
Recycling—Common Sense, Yet Not So Common

Shikha Chetal

Abstract

Recycling is an essential practice that has numerous environmental and financial benefits. However, recycling is virtually non-existent in many cities of the United States, while other cities boast high recycling rates. There are several demographic as well as policy factors that contribute to these differences. In this paper, I conducted a statistical regression analysis to establish the relationship between residential recycling rates and percent of population with bachelor's degrees or higher, population density, per capita income, mandatory recycling, and per capita recycling budget for a dataset of the twenty-one largest cities in the United States. The results show that there is no statistical relationship between these variables and recycling rates. One of the potential reasons for this result is the lack of data on the subject. Therefore, one of the conclusions of the study is that efforts need to be made to better evaluate the performance of recycling programs by gathering information and then implementing the findings to enhance the national recycling average. I also make a number of policy recommendations to increase recycling.

Introduction

The highly-industrialized and consumer-dominated nature of our economy renders itself extremely wasteful. Most human activities create some amount of waste, and the amount of waste generated has done nothing but increase over time. The total municipal solid waste generated in the United States has grown from 88.1 million tons in 1960 to 251.3 million tons in 2006 (Environmental Protection Agency 2007). Per capita municipal solid waste has increased from 2.7 pounds/day in 1960 to 4.6 pounds/day in 2006 (Environmental Protection Agency 2007). One method to mitigate the problem of extensive waste is to recycle. Recycling cuts greenhouse gas emissions, which contribute to global warming, and reduces energy consumption and the air and water pollution associated with making new products from raw materials (Environmental Protection Agency 2007).

Although, recycling has been in practice for decades and the need for recycling now is greater than it has ever been, it is virtually non-existent in many cities of the United States, while other cities boast high recycling rates. Cities such as Houston, Indianapolis, Las Vegas, and Oklahoma City host recycling rates under 10% (Municipal Recycling 2007). On the other hand, Portland and San Jose host recycling rates of above 50%. The national average recycling rate is 28.5% (Simmons 2006). These discrepancies are representative of massive deficiencies in the recycling programs of certain cities. In this paper, a statistical analysis will be used to address some of the reasons that contribute to the large gaps in recycling practices among different cities in the United States and to suggest measures that might be taken to lessen these gaps and increase recycling rates.

Background

A limited number of studies have investigated the factors that contribute to the success or failure of recycling programs throughout the United States. Many of these studies were conducted in the 1990s or before, when the recycling industry was booming and recycling programs were being initiated in many cities, and were helpful in identifying important components of successful programs and the factors that contribute to their success.

RECYCLING POLICIES

The federal government has not set any enforceable standards related to recycling. The Environmental Protection Agency (EPA) has set a goal for the national recycling rate to be 35% by the year 2008; however, this goal is voluntary and not enforceable (Environmental Protection Agency 2007). This leaves it up to the states to set enforceable goals for recycling authorities to meet (Lockhart 2003). For instance, California is one such state that enforces a diversion rate on its cities. California bill AB 939 mandated that local jurisdictions meet numerical diversion goals of 25% by 1995 and 50% by 2000, and established an integrated framework for program implementation, solid waste planning, and solid waste facility and landfill compliance (California Integrated 2007). The EPA also provides guidelines for recycling programs. In addition to policies, the EPA publishes reports on and analyzes the handling of solid waste nationally.

BioCycle, a magazine that advances composting, organics recycling and renewable energy, in collaboration with Columbia University's Earth Engineering Center, produced *The State of Garbage in America*, which reports national data on the amount of municipal solid waste generated and recycled (Simmons 2006; About BioCycle 2007). By breaking down the data on tons of garbage recycled, tons incinerated, and tons landfilled, the report provides an overview of municipal waste management in the United States. The report's potential for enhancing local recycling programs, however, is limited somewhat by the fact that it was done on a state-by-state basis.

POLICY VARIABLES

To investigate the policy decisions that lead to the success of recycling programs, David H. Folz analyzed data from the years 1990 and 1997 for 158 cities, and concluded that mandatory recycling, curbside recycling collection and free recycling bins, composting programs, and the banning of disposal of yard wastes led to higher success rates among recycling programs (Folz 1999). Another study found that curbside pickup or drop-off, the main type of recycling program, is correlated with increased recycling rates (Lockhart 2003).

