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WASTE GENERATION IN THE BUSINESS COMMUNITY OF
EAST LANSING, MICHIGAN AND THE POTENTIAL
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WASTE GENERATION IN THE BUSINESS COMMUNITY OF EAST LANSING, MICHIGAN AND THE POTENTIAL FOR RECYCLING

By

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ABSTRACT

WASTE GENERATION IN THE EAST LANSING, MICHIGAN BUSINESS COMMUNITY AND THE POTENTIAL FOR RECYCLING

By

Kenneth Irving Stern

At-source sampling was done at 19 retail, restaurant, and printing firms in the East Lansing, Michigan business community to determine if more accurate and complete estimates of materials generated can be made by dis-aggregating the commercial waste stream into sub-sectors. Corrugated cardboard comprised over 40 percent of the retail waste stream, and over 70 percent of printshops' waste was paper products. Individual firms averaged as much as 67 percent corrugated and 80 percent paper wastes, respectively. These are significantly higher ratios than are being reported by disposal-based studies. Overall, 67 percent of the commercial waste stream may be recyclable paper materials.

At-source examination of the waste stream can provide planners with a more accurate assessment of the materials available in local waste streams. This will assist in developing collection programs that maximize recycling and prevent loss of resources that are missed when the waste stream is incompletely identified and quantified.

This thesis is dedicated to my father, who came to want this--for me--far more than I did.

and

To the Recyclers of Ingham, Eaton, and Clinton Counties, for a brainstorming session with staff members in the fall of 1986 found a kernel of an idea that became this document.

ACKNOWLEDGEMENTS

This list may seem long, but in my quest to develop this project I reached out far and wide and received assistance from as far away as New York and California and from Minnesota to Texas. I cannot thank everyone who helped me out, either nationally or locally, but I do want to acknowledge the assistance I received from City of East Lansing staff, the local business community--including the many employees in the 19 participating firms--MSU students and faculty, and other recyclers who helped as I developed the project, conducted the field sampling, and researched this thesis.

I am deeply grateful to my advisor, Tom Edens, for his patience, interest, and willingness to persevere. He gave freely of his time, and his assistance helped this document finally become complete. Cynthia Fridgen and Ray Vlasin, committee members, also were available, and I appreciate their participation. Jon Bartholic, who started me out in the Department, gets thanks for sending me on my way, allowing me to present my research at state and national conventions.

My many student helpers made the field sampling possible, coming out early and late, under all kinds of weather conditions. Extra stars go to Shirley Businski, Angela Faraci, and Melinda Miller, who went farthest above and beyond the line of duty. Thanks also to Glenn Barner, Eric Frakes, Dave Frey, Andy Myers, and

Sharon Phillips. Tom Young helped early and Jim Garland helped later on with computer and writing tasks. Alberto Pulido also offered much needed assistance.

To fellow RD grad students, especially those who came out to help and for a look-see at field work in action, thanks. Many of you are gone, but you are not forgotten.

John Czarnecki, former East Lansing mayor, and Tom Dority, East Lansing city manager, were interested in my ideas and gave the official seal of approval to this project when it was merely a concept. I hope this research helps in the development of recycling collection in the commercial sector of my adopted hometown.

Peter Eberz, Jim Frey, Kurt Guter, and Bryan Weinert were waste management and recycling professionals who were willing to offer advice. Through Resource Recycling Systems I was able to watch a waste assessment being done at a landfill. Your time and attention have been greatly appreciated.

The Recyclers of Ingham, Eaton, and Clinton Counties started me on this quest, and along the way let me use their truck, trailer, computer, and office. Thanks folks. You are succeeding in getting recycling expanded throughout the area, even if the going is slower than we would like.

My family members, who may have come to doubt that this student sibling would ever graduate, were always supportive in the hope they would hasten my departure from the halls of academia. Thanks mom and dad, for much more than your interest in this project. Eva, you watched this develop ever so slowly over the years, but never wavered in your support, concern, or patience. Thanks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The handling and disposal of solid waste is becoming a major problem for communities throughout the United States. The two most important concerns are that one third of the nation's landfills will reach capacity and close by 1991 and that very few new facilities are being built as replacements (U.S. EPA 1989). Many other landfills fail to meet federal or state standards and are listed as environmentally contaminated sites (Concern 1988). These factors are causing disposal costs to escalate on a continuous and long term basis (Figure 1).

