ANALYSIS OF PROBLEMS AFFECTING THE EFFECTIVE MANAGEMENT OF MUNICIPAL RECYCLING PROGRAMS IN THE UNITED STATES

by

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DEDICATION

This is dedicated to the multiple individuals who took the time to pray, support, invest, and mentor me over the years. I am truly blessed to have the opportunity to contribute to the advancement of science and policy.

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I would like to first give all glory and honor to God from whom I derive my strength. I would like to thank the many friends, relatives, and supporters who have made this happen. I want to say a special thanks to my advisor Dr. Younsung Kim, my committee members, and Dr. Lucas Nunez for imparting their vast knowledge and experience while I conducted my research. Finally, I would like to thank the NSM faculty at Ferrum College for fostering my love of science and a providing me with a foundation upon which I have built my educational and professional career.

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LIST OF ABBREVIATIONS

Municipal Solid Waste.....MSW
Extended Prouder Responsibility .....EPR
Environmental Protection Agency.....EPA

ABSTRACT

ANALYSIS OF PROBLEMS AFFECTING THE EFFECTIVE MANAGEMENT OF MUNICIPAL RECYCLING PROGRAMS IN THE UNITED STATES

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From 1960 to 1985, the recycling rate in the United States increased approximately 5%. During the 10-year period between 1986 and 1995, it had rapidly grown to 25.7%. However, in the nearly 20 years following, the recycling rate started to stagnate at around 35% (EPA, 2019). The recycling rate is defined as the total amount of Municipal Solid Waste (MSW) recycled by the total amount of MSW generated in a year. Since recycling is becoming a cornerstone of waste management, the stagnated recycling rate raises a question of which problems are due to current management practices.

This study responds to this research gap and aims to investigate factors that may influence the management of public or private recycling programs. To this end, individuals within a minimum of one year of experience in waste management industry were surveyed and asked to rank already-identified problems as well as emerging problems that affect managing recycling programs. Recycling program managers play versatile roles as consumers, mangers, and producers in the material flow of recyclable

material. The findings indicate that market variability for recycled materials, contamination of recyclable materials, and public participation in recycling programs as key inhibiting factors in order. China's recent policy on banning imports of foreign wastes was also pointed out as an emerging concern for managing recycling programs. This study contributes to the field of waste management by offering a much-needed in-depth understanding of problems associated with current recycling practices and management.

1. INTRODUCTION

In the United States, recycling rates increased approximately 154% between 1985 and 1995, however, between 1995 and 2011 recycling rates only increased by 35% (Starr and Nicolson, 2015). Recycling of Municipal Solid Waste (MSW) is defined by the United States Environmental Protection Agency (EPA) as, "a series of activities by which discarded postconsumer materials are collected, sorted, processed, converted into raw materials and used in the production of new products" (EPA, 1997). The EPA defines the rate of recycling or recycling rate by dividing the total amount of MSW recycled by the total amount of MSW generated in a year (EPA, 1997). The standard methodology for determining recycling rates also accounts for imports and exports of waste at all government levels in the US and internationally. In this study, the standard equation developed by the EPA for calculating recycling rate has been used.

Figure 1 depicts the combined recycling and composting rates reported by the EPA, referred as singularly recycling rate in this study, from 1960 to 2017. The recycling rate has been split into three periods. Period one (1960 – 1985) was characterized by a period of *slow growth* in which the recycling rate increased less than 4% in a 25-year period. Period two (1985-2010) was a period of *rapid growth* where the recycling rate increase approximately 25% in a 25-year period. Since 2010, the percentage of recycled and composted material has plateaued around 35%, with the recycling rate leveling at

25% and composting rate leveling at 10%, which is referred to as a period of *stagnation* (EPA, 2019).

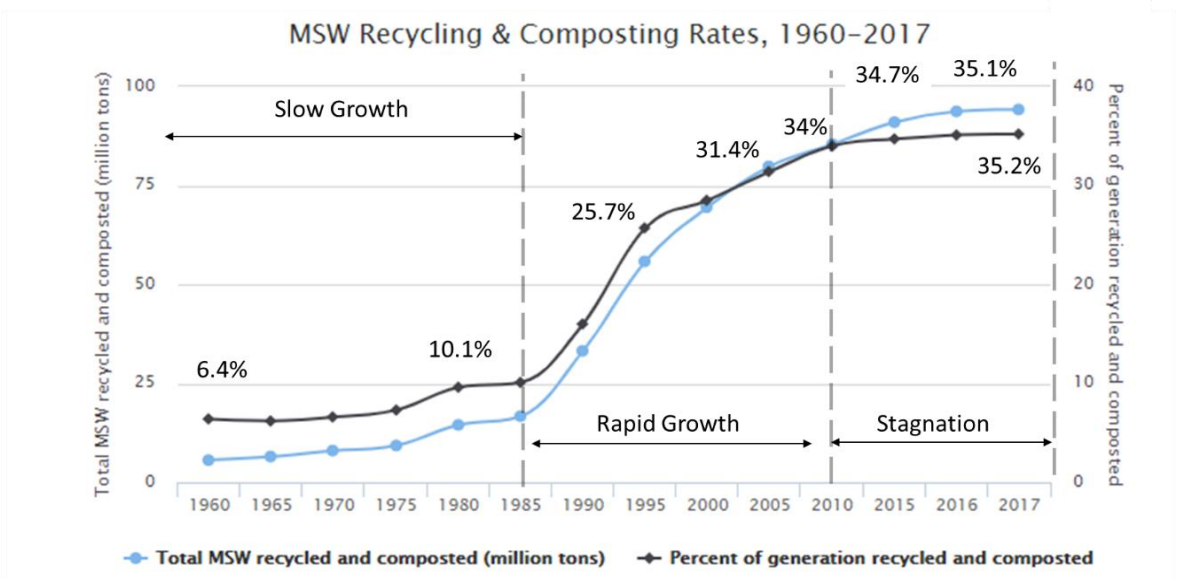

Figure 1 MSW Recycling & Composting Rate, 1960-2017 (EPA, 2017)

Recycling is an important component in the three pronged reduce, reuse, and recycle strategy designed to reduce waste generation. Recycling has been a cornerstone in the effort to reduce the amount of municipal solid waste (MSW) that is mostly landfilled. The term landfill refers specifically to landfills for municipal solid waste. The stagnation of the recycling rate is indicative of a potential informational gap, which raises a question of how to increase the recycling rate.

Two contributing factors regarding the current plateau in the national recycling rate can be classified into: (1) the external environment that contributed to the drastic

increase in the recycling rate between 1985 and 1995 and (2) the role that local governments have played in recycling and waste management. These two factors are outlined in the following paragraphs.

1.1 Factors Contributing to the Increase in Recycling Rate

With respect to the external environment, recycling of municipal solid waste (MSW) in the United States, as a national priority, increased during the Progressive era (1890's – 1920's) (Library of Congress, 2020) with the adoption of federal environmental laws that enforced stricter regulation for various wastes and pollutants. Recycling programs are designed to divert waste from municipal solid waste landfills and are a large part of effective and long-term waste management strategies. The development and adoption of recycling technology by "solid waste actors" (Lounsbury, 1997) such as collection agencies, landfill operators, waste management firms and a reduction of available landfill space for MSW resulting in increased MSW landfill tipping fees (Morris, 2011). Landfill tipping fees are the fees that landfills charge to deposit waste within a landfill. These are factors that resulted in the increased cost-effectiveness of recycling programs. (Lounsbury, 1997).