In 2006 the United States Government Accountability Office (GAO), in a study of successful recycling programs across the country, identified key practices used to increase recycling, the federal government's steps to encourage recycling, and federal policy options that could help increase recycling rates (GAO 2006). It found that making recycling convenient for their residents, offering financial incentives for recycling, and conducting public education and outreach are the top three methods used by the coordinators of successful programs to increase recycling rates.

DEMOGRAPHIC VARIABLES

Many studies have reported that demographics play a role in the decision to participate in recycling. For instance, a study using telephone interviews to evaluate recycling behavior, attitudes, and knowledge of adults in the households of a suburban city found that, while many common demographic variables do not affect a person's decision to recycle, those who had higher family incomes and resided in single-family homes were more likely to recycle (Oskamp 1991). Similar results were found in a Georgia study which concluded that recycling efficiency (rate) was higher for households lived in by home-owners who possessed at least a high school diploma and had an annual income greater than \$20,000. Data collected from 43,000 households showed that size of residential area, type of dwelling, education, and income are significant determinants of whether recycling facilities are available and used (Berger 1997). In contrast, data collected in Great Britain, Italy, and Netherlands showed that demographic variables such as family income and education had little correlation with recycling behaviors (Yi 1999). This study's authors felt that recycling behavior could best be attributed to environmental knowledge and attitudes.

A more recent study identified significant correlations between recycling participation rates and median value of owned homes, percent renter occupied housing units, and percent bachelor degree or higher (Lockhart 2003). Data for this study was collected by surveying the recycling coordinators of the fifty U.S. state capitals, twenty-six of which provided data. The study examined the type of recycling program, mandatory recycling, age of program, outreach program, materials collected, municipal solid waste fee policy, percent bachelor's degree or higher, median value of owned homes, and percent renter occupied housing units. The current study takes an approach somewhat similar to Lockhart's; however, there are significant differences in the sample (the specific cities and the total number of cities surveyed) and the variables used.

Variation in the results presented by previous studies might be due to a number of factors, including the choice of population to be analyzed and, in behavioral studies, the nature of the data being used. Also, due to the lack of standardized data on recycling programs, research studies create their own metrics to measure recycling performance, potentially leading to disparate results.

For this study, I decided to focus on large cities, as they have the biggest environmental impact and recycling performances would reap the largest environmental benefits. Many studies have tended to focus either on demographic variables or on recycling policies. In this paper, both types of variables will be taken into account. Demographic variables can help predict where recycling programs are more likely to be successful, and recycling policy variables can give recycling program authorities a tool for actively increasing their recycling rates.

Methodology

In order to find the relationship between residential recycling rates and five key variables—percent of population with bachelor's degrees or higher, population density, per capita income, mandatory recycling, and per capita recycling budget—I used a regression analysis, with the dataset coming from the report *Municipal Recycling 2007*. For the regression, I used data on only twenty-one of the thirty largest U.S. cities, since some data was missing on nine cities. The cities included are New York, Los Angeles, Chicago, Houston, Philadelphia, Phoenix, San Antonio, Dallas, San Jose, Indianapolis, San Francisco, Columbus, Austin, Memphis, Baltimore, Milwaukee, Charlotte, El Paso, Boston, Denver, and Oklahoma City. The residential recycling rates obtained from the *WasteNews Municipal Recycling Survey* for all thirty cities have been shown in Figure 1.

The residential recycling rate is the dependent variable, with the independent variables being the percent of population with bachelor's degrees or higher, per capita income, mandatory recycling, and per capita recycling budget. Table 1 provides a description of the variables used.

