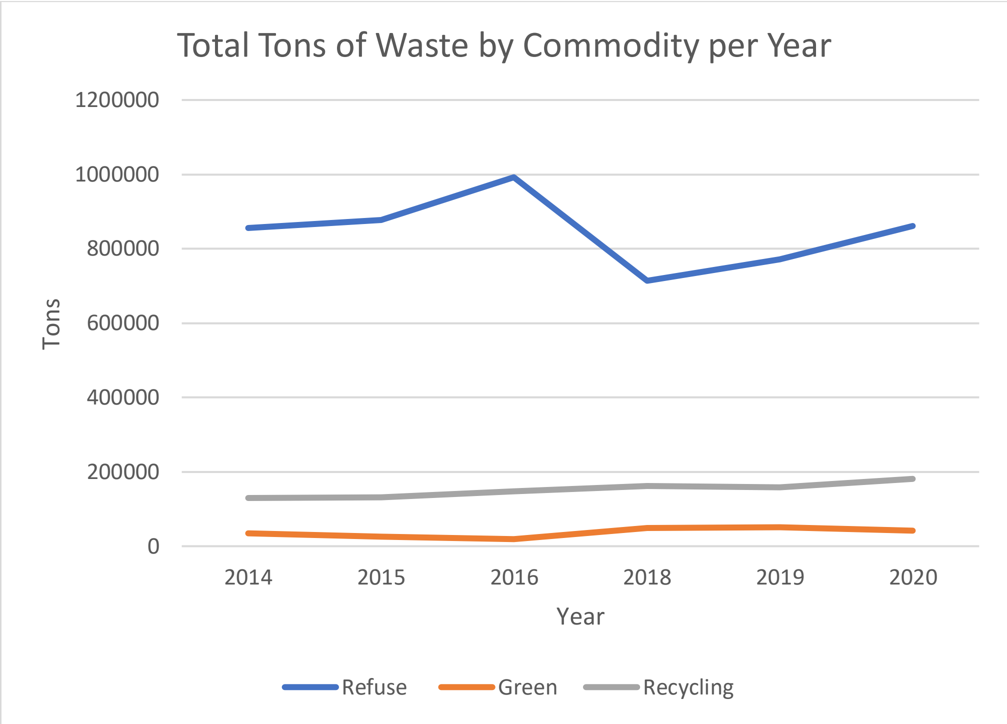
Table 10 below further presents the descriptive statistics for each commodity by year.

Table 10: Descriptive Statistics of Waste Tonnages by Commodity per Year

	Refuse	Green	Recycling
Mean	845132.89	37099.74	151669.9
Median	857846.24	38750.3	152662.72
Standard Deviation	95425.79	12661.05	19714.85
Minimum	713859.89	19054.06	129657.17
Maximum	992210.71	51057.44	181102.5

Graph 9 below visualizes the total tons of waste collected by commodity each year.