1.2 Role of Local Government in Waste Management

Recycling programs in the United States are regulated at the federal level by the Environmental Protection Agency, which sets the national environmental quality standards. The Resource Conservation and Recovery Act, Clean Water Act, Clean Air Act, and Comprehensive Environmental Response, Compensation, and Liability Act give the EPA widespread authority to monitor and regulate waste management and disposal

(Shahnawaz et al., 2019). States are allotted some regulatory power through partial preemption where state law is valid if it does not conflict with federal laws or statues (Lester, 1995). In relation to environmental regulations, individual states, within the United States, are required to develop and implement programs and plans designed to monitor and enforce with standards set by the EPA. Each state is broken into smaller independent governmental entities that will be referred to in this paper as local governments. These local governments are required to comply with EPA regulations and enforce standards that are mandated and defined in state management plans (Hickman, 1993). Local governments report compliance to their respective state governments. State governments then document compliance through state management plans and submit reports to the federal government through the EPA.

Local governments play an important role in waste management. In 2008, there were almost 90,000 local governments in the United States including counties, cities, municipalities etc. with a wide range of organization and authority granted to them by state constitutions (Briffault, 2008). The level of decision-making power (autonomy) that localities have varies by state, but overall local governments are the most involved in the implementation and management of waste management programs including recycling (Scheberle, 2012). Waste management includes the use of landfills and the implementation of waste diversion (Stegmann, 2019).

Waste diversion is the process of diverting waste from landfills through alternative methods like source reduction, combustion, composting, waste to energy and recycling (EPA, 2008). There are three stream sources for recycling and those are

residential, commercial and industrial. Households are the primary source of MSW, accounting for 55 to 65 percent of total MSW generated, followed by the commercial sector and industrial sector (EPA, 2008). There are four levels of recycling including: primary, secondary, tertiary, and quaternary (Hopewell et al., 2009 & Garcia 2016). Primary recycling involves mechanically processing materials into a secondary product with equivalent properties, while secondary recycling is the process of processing materials into products with lower properties (Garcia 2016). Tertiary recycling is the process of recovering the chemical properties of a product and finally quaternary recycling is focused on energy recovery (Garcia 2016). For the purpose of this paper, the term recycling will refer to recycling as a collective form of waste divergence that includes all levels mentioned.

Study Objectives

This study aims to 1) identify inhibiting factors associated with the effective management of recycling programs and 2) understand if already known (established) factors have been addressed. The data collected from the literature review were used to develop and conduct a survey designed to rank factors based on their level of influence on recycling program management. The factors identified by a literature review as well as the data collected from the survey have been used to answer the following research questions: 1) Why has the recycling rate not improved since 2010?, and 2) What are the major factors affecting problem associated with recycling programs in the US? Understanding the factors that influence recycling programs provides an insight into why the recycling rate has been stagnated. It will also help identify areas for further

improvement of local recycling programs. To answer the questions, the target audience being surveyed is recycling program managers. Recycling program managers take the role of consumers, mangers, and producers and they have the potential to provide a holistic perspective not previously explored in literature. Recycling programs are consumers because they collect recyclable materials. They are also producers because they obtain materials that they then sell to secondary markets. Recycling program managers develop approaches that allow for the maximum collection of materials ranging from high quality to low quality, while ensuring that the quality of materials that are flowing out of the program are still high enough to produce profits.

2. LITERATURE REVIEW

Starting in 1960, the EPA began reporting to record the national percentage of combined recycled and composting rates of municipal solid waste (EPA, 2019). In the 25-year period between 1960 and 1985, the recycling and composting rate increased approximately 5%, but in the 10-year period between 1986 and 1995 the recycling and composting rate increased rapidly from 10.1% to 25.7% (EPA, 2019). In the nearly 20 years following the recycling rate and composting rate increased but at a slower rate and has since started to stagnate around 35% for combined and 25% for the recycling rate alone (EPA, 2019). In response to slowing recycling rates following a period of rapid increase, Dr. David H. Folz conducted a study to identify problems associated with municipal recycling programs and factors that influence the design of recycling programs in the United States (Folz, 1990).

Folz conducted a nationwide survey in 1989 and then expanded on that survey in 1996.[1] In 1989, Folz distributed a national survey to the recycling coordinators of 450 cities across 25 states, and 264 officials responded (Folz, 1990). Of the respondents who completed the survey 60% were full-time recycling coordinators and 40% were part-time employees the majority of which "held positions in local public works departments" (Folz, 1990). Table 1 shows the problems that Folz identified that are associated with municipal recycling programs.

[1] Folz conducted two surveys – the first survey was done in 1989 (Folz, 1990) and the second survey was done in 1996 (Folz, 1999).

Table 1: Importance of Problems in Municipal Recycling Programs (N=264) (Folz, 1990)

Problem	Mean Score*	Rank
Finding Markets for Recyclables	4.15	1
Getting residents to participate in the program	3.70	2
Lack of sufficient state grants or other financial assistance	3.50	3
Securing adequate local government assistance for recycling	3.40	4
Obtaining information/ technical assistance for recycling	2.83	5
Theft of recyclables	1.76	6

*1= Not Important and 5= Important

Folz redistributed his survey in 1996 to the same individuals from his initial survey and had 158 individuals respond for a return rate of 64%. In the secondary survey the average years of experience for respondents had increased from 6.7 years (1989) to 8.9 years of experience (1996). Folz compared the results of the 1996 to the 1989 survey and Table 2 shows that there was a shift in the ranking of problems associated with municipal recycling programs from 1989 to 1996 (Folz, 1990 and Folz, 1999). In 1989, the top three problems, in order, were lack of reliable markets for materials, getting residents to participate in recycling , and unfunded state mandates (Folz, 1990). In 1996, the top three problems were financing recycling programs and budgetary concerns, getting residents to participate in recycling, and lack of reliable markets for materials (Folz, 1999). While these results do not determine the factors that influence the continual

management of recycling programs once established, they do provide a baseline for consideration in this study. In the 25 years since Folz's 1996 survey, the recycling rate has begun to plateau and multiple studies have focused on how to better understand problems including participation, program management and markets for recycled materials and how to address them.

Table 2 "The Importance of Problems in Municipal Recycling Programs in 1989 and 1996" (Folz, 1999)

	Mean 1989*	**Scores 1996***	**Rank in 1989**	**Rank in 1996**
Financing the recycling program & securing an adequate budget	3.37	3.68	4	1
Getting Residents to participate	3.70	3.59	2	2
Lack of reliable material markets	4.17	3.37	1	3
Unfunded state mandates	3.47	3.28	3	4
Obtaining information about best recycling practices	2.85	2.76	5	5
Theft/ scavenging of recyclables	1.78	2.16	6	6

*1= Not Important; 5=Important

2.1 Recycling Programs from a Consumer Perspective

Recycling programs for residential municipal solid waste can be implemented through a variety of different collection methods including curbside, drop-off or a combination of curbside and drop off. Drop-off involves having a separate predetermined collection location, usually either at a waste management facility or a sorting center, that

participants can go to and drop off their recyclable materials. Some facilities charge a fee for dropping off recyclable material while other do not. Curbside collection involves employing a collection service, public or private, that picks up recyclable materials at an individual's home and then transports it to a waste management facility (Lakhan, 2015).