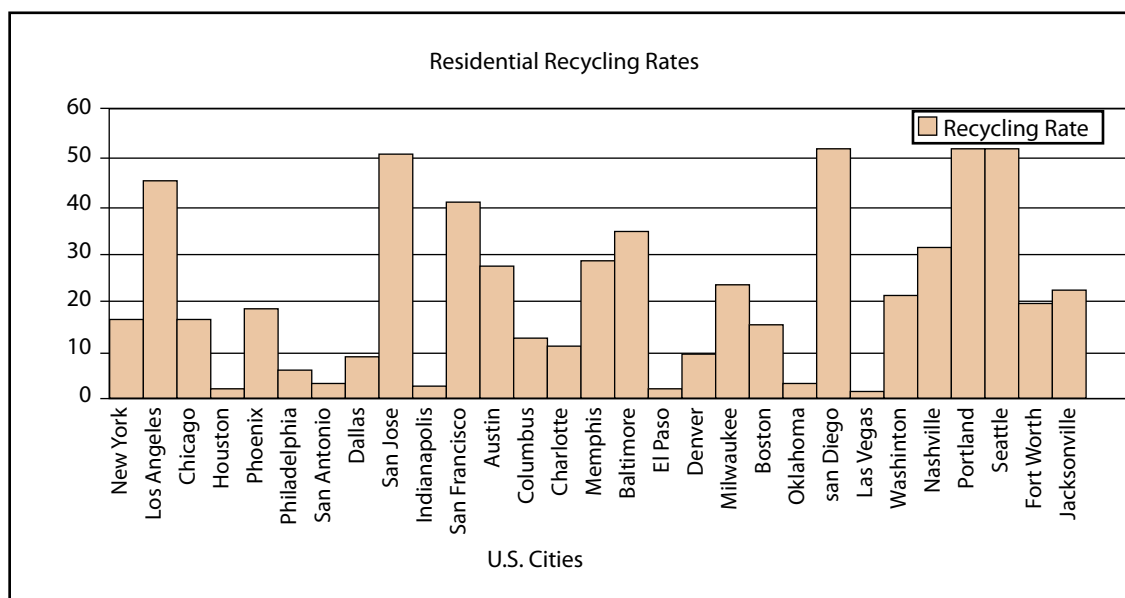


Figure 1. Residential recycling rates for the 30 largest U.S. cities.

Table 1. Variables included in the regression analysis and their description.

Variable	Abbreviation Used	Description Units
Recycling Rate	RR	Percentage of materials recycled of the total municipal waste by weight
Recycling Rate (transformed)	ARR	Arcsine of the recycling rate
% Population with Bachelor's Degrees or Higher	BD	Percentage of population with bachelor's degree or higher
Population Density	PD	Persons living per square mile
Per Capita Income	PCI	Average income per person in U.S. dollars
Mandatory Recycling	MR	Yes (1) or No (0)
Per Capita Recycling Budget	PCRB	U.S. dollars

I used a regression analysis to evaluate recycling rate discrepancies. However, various other factors might go into determining the performance of a recycling program. While some factors cannot be quantified, there are others that can; however, the availability of data for recycling programs is a problem that has been faced over and over by researchers in this field. While many studies conduct their own survey to collect data from individual recycling coordinators, this was not possible for my research, given its short duration. To compensate for this shortcoming, I will discuss some of the variables that could have been used in the regression, if data were available, as well as other factors that are qualitative in nature.

HYPOTHESES

In order to study the variance in residential recycling rates, I examined two categories of factors that influence the success or failure of a recycling program: (a) demographic or geographic factors that cannot be controlled but that might provide insight into the program's success or failure, and (b) factors that are particular to the recycling program and can be controlled to increase recycling rates.

The category of uncontrollable factors includes percent of population with bachelor's degrees or higher, population density, and per capita income. Several hypotheses about these factors can be offered. Higher recycling rates can be expected when a larger percentage of the population holds bachelor's degree or higher, due to this population's widespread knowledge of environmental issues. Higher recycling rates can also be expected with higher population density, as landfill space is more difficult to acquire. Cities with higher per capita income are more likely to have higher recycling rates because they possess capital to invest in recycling programs.

The category of controllable factors includes per capita budget allotted to the recycling program and mandatory recycling in all establishments. These factors can also be seen as recycling program policies. Several hypotheses about these factors can be advanced. Greater per capita expenditures for recycling programs will result in more effective techniques for increasing recycling rates. Educating the citizens about recycling, providing free recycling containers and single-stream recycling, and scheduling more frequent pick-ups should lead to higher recycling rates. Similarly, stricter recycling laws (up to and including mandatory recycling) and enforcement should lead to higher recycling rates, due to the costs of non-compliance.

DATA

The main source of residential recycling data used in this paper is a recycling survey conducted by *WasteNews*, a weekly electronic magazine reporting on the waste management, recycling, and landfill industries (Municipal Recycling, 2007; *WasteNews* 2008). This survey provides self-reported recycling rates (dependent variable) and additional information about recycling programs in the 30 largest cities of the U.S. for the year 2006. The recycling rate for a city is measured by the percentage of materials recycled out of the total municipal solid waste generated. Data on the independent variables—population, population density, percent of population with bachelor's degrees or higher, and per capita income—were obtained from the U.S. Census Bureau (American Factfinder 2006).