Graph 9: Total Tons of Waste by Commodity per Year



Source: City of Phoenix Public Data Portal

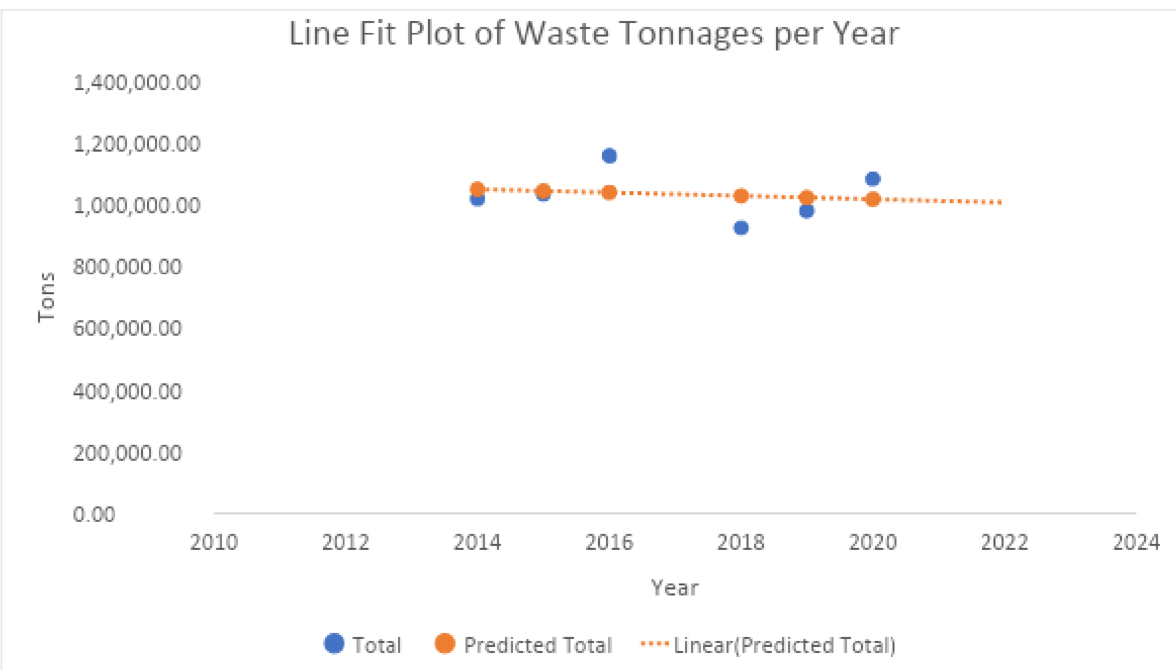
From the chart, it is evident that waste categorized as refuse was the only category that experienced any visually considerable changes of waste tonnages each year. Recycling and green waste categories seem to have remained relatively stable over the years, however still show slight increases in total waste tonnages in 2020 compared to 2014.

Analysis of Phoenix Data

Correlation

Although the data indicate that there were small increases in total waste tonnages in 2020 compared to 2014, correlation analysis revealed no statistically significant relationships between year and total tons of waste. With a Pearson's r of -0.155 and a p-value of 0.770, the relationship between year and total waste tonnages, although negative, was not significant at any level. The correlation matrix is included in **Appendix D**. The negative linear relationship between the year and total tons of waste collected is shown in the scatterplot below.

Graph 10: Scatterplot with Fit Line of Year and Total Tons of Waste



Further correlation analysis was conducted to examine for any significant relationships between year and the total tons of waste collected by commodity. The correlation matrix is included in **Appendix D**. As is evident from the correlation matrix, none of the relationships between year and commodity were calculated to be statistically significant except for that between year and recycling. With a Pearson's r of 0.953 and a p-value of 0.003, the relationship between year and total tons of waste categorized as recycling was found to have a positive statistically significant relationship at a p level of 0.01. This meant that as the year increased, the amount of recycling wastes collected also increased. The only correlational relationship that was found to be negative was that between year and refuse waste, however with a Pearson's r of -0.419 and a p-value of 0.408, this relationship was not found to be statistically significant at any p-level.

Regression Analysis

As was done with the Los Angeles data and Austin data, a regression analysis was conducted on the Phoenix data to examine if and how the date/time of waste collection could predict changes in total pounds of waste collected over time. Results returned that the F-value was 0.098 and the $r^2 = 0.024$. This meant this regression model could explain 2.4% of the fitted data. The p-value was calculated as 0.769, and therefore did not indicate significance at any p-level. The B coefficient was calculated as -5310.04 for this regression model, meaning every increase in year would be associated with a decrease of 5310.04 total pounds of waste.

Discussion

The various analyses conducted on the waste tonnage data for each city reveal that most of the relationships observed between year, the total amount of collected waste, and the total amount of collected waste by commodity were not statistically significant at any level. In Los Angeles, although it was not determined to be statistically significant, there has been a decrease in the overall total waste tonnages collected from 2016 to 2020. Additionally, there was a statistically significant decrease in bulky wastes. This decrease in total waste tonnages may seemingly be attributable to the West Los Angeles district, as this was the only district in the city that had a negative relationship between waste tonnages and year. Regression analysis predicted that total waste tonnages would decrease as years increased.