This collection method can be further split into single-stream or multi-stream collection methods. Single-stream is when all recycled materials are collected in a single comingled container and separated once it reaches the recycling and or waste management facility. Multi-stream collection is when participants are required to pre-separate their recyclable materials and then those separated materials are collected in compartmentalized trucks (Lakhan, 2015).

Research indicates that the single-stream method has lower collection costs compared to the multi-stream methods because it eliminates the need for special compartmentalized trucks (Lakhan, 2015). However, there are higher contamination levels associated with single-stream collection compared to multi-stream collection, which can result in lower acceptance rates at the facility (Brooks, Wang, & Jambeck, 2018) and lower prices for commodities (Stromberg, 2004; Lakhan, 2015). Todd (2002) also found that the single-stream collection method has higher contamination during the sorting process because this type of collection requires separation methods and technology that are not always available. However, the multi-stream method can have lower associated operational costs because it does not require as much sorting technology as the single-stream method (Lakhan, 2015). Lakhan (2015) also found that public participation was higher with single-stream collection compared to the multi-stream

methods. Siddique et al. (2010) conducted a panel study to determine which factors affect recycling rates and waste management overtime. The results revealed that when curbside collection and drop-off locations were implemented simultaneously as part of a recycling program there was an associated increase in the recycling rate (Siddique et al. 2010). Feiock and Kalan (2001) found that when program characteristics like collection methods are included as coefficients in a regression analysis, they did not have a statistically significant effect on the recycling rate. However, Siddique et al. (2010) contradicts the findings of Feiock and Kalan (2001) that program characteristics such as collection methods do not have a significant impact on recycling rates.

Participation Trends

Tabernero et al. (2015) found that in communities where people believed that they could recycle effectively, they were more likely to engage in recycling behaviors at a higher frequency compared to those who did not. Multiple studies have examined various socio-demographic variables and found that individuals who are older, have a higher income, and have a higher level of education are more likely to recycle (Siddique et al., 2010; Starr and Nicolson, 2015). However, Tabernero et al. (2015) conducted a cross-sectional analysis and found that inputting "self-efficacy" into the equation reduced the impact of socioeconomics on recycling behavior. Siddique et al. (2010) found that a positive correlation between education of the public and the recycling rate, and that by spending one dollar, a year per person in public education programs the overall recycling rate would increase by about 2% in Minnesota. Starr and Nicolson (2015) examined factors that increase participation in municipal recycling and found that in relation to

collection methods, curbside programs had the highest participation, but also higher administration costs as compared to drop-off programs.

Starr and Nicolson (2015) found that mandatory programs often have associated administration costs that can exceed the revenue generated from increased participation. Feiock and Kalan (2001) conducted a longitudinal study analyzing how recycling program management affects recycling rates at the local level by using the data of counties in Florida. The authors found that education[2] and income[3] had positive effects on the recycling rates due to increased recycling participation from individuals who had higher education levels and income.

2.2 Recycling Program Management

Waste generation on a global scale is on the rise and is projected to increase over 70% from 2.01 billion tons per year to 3.40 billion tons annually by the year of 2050 (Deus et al., 2020). Waste management is not only an important part of ensuring public health and safety. It also plays a role in climate change adaptation and mitigation. In 2016, solid waste management was responsible for approximately 1.6 billion tons of "CO_2 equivelent greenhouse gas emissions," which accounts for around 5% of emissions on a global scale (Towa et al. 2020).

Recycling programs are an integral part of waste management and multiple studies have focused on collection (Folz, 1990 & 1999; Lakhan, 2015; Tabernero et al., 2010; Starr & Nicolson, 2015; and Siddique et al., 2010), processing of materials

[2] Feiock and Kalan (2001) defined education as "percentage of the county population that graduated from high school".
[3] Feiock and Kalan (2001) defined income as "individual per capita income level by county".

(Brooks, Wang & Jambeck, 2008; Todd, 2002), and examining markets for recycled materials (Hopewell et al. 2009; Geda et al., 2020, Stromberg, 2004) and in the process revealed different components of recycling program management.

Program Costs

One component mentioned in both Folz's 1990 and 1999 studies was the difficulty associated with complying with unfunded state mandates and financing recycling programs. States have indirectly managed recycling programs through the implementation of state mandates that require that a certain proportion in a waste stream to be recycled (Feiock and Kalan, 2001). Recycling programs have costs associated with collection, processing and separation, and MSW landfill tipping fees are associated the disposal of contaminated materials. Funding and incentives provided by states to local governments do not always match program costs. A study by Silva et al. (2019) found that one of the major problems reported by municipalities was a lack of resources to be able to reinvest and improve recycling programs, including hiring more employee and purchasing updated equipment.

National Trends in Waste Management

Tipping fees and landfill capacity also influence how local authorities manage waste, but on a regional scale. In 2015 the national MSW landfill capacity was predicted to last for the next 62 years, but at the state level predicted landfill capacity ranged from as little as 5 years to 60+ years (Zimlich, 2015). However, according to a report produced by the Waste Business Journal the national landfill capacity has dropped to less than 20 years as of 2020 (Rosengren, 2020). Tipping fees are directly correlated with landfill

capacity and in regions where the landfill capacity is limited, the tipping fees will be higher compared to areas where landfill capacity is higher. For example, the tipping fees for Northeastern states are the highest ranging from 50 to 70 dollars per ton and the average tipping fees of western states are the lowest ranging from 18 to 25 dollars per ton (Directory of Waste Processing & Disposal Sites: U.S., 2019). Margallo et al. (2019) hypothesized that an abundance of land and "lack of policy and incentives for alternative practices" both contributed to the continued reliance on MSW landfills in the US.

While the national recycling rate has stagnated at 35%, recycling rates at the state and local level have varied. Wallet Hub conducted an in-depth analysis using data reported by federal and state agencies as well as nongovernment organizations in order to rank states by their level of "environmental friendliness" (Kiernan, 2019). The top 5 states with the highest percentage of recycled MSW were in order: Maine, Minnesota, Arkansas, California, and New Hampshire and the states with the lowest percentage of recycled MSW were as follows: Arizona, Mississippi, Alaska, Oklahoma, Utah, and Louisiana (Kiernan, 2019). At the local level the cities with the highest recycling rates are San Francisco, CA (80%), Los Angeles, CA (76.4%), San Jose, CA (75%), Portland, OR (70%), and San Diego, CA (68%), which are all well above the national 35% recycling rate (Tufano, 2015). California does have a long-term goal of transitioning to zero waste and has set strict landfill diversion percentages with a statewide goal of 75% by 2020, which could be why four out of the top 5 city recycling rates are within California (Tufano, 2015).