The data were compiled using a spreadsheet, and then statistical tools in MS Excel were used to perform linear multiple regression. Regression is an efficient way to analyze the data in order to find correlations between the dependent and independent variables, and multiple regression allows the user to take multiple variables into account and find relationships among them. The regression was performed twice: once with the recycling rate and once with the arcsine of the recycling rate. The latter regression was done because, by itself, the recycling rate, expressed as a percentage, might not provide an accurate measure of linear correlation; therefore, it was transformed in the second regression to achieve

linearity (Sewall 2008; Dallal 2007). The second regression was not necessary in analyzing the percent of population with bachelor's degrees or higher because all values fell in the middle of the spectrum.

Results

A summary of the results obtained from the regression is presented in Table 2 and Table 3. Table 2 consists of the results obtained when the recycling rate was used as the y-variable.

Table 2. Regression results using recycling rate as y-variable.

	Coefficients	P-value
Intercept	-3.82	0.82
% Bachelor's Degrees or Higher	-0.33	0.75
Population Density	0.0007	0.36
Per Capita Income	0.001	0.54
Mandatory or not	-9.05	0.48
Per Capita Recycling Budget	0.31	0.093
Adjusted R Square	0.17	
F-statistic	1.80	
Overall P-value	0.17	

Table 3 consists of the results obtained when the arcsine of the recycling rate was used as the y-variable.

Table 3. Regression results using an arcsine transformation of recycling rate as y-variable

	Coefficients	P-value
Intercept	-0.044	0.80
% Bachelor's Degrees or Higher	-0.0036	0.74
Population Density	7.5E-06	0.36
Per Capita Income	1.08E-05	0.53
Mandatory or not	-0.096	0.47
Per Capita Recycling Budget	0.0033	0.083
Adjusted R Square	0.18	
F-statistic	1.87	
Overall P-value	0.16	

In both cases, it can be seen that the adjusted-R² and the F-statistic values are fairly low and that the p-value is high, which indicates that the data does not permit a good statistical model. Also, there was no real benefit in transforming the recycling rates because the residuals for both regressions were random.

For the following description of results, values from the first regression (the one in which the

y-variable is the recycling rate) will be used. The regression equation for this model is:

$$RR (\%) = -3.82 - 0.33 * BD (\%) + 0.0007 * PD (\text{per sq. mi.}) + 0.001 * PCI (\$) - 9.05 * MR (0 \text{ or } 1) + 0.31 * PCRB (\$)$$

PERCENT OF POPULATION WITH BACHELOR'S DEGREE OR HIGHER

The results of the regression show a negative correlation between percent of population with bachelor's degree or higher and recycling rate. For every 1% change in percent of population with bachelor's degree or higher, the recycling rate changes by a factor of -0.33, assuming that all other factors are held constant. However, the p-value is 0.75, which is large and thus insignificant.

POPULATION DENSITY

A small positive correlation was found between population density and recycling rate. For every change of 1-unit (persons per square mile) in the population density, the recycling rate changes by a factor of 0.0007, assuming that all other factors are held constant. However, the p-value is 0.36, which makes the result insignificant.

PER CAPITA INCOME

A positive correlation was found between per capita income and recycling rate. For every \$1 change in per capita income, the recycling rate changes by 0.001, assuming that all other factors are held constant. However, the p-value is 0.54, which makes the result insignificant.

MANDATORY RECYCLING

A negative correlation was found between mandatory recycling and recycling rates. This could be explained by the fact that only three of the twenty-two cities have mandatory recycling programs. The negative correlation could therefore be a result of other deficiencies in those three recycling programs.

PER CAPITA RECYCLING BUDGET

A positive correlation was found between the per capita recycling budget and the recycling rate. For every \$1 change in per capita recycling budget, the recycling rate changes by 0.31%, assuming that all other factors are held constant. The p-value is 0.09, which is comparatively smaller and therefore more significant than for the other variables, but insignificant if looked at individually.

Discussion

The adjusted-R² value is high and the overall p-value is higher than the significance level of 0.05. This means that there are no significant relationships between any of the tested independent variables and the dependent variable. Therefore, the hypotheses that positive correlations would be found between recycling rate and the percent of population with bachelor's degrees or higher, population density, per capita income, mandatory recycling, and per capita recycling budget are not supported by the results of the statistical analysis.