In Austin, there was a slight increase in the amount of waste collected in 2020 compared to the amount collected in 2009. However, the pounds of waste collected in 2020 was largely decreased from the total amount collected in the two years prior, which saw the maximum amount of waste collected for the city. Yard trimmings was the only waste category that was found to have a negative correlational relationship with year, although statistically insignificant. The correlational relations between refuse waste and year and recycling waste and year categories were found to be positive and statistically significant. Contrary to the case of Los Angeles, regression analysis predicted an increase in total waste amounts each year.

Finally, in Phoenix, there was a relatively stable trend of waste tonnages collected from 2014 to 2020. Although there was a very slight increase in waste tonnages collected in 2020 compared to the amounts collected in 2014, correlation analysis revealed a negative relationship between refuse waste tonnages and year along with positive relationships between year and green waste and year and recycling waste, the latter being determined as statistically significant. Furthermore, regression analysis predicted that total waste tonnages for the city of Phoenix would decrease each year.

The results of the analysis conducted in this study found no consistent pattern or trend in the amount of waste collected annually in cities that had adopted zero waste commitments and one that had not. Furthermore, many of the correlational relationships observed between the year and the reported amounts of waste collected by the type of waste were determined to be insignificant. In general, none of the cities saw a significant change in waste production each year regardless of whether or not it had pledged to work towards zero waste, indicating that the Zero Waste Policy did not have a significantly influential effect on waste production.

Each of the cities experienced different phenomena with regards to waste generation. For example, in Los Angeles, there was a decrease in total amount of waste collected in 2020 from what was collected in 2016, however upon observation of the data categorized by various districts and waste commodities, it is clear that this occurrence can be credited to just one district and largely one waste commodity. Analysis revealed that West Los Angeles was the only district that saw a decrease in waste tonnages as years increased. Furthermore, this decrease was due to specific decreases in tons of refuse and yard trimmings. It may be worthy to examine West Los Angeles individually in order to isolate causes and/or reasons specific to the West Los Angeles service zone for this occurrence. As mentioned previously in this paper, one of the main goals stated by the Zero Waste LA franchise was to address the three million tons of waste disposed annually by businesses, consumers, and residents throughout Los Angeles. Specifically, with regards to waste reduction, it had aimed to reduce landfill disposal by one million tons per year by 2025 and reduce waste by 65 percent in all eleven of the city's service zones. As it pertains to these particular goals, it seems as though the city of Los Angeles has not yet met the standards it had committed to as a whole. However, there seems to be a prediction that total waste tonnages will continue to decrease by year, therefore it may be of interest to examine whether or not the tonnages will have continued to do so in 2025. Another goal of the Zero Waste LA franchise was to provide transparent and predictable recycling service rates for the next ten to twenty years. Taking into consideration the increase in tons of recycling that was collected from 2016 to 2020, further analysis into the possible correlational and/or causational relationship between this particular policy agreement and the increase of recycling could be completed.

Of the three cities, analysis revealed that Los Angeles and Phoenix were the only two cities that were found to have a negative predicted relationship between year and total tons. Although Austin, like Los Angeles, had enacted policies to help reduce waste production, based on the analysis and future prediction of waste production values, it seems as if the amount of waste produced will increase as the year also increases. This finding supports the conclusion that implementation of policy such as Zero Waste frameworks in cities does not lead to waste reduction or any specific pattern of waste reduction when compared to cities that have not implemented such policy.