International Trends in Waste Management

Internationally, there has been a transition from a linear to a circular economy and more countries are trying to understand the environmental impacts of solid waste and implement more "integrated and sustainable" forms of waste management (Margallo et al., 2019). Eunomia and the European Environmental Bureau produced a joint report identifying the top 25 recyclers of MSW based on reported recycling rate from 2014-2016 (2017). The top recycler of MSW was Germany at just over 65% followed by Wales, Singapore, South Korea and Taiwan with the United State landing at the 25th spot with a recycling rate of 35% (Gilles et al., 2017). The report also identified management and policy characteristics that the countries that were labeled as top recyclers had in common. The common characteristics included "comprehensive schemes to enable people to recycle, funding for recycling, clear performance targets and policy objectives, and financial and behavioral incentives to directly and indirectly encourage citizens to recycle" (Gilles et al., 2017).

2.3 Recycling Program from a Producer Perspective

There are several key factors that affect the ability of managers of recycling programs to recycle materials or sell recyclable materials as potential products. Recycling trends, market variability, and international policy are part of the factors.

Recycling Trends

In the 25 years since Folz's initial surveys (1989 and 1999) there have been variances in the types of materials that are considered acceptable for collection. In 2017 the total MSW generated by material was 267.8 million tons (EPA, 2019) with paper and

paperboard comprising 25% of material followed by food (15.2%), plastics (13.2%), yard trimmings (13.1%) and metals (9.4%). However, the total amount of MSW recycled and composted was 97.4 million tons and the top materials were paper and paperboard (46.9%), yard trimmings (25.9%), metals (8.8%), and glass and wood both at 3.2% (EPA, 2019). Figure 2 shows the inconsistency between the type of materials generated as compared to the type of materials recycled. The figure shows that there are a large portion of materials that are generated that are not currently being recycled.

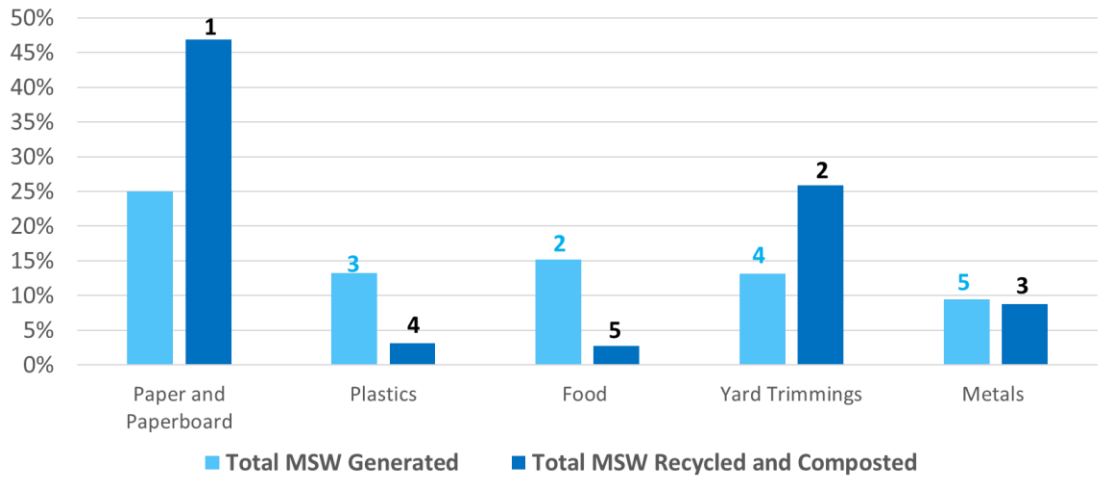

Figure 2 Total MSW Generated vs Recycled and Composted by Material, 2017 (EPA, 2019)

Recycling of paper, cardboard, and metals like aluminum and steel are all examples of recyclable materials that have developed methods for collection and processing, and pre-established secondary markets. Plastic, however, is a relatively new material. Plastic has multiple applications, it is versatile, cheap to produce, and has a strong strength to surface ratio (Barnes, 2019; Geyer et al., 2017). Global plastic

production has displayed a sharp incline beginning around 1950 at 2 million tons per year and increasing to over 381 million tons per year in 2015 (Ritchie and Roser, 2018). Over the 65-year period, plastic production only decreased twice in 1975 and in 2008 (Ritchie and Roser, 2018). Rapid production and consumption of plastic has introduced a new material into the MSW stream and shifted how local authorities manage waste.

Extended Producer Responsibility (EPR) is a concept describing that producers are encouraged to take end-of-life considerations when designing their products. EPR would help to reduce the physical and economic burden from local waste management and recycling programs (Kumar et al., 2019). In adherence with EPR laws and international demands for transitioning to a circular economy, there has been a recorded increase in companies using recyclable material in their products or increasing the recyclability of their products (Geda et al., 2020). However, Geda et al. (2020) also found that when 'sustainability levels' vary between producers and secondary consumers, developing a solution becomes increasingly more complex. This can create inconsistency in how producers manufacture products and the amount of recyclable material that is available from the product at the end of life, which can affect waste managers' ability to sell recyclable materials.

Market Variability

As producers, recycling managers must operate in a complex secondary market that has high levels of variability. The main materials collected for recycling include paper and paperboards (including cardboard), metals (including steel, lead-based batteries, and aluminum), glass, plastics and textiles (EPA, 2019). Metals are often seen

as having the ability to be recycled multiple times without an associated loss of quality (Rigamonti et al., 2018). To facilitate their desired application, pure metals are combined with alloying element additives; during the processing of scrap metal, these alloys can reduce the variability of secondary applications. However, alternative methods of processing have increased the shelf life of recycled metals and created an established secondary market for recycled metals (Rigamonti et al., 2018). Aluminum has an established secondary market with both open and closed loop systems, and the properties of aluminum are generally not degraded during the smelting process, and theoretically aluminum can be recycled indefinitely (Liu and Muller, 2012). Like all things, there is a potential for aluminum to be degraded during the recycling process, but it is "metallurgically possible to maintain the same properties" (Liu and Muller, 2012).

Price volatility is driven by uncertainty created through a lack of information and an inadequate understanding of the supply and demand which is a large component of the recycling industry and secondary recycling markets (Stromberg, 2004). The market for recycled materials varies depending on materials. Some market for materials like scrap metals, particularly steel and aluminum have historically been more stable, but other markets like those for scrap plastic are more volatile. Contamination, uncertainty, and the price of virgin materials have all contributed to the fluctuation of market prices for recyclables. Stromberg (2004) found that in the years between 1998 -2001, the prices of virgin materials stayed relatively consistent, but the prices of recycled materials including newspaper and plastic were fluctuated in price. Also, some virgin materials like plastic resin and steel have a higher price volatility because of their natural sources.