The definition of "proper" for handling solid waste has changed: Landfilling, once the primary method of disposing of solid waste, is now placed last in governmental policy hierarchy, to be used when other options are exhausted (U.S. EPA 1989; MDNR 1988). In Michigan, for example, the state's Department of Natural Resources made adoption and implementation of a statewide solid waste management-policy its top priority for 1988; state legislation required a strategy that "will reduce land disposal of solid waste to only 'unusable residuals' by the year 2005" (MDNR 1988). Michigan's goal is to minimize landfill needs to a 15 percent remnant. This is vastly different from disposal practices today: Ninety percent of the state's solid waste is landfilled, less than 10 percent is recycled through the waste hauling disposal system (not including beverage containers collected through deposit), and the remainder is incinerated (Figure 2) (MDNR 1988). Recycling is

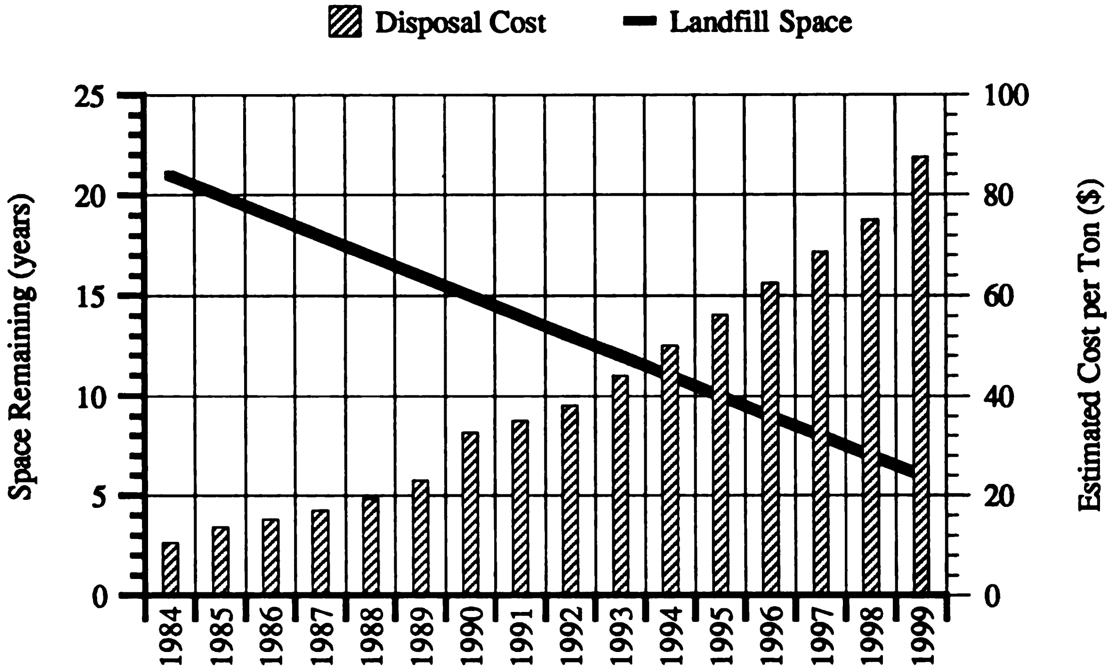


Figure 1. Cost and space estimates for landfilling solid waste in Lansing, Michigan (Adapted from K. Guter, personal communication 1990).