As mentioned and discussed in the literature review earlier in this paper, there were differences in the types of strategies and policies each city enacted under their Zero Waste policy. While both cities were very diverse in the kinds of policies they used, Los Angeles seemed to focus on addressing the situational and environmental factors that create social norms around waste production, Austin seemed to place a special emphasis on using economic incentives to alter individual behavior. Based on this understanding, it is worth considering whether or not this influenced the overall effectiveness of the Zero Waste program that was observed in each city from the data analysis. Under this idea, it can be concluded that policies that target situational factors around waste production, influence social norms, and alter individual beliefs towards waste and waste management are more effective than economic based policies in reducing waste production.

Further comparison of the waste data for the three cities made it clear that the amount of waste in the refuse commodity that was being produced was much larger in quantity than the amount of waste produced for other waste categories, contrary to the goals of the Zero Waste programs. Although the total amount of refuse waste collected in each city differed in terms of how they increased and/or decreased throughout the period data was collected for, visualizations of the data made it especially clear that refuse type waste was still the most abundantly produced waste type. In addition, although both the Zero Waste programs in Los Angeles and Austin reserve special policy considerations to increase recycling, data indicated that the amount of recycling waste that is produced in each city did not show any significant changes. Interestingly, Phoenix was the only city that showed a significant increase in recycling waste production, as the amount of recycling waste collected in Austin, although increased compared to the levels at the beginning of data collection in 2009, was not significant.

Limitations

Due to the different sources from which the data for each city were obtained, limitations for this study were seen largely within the discrepancies in the format and organizational standards for which the data were presented. For example, while the datasets for waste tonnages in Los Angeles were presented in few categories and in a single consolidated dataset, data for Phoenix were made available in multiple csv files with a large number of categories-many of which were missing a significant proportion of values. Due to this, categorization and organization of waste amounts into smaller groups for final analysis was determined based on 1) completion and availability of data in each of the categories and 2) individual discretion. There was no guarantee that the categories that were used to complete the “refuse” category of waste for the city of Austin, for example, were the same categories of waste that were used in the pre-organized waste categories set by the data for Los Angeles. Therefore, there is a possibility that this kind of discrepancy in data between each of the city datasets could have altered the results of analysis and further, the conclusions of the comparison analysis.

Policy Recommendations

In order to begin effectively controlling waste prevention, waste related policy should set specific goals aimed at both environmental protection and eventual waste reduction. Some of these goals may include minimizing resource and energy impacts, achieving waste reduction at the unit level (i.e. product, household) and at a societal level, development of a merit system that properly utilizes city infrastructure in a way that benefits waste reduction, and ensuring community contribution in the process of policy drafting. Setting such specific goals will ensure that the policy is working as intended and will provide a reference for future analysis.

While the Zero Waste franchises did outline goals that would help address waste production in each of the cities, in order to make more impactful and effective changes to total waste production, future policies regarding waste in all of the eleven districts should acknowledge the situational differences between each district and implement more specific regulations tailored to each service district. However, across all kinds of policies and strategies that are implemented, the policies should target reducing refuse waste production at the source rather than discuss ways to treat or divert refuse wastes that are created. Regulations that further propose to channel said refuse waste towards other management technologies such as recycling and rescue programs should be a secondary strategy consideration. Based on the literature review and the conclusions of studies on source reduction strategies completed in international countries, future policy should consider implementing an elastic unit-based pricing system for residential wastes to replace the current fixed pricing of waste collection typically seen throughout most of the communities in the United States. This type of policy may be effective in economically incentivizing waste reduction behaviors at the individual and/or household level.

Policies may also be specific in the type of product or material they target for reduction. For example, certain policy may address the excessive amount of waste that arises from product packaging and promote environmentally friendly packaging designs instead. Evidently, policies that are specific to product and/or material will vary by area they are implemented for, therefore communication between consumers, producers, and community members is essential. The policy should ensure participation from the businesses that create the products and the local government that promotes awareness of alternative options.