Contamination in the recycling industry can decrease the quality of materials during the sorting and recycling process. Contamination of paper can "reduce strength of secondary fiber" (Rigamonti et al., 2018) and contamination of plastic can cause visual imperfections and secondary products as well as reducing "strength integrity" (Design for Recycling Content Guide, 2018). Rigamonti et al. (2018) conducted a review examining the quality of secondary materials produced from recycled materials and found that fiber products (including paper and cardboard) can be recycled on average between 6-7 times. However, in each time that the fibers are recycled, the bonds that hold the fibers together are weakened which decreases "resilience" (Rigamonti et al. 2018). This means that on its own recycled fibers have a lower quality or value, and often need to be combined with virgin fibers to ensure structural integrity. Azapagic et al. (2003) also found that companies assign a higher level of risk to recycled materials because of the public perception that recycled materials, like plastic, are of inferior quality or have a higher potential for contamination. Similar findings by Nicolli et al. (2012) and Stromberg (2004) provide evidence that public misperceptions and risk aversion can have an impact on recyclable materials as a commodity.

International Import Policy

Starting in the 1980s, China began importing foreign waste to subsidize the shortfall of raw materials in their country and by 2016 had become the largest importer of solid waste in the world (General Office of the State Council, 2017). In recent years, China has begun promoting a circular ecological economy and reduce the illegal import of solid waste, as China issued *the Implementation Plan for Prohibiting the Entry of*

Foreign Waste and Advancing the Reform of the Solid Waste Import Administration (General Office of the State Council, 2017). The policy was implemented in 2018 and banned the import of over 24 different types of solid waste including several recyclable materials like non-industrial plastics (Wang et al., 2020). China expanded the list of banned imports in late 2018 and early 2019 to include scrap metal material and industrial plastic waste (Qu et al., 2019). A study by Brooks, Wang, Jambeck (2018) found that by 2030 approximately 111 million metric tons of plastic waste alone would be displaced by as a result of the Chinese policy.

The effects of the China's policy have been felt on a global scale and the implications for the solid waste management industry are still being explored (Wang et al., 2020). Hook and Reed (2018) tracked the impact of China's policy on waste exports and imports from 2017, before the ban, to 2018 after the ban came into effect in 2018. Hook and Reed (2018) found that in 2017 China and Hong Kong were the largest importers of waste. However, in 2018 after the ban, waste imports were shifted to other south Asian countries like Malaysia, Vietnam, and Taiwan (Wang et al. 2020). This claim is supported by the results of a study conducted by Wang et al. (2020) which found that after the implementation of China's ban trade flow volume increased in (was redirected to) other Southeast Asian counties. The amount of exported plastic-related wastes decreased in all the top exporters including the United States, Japan, and Germany (Hook and Reed, 2018). Qu et al. (2020) predicted that as waste imports shift to other developing countries that do not have the cost-effective technology for recycling, they

will begin to landfill more waste, and decreasing the amount of material that is recycled (Qu et al., 2020).

"Low-level" waste (Qu et al., 2020), including post-consumer plastics, normally exported to countries like China will become more expensive to manage and so there is a higher chance that they will be landfilled. A comprehensive assessment by Waste Dive (Tucker et al., 2019) on the impact of China's ban in the United States at the state level supports the conclusions drawn by Qu et al. (2020). Waste Dive found that since 2017 over 60 curbside recycling programs in the United States have been cancelled and some drop-off locations have also been closed (Tucker et al., 2019). Since the US has been impacted by China's ban is predominately local, municipalities have the authority to determine which actions best suit their programs. Actions taken by local recycling programs widely varies and include reducing the frequency of collection from weekly to monthly, excluding materials like plastics from collection and increasing collection fees (Tucker et al., 2019). Contracts with private facilities have also shifted with some companies increasing processing fees and adding additional fees for contamination in addition to revising which materials that they a contractually obligated to accept (Tucker et al., 2019).

3. METHODS

Survey Design

To address the following research questions a survey was designed and divided into three sections. The full survey can be found in the appendix.

- *Research Question 1: Why has the recycling rate not improved since 2010?*
- *Research Question 2: What are the major factors affecting problems associated with the recycling rate in the US?*

Section one of the three-part survey focused on collection methods and included comparison questions on collection methods and open-ended questions designed to provide additional information that may be expanded upon during the discussion. Section two was based on Folz's 1989 and 1996 studies which identified the major problems associated with municipal recycling performance, which will be referred to as established factors. Responses to each of the factors in section two had the option to *rate the following factors individually, from 1 to 5 with 1 being not important and 5 being highly important influence on how recycling programs are managed*. Section three focused on identifying respondents' viewpoints on emerging factors identified during the literature review of both peer reviewed sources and grey literature from reputable sources. In section three, emerging factors were presented as statements and respondents were asked to *rate the following statements from 1 to 5, with 1 = strongly disagree, and 5 = strongly agree.*

Data Collection

The survey was posted on the Solid Waste Association of North Americas (SWANA) open forum and the open forum for the Planning & Management Technical Division (www.community.swana.org). The survey was posted March 16, 2020 and the survey link was left open for a 3-week period which ended April 3, 2020. In order to qualify for the study, participants needed to have at least one year of experience in the waste management industry and be 18 years of age or older. Participants were asked at the beginning of the survey how many years of experience they had in the waste management industry and if their response indicated less than one year, their responses were discarded. The survey was anonymously conducted. Once the survey period was closed, all open-ended responses in section one were summarized into major categories that shared similar descriptions and converted into numerical representation. Section two and three already had numerical values based on rating response.

In Section 1, Question one asked about years of experience and the results were converted to an experience level of 1 (<10 years), 2 (10-25 years) or 3 (>25 years). Question two was converted into two separate factors: cost-effectiveness between single-stream and multi-stream collection methods and rate of public participation between the collection methods. Responses for single-stream received a value of 0 and responses for multi-stream received a value of 1. Any responses that did not fit into the two categories was determined as N/A or non-applicable. Question three focused on identifying which collection methods among curbside pick-up only, drop-off only, and a combination of both was the most effective and each response was separated into three categories

receiving a separate numerical value: curbside pick-up only (0), drop-off only (1) and a combination of both (2).

Data Analysis

Data analysis was conducted using an independent t-sample test and regression analysis by RStudio. 54 waste management program managers and coordinators answered to the survey and all 54 responses were included in the regression analysis investigating the impact of experiences (years of experience and/or experience levels) on preferences on collection methods, rating established factors, and rating emerging factors. The variables are as follows; *years* meaning the years of experience an individual reported having in the waste management industry. One individual reported having 40 plus years of experience and that value was converted to 40 years of experience and *Experience_Level* represents the level of experience an individual has in the waste management industry which was assigned based on years of reported experience and divided into experience levels 1, 2, and 3. A welch two sample t-test was conducted to compare the experience levels and collection types responses. A paired-samples t-test was conducted in RStudio to compare the mean scores for internal and external emerging factors. A paired sample t-test is used to compares two paired means that are from the same object or group (Kent State University, 2020).

4. RESULTS AND DISCUSSION

In recent years the recycling rate has become stagnant. Analyzing factors that influence recycling rates could help identify ways to increase the rate of recycling at the local level. The results of this survey could provide evidence of already-identified factors (collection methods, program participation, and markets for recycled commodities) and new factors (China's 2018 import policy and material contamination) that are contributing to the plateau of recycling rates. Once significant factors contributing to the stagnation of the recycling rate are identified, steps can be taken to develop solutions to address those factors and subsequently increase the recycling rate. The survey described in this paper can be found in the Appendix for reference.