The results of the per capita recycling budget are worth mentioning because the p-value of the relationship between per capita recycling budget and the recycling rate is 0.09, which is significant at the 10% significance level. I found no other studies that looked at the relationship between per capita recycling budget and recycling rate; hence, this factor warrants further inquiry.

The correlation matrix for the variables used in the multiple regression is shown in Table 4.

The correlation coefficient between percent population with bachelor's degree or higher and recycling rate is 0.37, that between per capita income and recycling rate 0.46, and that between per capita recycling budget and recycling rate 0.42. All three values show that these variables are somewhat correlated. A previous study has also reported a correlation of 0.37 between recycling rate and percent population with bachelor's

Table 4. Correlation Matrix of the variables used in regression.

	Recycling Rate	% Bachelor's Degrees or Higher	Population Density	Per Capita Income	Mandatory or not	Per Capita Recycling Budget
Recycling Rate	1					
% Bachelor's Degrees or Higher	0.37	1				
Population Density	0.26	0.32	1			
Per Capita Income	0.46	0.93	0.40	1		
Mandatory or not	-0.08	-0.27	0.54	-0.22	1	
Per Capita Recycling Budget	0.42	0.087	-0.08	0.17	0.03	1

degree or higher (Lockhart 2003). More data should be collected in order to establish the significance of the association between education level and recycling rates. Such an association would signify the need for greater efforts in recycling and education about recycling in areas where most of the population does not possess bachelor's degrees.

The correlation coefficient between population density and recycling rate is 0.26, and that between mandatory recycling and recycling rate is -0.08. Thus, these variables are not highly correlated with recycling rate.

All the correlations mentioned above might result from the characteristics of this particular dataset; hence, further research is needed to more accurately determine the relationship between these variables.

It should be noted that the dataset is small, and it can be expected that, had data for more cities been included, significant relationships might have been obtained, especially for per capita recycling budget. More data would also permit the use of more independent variables, if they were available. For instance, another variable that could be included is the use of single-stream or multiple-stream recycling (Skernolis 2008). Single-stream recycling means that residents do not have to separate different recyclables (e.g., glass, paper, metal), as they have to do in multiple-stream recycling. In single-stream programs, recyclables are separated mechanically or manually after pick-up (Skernolis 2008). Although this data is available for some of the 22 cities examined in this study, it was not included to avoid the problem of too many variables for a small set of observations.

Another reason that the results show insignificant relationships between the variables might be that the data used from the Municipal Recycling Survey is self-reported. Cities do not always use the same metrics to calculate their recycling rates (Truini 2008). Some cities might include different materials in the recycling rate from those specified by the surveyor. Demolition and construction materials, automobile scraps, and yard wastes are some of the materials that might or might not be included in self-reporting of recycling rates.

The availability of data is a substantial problem in research on recycling programs (Simmons 2006; Lockhart 2003). Because very few sources of data exist, the variables chosen for study are limited by the availability of data. Most researchers conduct specific surveys for their research; however, a survey of that type would require more time than is available for a project of this scope. If conducting a survey of recycling programs, future researchers might include other variables, such as age of infrastructure, cost

of recycled materials, proportion of budget spent on recycling education, and age of recycling program, all factors that might play an important role in recycling rates (Skernolis 2008).

QUALITATIVE VARIABLES

There are other factors that are difficult or impossible to quantify. One of these is location of the city. Cities located on the west coast near ports are at an advantage because of accessibility to Asia, the biggest market for recycled products (Skernolis 2008). This accessibility drives up the price for recycled materials and provides incentive for those recycling programs to increase recycling rates in order to increase their revenue. On the other hand, cities on the east coast often do not have a large or consistent market such as that found in Asia, and thus the costs associated with their recycling programs would be higher and their revenues lower. This factor might prevent some east coast cities from devoting resources to increasing recycling rates. Similarly, there might be other areas where the demand for recycled materials might be high for other reasons, putting certain cities at a comparative disadvantage.

The availability of landfill space is yet another factor. An attempt was made to include this factor in the research model by using population density as a variable. However, population density and landfill space might not be correlated, as space might be available outside the city limits. Thus, landfill space is another variable that is hard to quantify. The availability of landfill space might explain the low recycling rates in cities such as Houston, Dallas, San Antonio, and El Paso, where Texas' geographical area provides more potential landfill space than is available in other smaller states. This factor requires more research on a case by case basis. Where landfill space is readily available, the cost of garbage disposal might be less than that of recycling, reducing much of the incentive in establishing or expanding recycling programs (Skernolis 2008).