In addition, based on the information known about the both the impact of food wastes on the overall level of waste production and the negative impact of food wastes on the environment, policy targeting food rescue and food waste reduction will be effective in reducing waste production. Although the Zero Waste LA framework mentioned food rescue assistance as one of its strategies and goals, the policy was not specific enough to create any tangible impact. Cities may start by addressing food waste targeting educational environments such as schools and their role in contributing to the overall amount of food waste. In doing so, not only is there the potential to decrease food waste, but younger generations of individuals will be exposed to waste reduction efforts. Understanding that reducing food waste in institutional settings is difficult and that even with significant planning on the part of nutrition managers may result in food waste, excess food may be donated through food recovery organizations and/or composted rather than discarded.

Based on the importance that proper education has on influences waste related behaviors, future policy should continue to explore and examine new, innovative educational programs. These programs should not be limited to educational settings or institutions only, but instead should target the community members in the entirety of the area it is being implemented to. In order to help cities achieve this, policymakers could do well to consider creating new partnerships and collaborations with external education organizations that have expertise in effective solid waste management and reduction education.

At the very basic and elementary level, policymakers and city officials should continue to stress the importance of accurate data collection on waste amounts that are produced in their cities. This is essential for further analysis of program efficiency, especially as the Zero Waste programs in both Los Angeles and Austin grow closer to reaching their goal year deadlines. This current study experienced some difficulties that arose due to large portions of missing waste data that could have potentially altered the analysis results and presented them as different from true trends within waste production in each city. While many cities currently use the public data portal in order to share data on waste with the public, officials may consider implementing a separate, ongoing database specific to waste data that is updated on a timely basis. This will allow for more accurate data analysis and observation of potential policy effectiveness.

Conclusion

The results of this study indicated that, contrary to the intentions of each Zero Waste framework implemented in Los Angeles and Austin, there was no significant change in waste production in each city. Furthermore, there was no consistent pattern of influence that was observed in the cities with Zero Waste policies compared to Phoenix, where no such policy was implemented. It was also made clear that refuse type wastes are produced in much more abundant levels when compared to other waste commodities such as recycling, bulky, and yard trimming wastes. Although Los Angeles saw a decrease in total waste produced during the five years of data, this was not determined to be statistically significant and it remains uncertain whether or not this decrease occurred as a result of the Zero Waste framework that had been implemented. Furthermore, Austin observed an overall increase in total waste that was produced, contrary to the efforts of the Zero Waste Plan. Surprisingly, Phoenix, the only city analyzed that had not implemented any Zero Waste related policy showed a decrease in total waste amounts collected. Based on the inconsistency in results, this study cannot conclude that the Zero Waste Framework had any important or significant effects on overall waste production.

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Appendix A

Terms and Definitions (“Zero Waste LA” , 2014):

Collection Services- The collection, transportation, and delivery for disposal of solid wastes from
commercial and multifamily residential establishments

Commercial Establishment-All real property in the City except residential properties that receive
solid waste disposal services

Dwelling Unit-One or more rooms designed for single family occupancy

Hazardous Waste-Waste that may pose a risk of endangering human health or safety or may be
degrading to the environment (Health and Safety Code, 2005)

Multifamily Dwelling-Any building, structure, unit, or location purposed for residential
occupancy that receives solid waste disposal services from the City

Organics-Compostable solid wastes that are separated at the source and stored in a container to
be collected

Recyclables-Solid wastes capable of being recycled or reused, regardless of whether or not they
were separated at the source or stored with other solid wastes

Residential Premises-Single family dwellings and multifamily dwellings

Self-Hauler-Any person who, in the course of performing their primary work incidentally transports solid wastes but is not officially involved in the collection, removal, or transportation of solid wastes

Single Family Dwelling-Any building purposed for residential occupancy

Solid Waste-All putrescible and non-putrescible solid, semi-solid, and liquid wastes excluding hazardous wastes, radioactive wastes, medical wastes, and pharmaceutical wastes

Solid Waste Disposal Facility-Any facility fully permitted under government law and regulation to accept and dispose solid wastes

Solid Waste Hauler-Any person involved in the collection, removal, or transportation of solid wastes

Source-Separated Material-Recyclables that have been stored separated from other solid wastes and sorted by material type without being stored with other solid wastes, including recyclables