4.1.1 Years of Industry Experience

There were 54 total respondents to the survey and each survey response submission was reviewed to ensure that there were not duplicate submissions due to technical error. The number of years reported for *years of experience* in the waste management industry ranged from 1 year to 40 plus with average years of experience being 19 years in the waste management industry. When the years of experience were divided into experience categories, 15 individuals met the qualifications for level one (<10 years), 24 individuals met the qualification for level two (10-25 years), and 15 individuals met the qualifications for level three (>25 years). Figure 3 shows the distribution of respondents' years of experience in waste management industry.

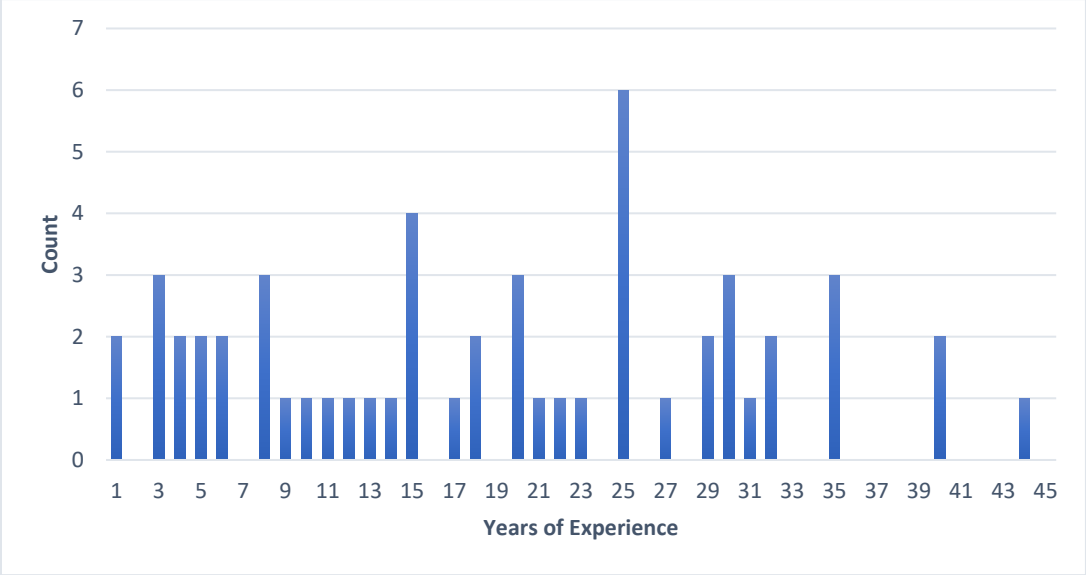

Figure 3 Years of Experience Results

Figure 4 includes the experience levels in correlation with the recycling and composting rates, and while the EPA graphic only extend from 1960 until 2017 experience level one would extend to 2018. The reported composting and recycling rates can be split into three major periods in relation to this research. Period one (1985-1994) represents a rapid increase in the percentage of municipal solid waste recycled and composted, approximately 15%. Level 1 individuals worked in the waste management industry when the recycling rate begin to become stagnant. Period two (1995-2009) represents a slower increase and or rise of recycling rate, approximately 10%. Level 2 individuals would have experienced the slowed growth and eventual stagnation of the recycling rate. Finally, period three (2010-2017) was the period when the recycling rate

begin to stagnate, and that period extends to present day. Respondents in in experience level 3 would have knowledge of the recycling industry throughout multiple transitions.

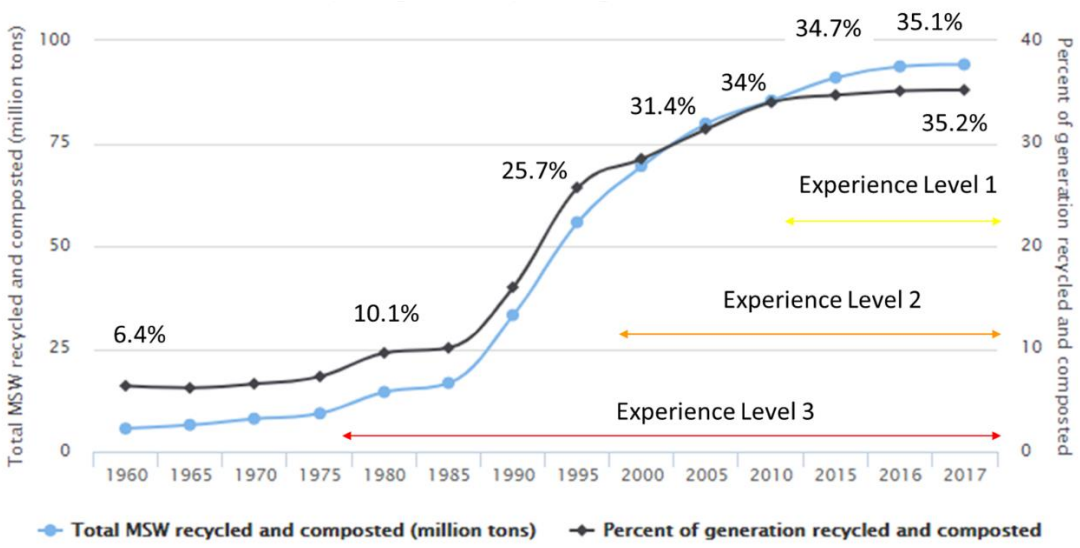

Figure 4 MSW Experience Levels and Recycling & Composting Rates, 1960-2017

4.1.2 Collection Methods

Question two and three of the collection methods section both focused on identifying and ranking problems associated with collection component of recycling programs. Question two was a two-part question that focused on determining if single-stream vs multi-stream collection was more cost-effective and/or had the highest rate of public participation. Initially there were two categories, single-stream or multi-stream and all other responses were excluded and labeled as NA. Once the survey period ended and the responses were analyzed, it was clear that not all the responses fit into the original

two categories. To account for the fact that open-ended questions have a higher susceptibility for interpretation and to reduce the number of responses that were excluded, a new category was included. Single-stream received a value of 0 and multi-stream received a value of 1, and both received a value of 2. Under the original two category review process 17 responses were excluded from the cost-effective category and 15 responses were excluded from the rate of public participation category. Table 3 shows the breakdown of the number of responses in each category and with the addition of a "Both" category. Seven responses were removed from the "N/A" category and included in the results.

Single-stream was ranked both the most cost effective and having the highest rate of participation compared to multi-stream. The results of this study reflect the finding of Lakhan (2015) which found that single-stream has lower collection costs and higher participation but contradict the findings of Stromberg (2004) and Brooks, Wang and Jambeck (2018). Stromberg (2004) and Brooks, Wang, & Jambeck (2018). The studies found that single stream has higher contamination and higher processing costs associated with source separation technology. One potential explanation would be that there is a disconnection between how managers weigh quantitative values like public participation and qualitative values like program costs. Higher public participation could supersede the higher collection and processing costs associated with single-stream collection and is an avenue that should be explored in further research.