Infrastructure cost is also a huge factor in the decision for a city to initiate or expand a recycling program. For instance, curbside recycling can lead to higher recycling rates; however, it requires a huge capital investment in the form of collection vehicles and recycling containers (EPA-530-R-92-015 1994; Folz 1999; Skernolis 2008). A curbside recycling program also has higher operating costs associated with it (Skernolis 2008). If a city with an existing recycling program has old infrastructure, then the cost associated with replacing the infrastructure could prevent the city from expanding the program and increasing recycling rates. Likewise, these additional costs could drive communities away from starting new recycling programs.

Policy Recommendations

A 2006 study conducted by the United States Government Accountability Office concluded that recycling stakeholders feel that a nationwide campaign to educate the public should be established. Such a program, the study concludes, would be best administered by the Environmental Protection Agency.

To enhance such efforts, the Environmental Protection Agency could create performance measures for recycling programs and gather performance data on those measures (GAO-07-37 2006). The lack of data on recycling programs is surprising, given that municipal recycling has been in practice for 12-15 years, and presents a problem. This lack of data results in inaccurate and widely divergent calculations of our waste stream. For instance, BioCycle reports that 131 million tons of municipal solid waste were recycled in 2002, while Franklin Associates, which works for the Environmental Protection Agency (EPA), reports only 70 million tons for the same year (Simmons 2006). The difference, a whopping 47%, is caused by different estimation methods used in the two studies. A nation-wide initiative to collect standardized data, possibly in the form of a database which could then be made available for research, is long overdue (Folz 1999; GAO 2006).

Because of the enormous amount of data collection required, state environmental protection

agencies, helped by federal funding, might be in the best situation to initiate this task. The enormity of the task means that it will take several years before results of such an initiative would be available to policy makers.

Some studies argue for the need for federal regulation of recycling. However, federal regulation is not the only, and may not be the best, way to go. There are various cities around the country that have successful recycling programs despite the absence of federal regulations making recycling mandatory. For instance, Los Angeles, San Jose, San Francisco, Seattle, and Portland have recycling rates that are well above the national recycling rate goal of 35% set by the Environmental Protection Agency (Municipal Recycling 2007). Given the huge burden of cost imposed by recycling programs on local authorities, the federal government could raise recycling rates by providing financial assistance to run recycling programs.

Legislation designed to address climate change might also provide the perfect opportunity for the federal government to step in and make some changes to recycling policies. According to Ed Skernolis of the National Recycling Coalition, recycling will gain more momentum as climate change bills are debated at the national and state levels (Skernolis 2008; National Recycling Coalition). This debate will hopefully spur further public awareness of and debate on the policies discussed in this paper.

Conclusions

The lack of significant relationships between recycling rates and the dependent variables examined—percent of population with bachelor's degrees or higher, population density, per capita income, mandatory recycling, and per capita recycling budget—indicates that there are other factors that determine the success or failure of recycling programs. Future research will need to focus on data regarding other important variables, some of which have been discussed above. In addition, qualitative variables specific to certain programs should be examined. A case study approach would best allow these variables and programs to be identified, so that they can serve as models to increase the effectiveness of other programs.

For future research, creating and conducting a survey specifically for the study is recommended. This ensures that the researcher will be able to determine and to focus on the most relevant cases as well as the most important variables. Also, future research studies might focus attention on improving recycling programs at the federal level, rather than examining them, as this study does, at the municipal level. The GAO study is a good model for such future studies. For instance, the GAO recommends that making recycling convenient and easy for residents, offering residents financial incentives for recycling, and conducting public education and outreach can increase recycling. Other methods listed in the study should also be investigated.

In conclusion, there has been substantial progress in enhancing recycling programs; however, a more unified approach, including the establishment of performance measures and standardized data collection on a wider range of variables and on a larger number of cities, is needed to accurately measure the progress of current recycling efforts and to best learn from them.

Acknowledgments

I would like to give many thanks to Professor Larry Berman and Brent Sewall for their guidance and encouragement in the completion of this research project. I would also like to show my appreciation for the UC Davis Washington Program staff, both in Davis and in Washington, DC, for their assistance throughout the program.

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