Transfer Station-A solid waste management facility where solid waste is received in order to either transfer to another solid waste management for processing, treating disposal, or

recover, or for subsequent transferring

Appendix B

Correlation Matrix between Year and Total Tons of Waste Collected in Los Angeles

Correlation Matrix

		Year	Tons
Year	Pearson's r	—	
	p-value	—	
Tons	Pearson's r	-0.527	—
	p-value	0.361	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix between Year and Commodity of Wastes in Los Angeles

Correlation Matrix

		Year	Bulky	Recycling	Refuse	Yard Trimmings
Year	Pearson's r	—				
	p-value	—				
Bulky	Pearson's r	0.991 **	—			
	p-value	0.001	—			
Recycling	Pearson's r	-0.706	-0.738	—		
	p-value	0.183	0.155	—		
Refuse	Pearson's r	-0.418	-0.308	-0.135	—	
	p-value	0.483	0.614	0.829	—	
Yard Trimmings	Pearson's r	-0.402	-0.280	0.014	0.955 *	—
	p-value	0.503	0.649	0.983	0.012	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix between Year and Total Waste Tonnages Collected by Districts of Los Angeles

Correlation Matrix

		Year	CSLA Washington	East Valley	Harbor	North Central	South Central	West Los Angeles
Year	Pearson's r	—						
	p-value	—						
CSLA Washington	Pearson's r	0.706	—					
	p-value	0.183	—					
East Valley	Pearson's r	0.092	-0.374	—				
	p-value	0.883	0.535	—				
Harbor	Pearson's r	0.235	-0.127	0.869	—			
	p-value	0.703	0.838	0.056	—			
North Central	Pearson's r	0.228	-0.500	0.387	0.204	—		
	p-value	0.713	0.391	0.520	0.742	—		
South Central	Pearson's r	0.777	0.485	0.606	0.641	0.100	—	
	p-value	0.122	0.408	0.278	0.244	0.874	—	
West Los Angeles	Pearson's r	_0.715	-0.042	-0.657	-0.594	-0.712	-0.766	—
	p-value	0.174	0.947	0.229	0.291	0.177	0.131	—

Note. * p < .05, ** p < .01, *** p < .001

Appendix C

Correlation Matrix between Year and Total Pounds of Waste in Austin

Correlation Matrix

		Year	Total Pounds
Year	Pearson's r	—	
	p-value	—	
Total Pounds	Pearson's r	0.549	—
	p-value	0.065	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix between Year and Type of Waste in Austin

Correlation Matrix

		Year	Refuse	Recycling	Yard Trimmings	Bulky
Year	Pearson's r	—				
	p-value	—				
Refuse	Pearson's r	0.635 *	—			
	p-value	0.027	—			
Recycling	Pearson's r	0.940 ***	0.835 ***	—		
	p-value	< .001	< .001	—		
Yard Trimmings	Pearson's r	-0.228	-0.509	-0.383	—	
	p-value	0.477	0.091	0.219	—	
Bulky	Pearson's r	0.270	-0.333	0.033	0.731 **	—
	p-value	0.396	0.290	0.918	0.007	—

Note. * p < .05, ** p < .01, *** p < .001

Appendix D

Correlation Matrix between Year and Total Tons of Waste in Phoenix

Correlation Matrix

		Year	Tons
Year	Pearson's r	—	
	p-value	—	
Tons	Pearson's r	-0.155	—
	p-value	0.770	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix between Year and Tons of Waste by Type in Phoenix

Correlation Matrix

		Year	Refuse	Green	Recycling
Year	Pearson's r	—			
	p-value	—			
Refuse	Pearson's r	-0.419	—		
	p-value	0.408	—		
Green	Pearson's r	0.681	-0.903 *	—	
	p-value	0.136	0.014	—	
Recycling	Pearson's r	0.953 **	-0.309	0.571	—

p-value	0.003	0.551	0.236	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$