Table 3 Most Effective Collection Type by Experience Level

	Curbside Only	Drop off Only	Combination
Experience Level 1	13.33%	0%	86.6%
Experience Level 2	20.8%	0%	76.16%
Experience Level 3	26.6%	13%	60%

(n=54)

Question three compared collection types, curbside only, drop-off only, or a combination of both in order to determine which type was more "effective". Results showed 75.9% of respondents believed that a combination of curbside and drop-off collection was the most effective, 20.3% stated that curbside only was the most effective and only 3.7% stated that drop-off only was the most effective. Table 3 shows the breakdown of responses based on experience level and as experience level increases the number of responses for curbside only or drop-off only increases, but the number of combination responses decreases.

Table 4 depicts the results of two sample t-test of equality of means. EL stands for experience level and the difference is the results experience between the two experience levels. The null hypothesis is that there is not a statistically significant difference between experience levels and collection type responses. The results of the analysis show that the differences between experience levels and curbside only responses are not statistically significant, but the differences between experience levels and drop off only and combination responses are statistically significant (Table 4). This means that the more experienced managers believe drop-off only methods would be considered more cost-effective as compared to less experienced waste managers with EL1 and EL2. Also, the

more experienced managers believe combination only would be less cost-effective as compared to less experienced waste managers with EL1 and EL2

Table 4 Two Sample T test of Equality of Means

		EL 1 vs EL 2	EL 2 vs EL 3	EL 1 vs EL 3
Curbside Only	Percentage Difference	7.47	5.8	13.3
	T statistic p-value	-0.603 0.55	-0.401 0.691	-0.894 0.379
Drop Off Only	Percentage Difference	0	13	13
	T statistic p-value	-2.46 0.021	-2.25 0.040	-2.25 0.040
Combination	Percentage Difference	10.44	-16.16	-26.6
	T statistic p-value	5.30 7.28 e-06	3.61 0.001	4.02 0.0004

+ the number of observations were 54 in all t tests.

The results could also be related to the how the experience levels were designed and when each type of collection method was introduced. Feiock and Kalan (2001) found in a study of Florida counties that recycling rates were higher in urban areas compared to rural areas. An individual's experience in urban or rural areas was not a factor included in this study but based on the influence that the rural/ urban classification had on recycling rate it may be an avenue that would be beneficial to explore in future studies.

4.2 Established Factors Comparison

Figure 4 shows a comparison of factors influencing the management of municipal recycling programs ranked by Folz initially in 1989 and again in 1996, compared to the

results of this study conducted in 2020. There were six factors listed in Folz's study, but the lowest ranking factor in both 1989 and 1996, *Theft and Scavenging of recyclables*, was not included in the 2020 survey. Financing the recycling program & securing an adequate budget and unfunded state mandates were combined in the 2020 survey and presented as *State and Federal Funding*.

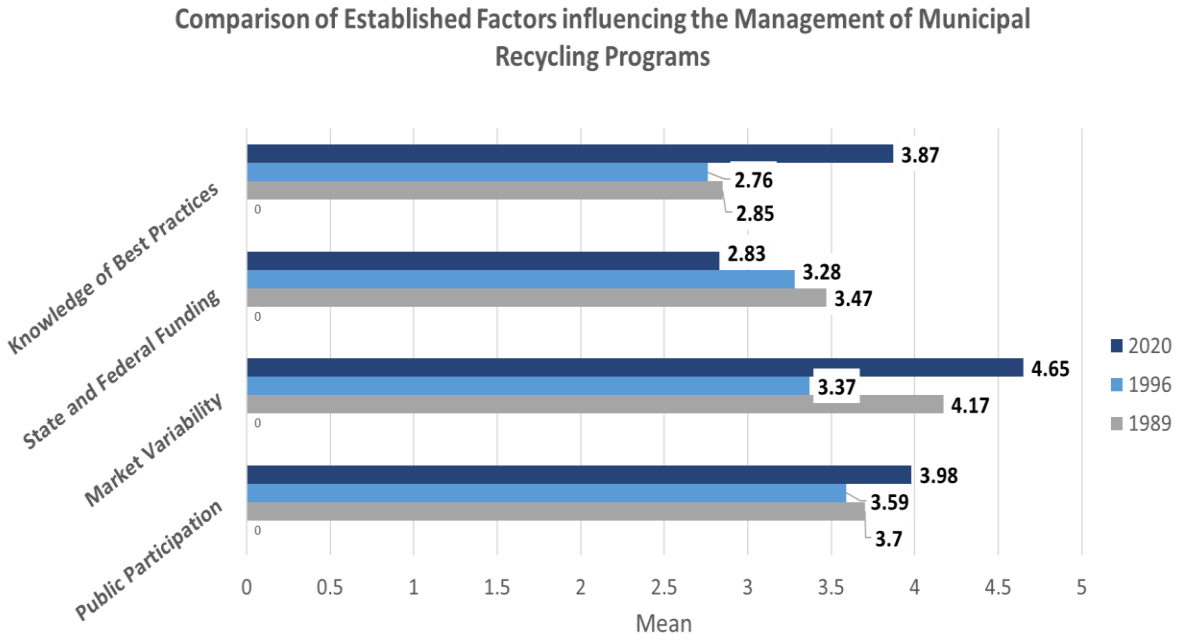

Figure 5 Comparison of Established Factors Influencing the Management of Municipal Recycling Programs

Hypothesis 1: The mean scores of factors listed in the current 2020 study should be lower than the mean scores of the factors listed in Folz's 1989 and 1996 studies.

In the 25 years since Folz's study, much research has been conducted to address the problems the author identified in municipal recycling programs (Folz, 1989; Folz,

1996). If the research had been applicable to the management of recycling programs, the factors identified in the current study would likely have had a lower average mean compared to similar factors identified in Folz's 1989 and 1996 studies. Both of Folz's studies were conducted during the *rapid growth* period when the recycling rate was rapidly increasing, while this current study was conducted during a period of stagnation. When Folz compared the results of his studies, the means for all factors had decreased from 1989 to 1996. This could be because as the recycling rate increased the impact/ influence/ importance that these factors had were decreasing. The results of the 2020 survey show that the mean scores regarding *Market Variability, Public Participation, and Knowledge of Best Practices* all received higher scores compared to the 1989 and 1996 studies. The only categorical value that decreased was regarding *State and Federal Funding* specifically financial assistance from the state and federal government. One possible explanation could be that as the recycling rate begins to stagnate the influence that the previously mentioned factors (*Market Variability, Public Participation, and Knowledge of Best Practices)* have on the management of recycling programs become more prominent.

4.3 Emerging Factors Comparison

The emerging factors comparison revealed that China's 2018 import policy, how an institutional and organization frames recycling and public education and outreach ranked as the highest emerging factors. The emerging factors were then split into internal and external factors based on the level of influence that program managers would have in controlling for these factors. Table 5 shows the breakdown of mean scores for each

internal and external factor as well as the mean score for internal and external factors. External factors ranked higher with an overall mean score of 3.93 compared to internal factors which ranked at 3.87.

A paired-samples t-test was conducted to compare the mean scores for internal and external emerging factors. There was not a significant difference in the scores for internal (M=3.87, SD= 0.64) and external (M= 3.93, SD=.63) factors; t(53) = -0.704, p = 0.484. Feiock and Kalan (2001) and Siddique et al. (2010) conducted analysis on how program characteristics affect recycling rates and found contradictory evidence. Feiock and Kalan (2001) found that program characteristics did not have a significant impact on the recycling rate, while Siddique et al. (2010) found that program characteristics did have a significant impact on recycling rates. The results suggest that internal factors like program characteristics do have an impact on the management of recycling programs, but there is not a statistically significant difference between internal and external means.

Table 5 Emerging Factor Comparison

Internal	**Mean Score**	**External**	**Mean Score**
Institutional/Organizational framing Effect	4.09/5.00	International Import Policy	4.48/5.00
Public Education and Outreach Program	4.07/5.00	Extended Producer Responsibility	3.98/5.00
Financial Assistance Shortfall	3.81/5.00	Plastic Production	3.72/5.00
Program Fees (Deficit)	3.5/5.00	State and Federal Program Assistance	3.53/5.00
Internal Factors	**3.82/5.00**	**External Factors**	**3.93/5.00**

5. SUGGESTIONS FOR FURTHER RESEARCH AND CONCLUSION

Unlike previous studies that have attempted to quantify different components of recycling program management, this study focuses on using descriptive statistics and identifies areas for further research. The three recycling collection methods discussed in this paper were *drop-off only*, *curbside only*, and *combination*. In *drop-off only* the participant drops off recyclables at a collection or processing facility. In *curbside only* recyclables are collected at the participants residence and transported to the processing facility. *Combination* includes programs that offer both curbside and drop off collection in tandem. In this study, a survey was conducted to determine what factors influence recycling program management.

Section 1 of the survey focused on recycling collection methods. Results from Section 1 of the survey showed that Experience Level had a statistically significant impact on responses for *drop-off only* and *combination* methods, however, Experience Level did not have a significant impact on *curbside only* responses. Single-stream collection was found to be more cost effective and had higher participation compared to multi-stream collection. Findings reveal a potential disconnect between how managers weigh program costs vs public participation. The revenue generated from increased public participation and collection could outweigh the collection costs and program costs associated with the different collection methods.

Section 2 addressed established factors that influenced the management of recycling programs and compared mean score rank to David H. Folz's 1989 and 1996

surveys (Folz, 1990, Folz 1999). These established factors were: *Knowledge of Best Recycling Practices*, *State and Federal Funding*, *Market Variability*, and *Public Participation*. Results from Section 2 of the survey showed that the mean for established factors did not decrease over time, as expected, for any factors except *State and Federal Funding*. There has been extensive research in the 25 years since Folz's initial study, however, this study suggests that the same established factors he identified are still limiting the growth of recycling programs and by extension the recycling rate.

Finally, Section 3 identified emerging problems that influence the management of recycling programs. Emerging factors were split into two categories: external and internal, based on the level of control that program managers have over these factors. External factors were*: International Import Policy*, *Extended Producer Responsibility*, *Plastic Production*, and *State and Federal Program Assistance*. Internal factors were: *Institutional/Organizational Framing Effect*, *Public Education and Outreach Programs*, *Financial Assistance Shortfall*, and *Program Fees (Deficit).* Recycling program managers ranked the significance of emerging factors on a scale of 1 to 5. A paired samples t-test was conducted in RStudio to determine if the mean difference in score between internal and external emerging factors is statistically significant. Results showed that the total mean score of external factors ranked higher than total mean score of internal factors, but statistical analysis showed that there was not a statistically significant difference in the score for internal and external factors ($t(53) = -0.704$, $p = 0.484$). That means that the difference between the overall ranking of internal and external emerging factors is not substantial.

This study builds on the findings of multiple prior recycling management studies but is unique in that it develops a more holistic perspective to better understand the interaction and effects emerging problems have on recycling program management methods. This study relied on waste management experts' real-world experience as a metric to rank problems within the waste management industry. Since 2017 the combined recycling and composting rate has stagnated at 35%. This study revealed the following factors that have contributed to the current stagnation of the recycling rate: rapid increase in global waste generation, increase in plastic production and consumption, gaps in consumer education, program funding shortfalls, and a lack of a centralized waste system.

This study is valuable because it provides a snapshot of the current state of the recycling industry from an internal perspective, this snapchat suggests that there is a need for an in-depth study. One limitation of this current study is that only one independent variable was collected, *years of experience*, which limited the number of independent variables in the analysis. A suggestion for future research would be to increase the number of independent variables collected including program experiences (public vs private and urban vs rural), and geographic variables like population density and distance to recycling facilities. The execution of an in-depth survey with enhanced survey design, multiple distribution platforms, and longer response periods would provide a larger more varied sample size with more independent variables. This would make the results more generalizable and more representative of the population.

Distributing a separate household survey focused on participation and collection behaviors during the same time period as the management survey could provide a holistic perspective on how program characteristics are perceived by the public. The household survey should include recycling behavior, collection methods and housing styles.

Individuals within the waste management industry can provide a holistic perspective on the state of recycling. They have the potential to play key roles in their respective recycling, scientific, and technical communities and to identify solutions to recycling issues as both consumers and producers. Even with the previously stated limitations of this study (number of independent variables), the results of the study show that the same problems identified by Foltz' initial studies (1989 and 1999) are still negatively impacting recycling program management today. This study also identified additional emerging problems impacting recycling program management (plastic production and program funding shortfalls). As a preliminary study, results have shown that there is still much to be understood and explored when it comes to established factors like participation and funding as well as emerging factors like the 2017 Chinese restriction of solid waste imports.

APPENDIX

Survey

Section 1

Please answer the following Questions

1. How many years of experience do you have in the waste management industry?
2. Do you think that single-stream or multi-stream collection is more cost-effective? Has the highest rate of public participation?
3. Which of the following do you think are most effective collection methods curbside pick-up only, drop off only, or a combination of both?

Section 2

4.	1	2	3	4	5
Market variability for recyclable materials					
Public participation in recycling programs					
Financial assistance from the state and federal government					
Obtaining knowledge of best recycling practices					

Rate the following factors, individually, from 1 to 5, with 1 being not important and 5 being highly important influence on how recycling programs are managed.

Section 3

	1	2	3	4	5
How an organization communicates (defines) recycling to the public influences recycling program management.					
An increase in plastic production and plastic waste has had a strong impact on the management of recycling programs.					

Current funding is adequate to cover the shortfall between funds generated by recycling programs and the costs to run the program.					
China's recent policy on limiting the imports of waste has had an impact on waste management.					
Public education and outreach programs increase the rate of recycling.					
Collection and disposal fees are adequate to cover the deficit created by the decrease in profits from recyclables.					
Extended Producer Responsibility laws are an important component of establishing a holistic approach to product production and waste management.					
Excluding funding opportunities, federal and state level governments have provided adequate support to local recycling programs.					

Rate the following statements from 1 to 5, with 1 = strongly disagree, and 5 = strongly agree.

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