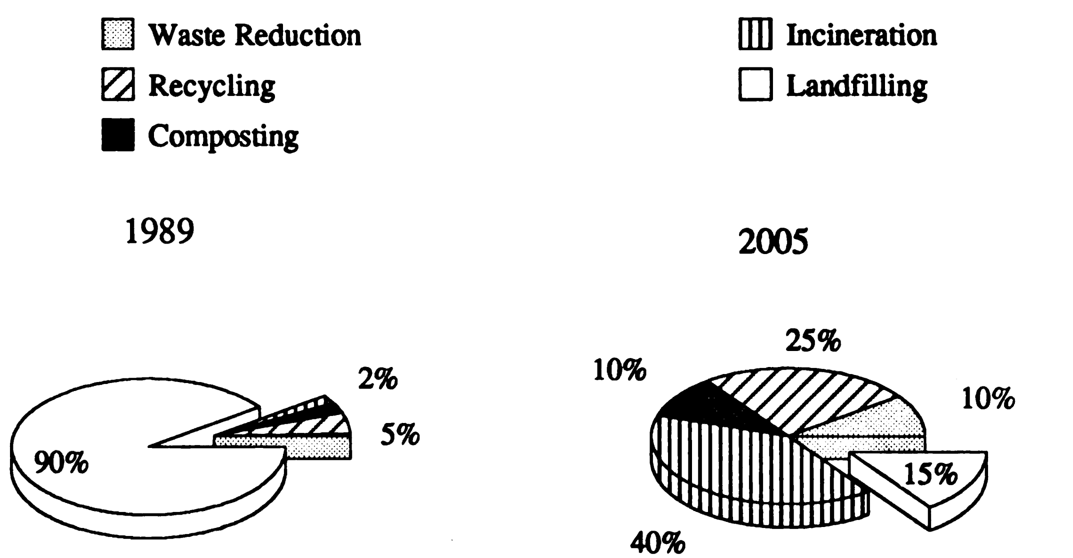


Figure 2. Current and projected waste disposal practices for Michigan's solid waste (Adapted from MDNR 1988).

intended to supplement and replace waste collection and landfill disposal as the primary waste management technique as communities meet solid waste diversion goals set by our governments (MDNR 1988, U.S. EPA 1989). Recycling strategies are oriented to the re-direction of used materials back into the manufacturing stream for processing into new products. There is a long established secondary materials industry in this country, but it has traditionally been a small sector and has not been involved with municipal-wide collection of solid waste.

The switch in policies and the creation of programs necessary to develop alternative waste management strategies will fundamentally change the way waste is disposed of throughout the United States (MDNR 1988, U.S. EPA 1989). A completely new physical and social infrastructure will be built as society develops alternative methods of handling its solid waste. To be successful, recycling programs will have to collect the majority of readily available materials placed in the waste stream. If collection programs do not adequately divert materials, recycling goals will not be reached and recyclables will continue to be landfilled or incinerated in large quantities.

Proper planning, based on sound, well developed information, is needed to make this transition in waste management. It is imperative that accurate and useful data assessing the quantity, composition, and status of waste, **as it is generated**, are available. The standard methods for determining waste stream composition are inadequate for the planning needed for large scale recycling programs. This thesis focuses on the commercial sector to attempt to show that current planning for large scale recycling significantly underestimates that sector's recycling fraction. Chapter II will show that little information is available on commercial sector composition, and that it is not applicable for analyses derived from loads mixed thoroughly together in the process of waste collection. It questions whether the high levels of recycling called for will be met if significant portions of materials continue to be landfilled because they have been undercounted or underestimated. Chapter III reviews the use of waste stream assessments and their changing status in planning large scale recycling programs.

This research examines waste production at the micro-level of the individual firm in the East Lansing, Michigan business community. It estimates sub-sector contributions and makes a comparison with results based on the standard sampling techniques commonly used to assess the complete municipal solid waste stream. If at-source sampling provides more accurate assessments of commercial sector waste composition than disposal based sampling techniques, it needs to be considered as a replacement method.

This research project seeks to improve the level of information available by more accurately documenting materials in the commercial waste stream. A full accounting of materials available for recycling prevents the significant consequences of seriously underestimating the amount of materials. The methodology and the principles underlying it are discussed in Chapter IV.

Chapter V presents the results of the field research and compares the East Lansing commercial sector waste composition ratios to other disposal based studies through a Westchester County, New York study that used similar at-source sampling techniques as the basis for making county wide projections of waste generation and composition in its commercial sector. Comparisons are also made with studies where "pure load" packer trucks were used to assess sub-sector waste streams.

Finally, in Chapter VI, the conclusions stemming from both the empirical work and the comparisons made with disposal based studies will be advanced.

CHAPTER II

PROBLEM STATEMENT

Introduction

Waste management programming is locally planned, based on assessments of area or regional conditions. If the level of information is incomplete, deficiencies in design will occur (Metropolitan Council 1988). The standard methods used for collecting data (as summarized by the MDNR Solid Waste Stream Assessment Guidebook, 1986) for planning purposes appear to be inadequate, and do not accurately or completely estimate waste in the commercial sector (Robinson and Robinson, 1986). Disposal based sampling methods for assessing waste composition, generation rates, and quantities are not adequately capturing the complexities of the non-residential waste streams. A critical reading of the at-landfill sampling techniques reveals that representative and complete samples of commercial sector waste are not being made (Robinson and Robinson 1986, Metropolitan Council 1988, U.S. EPA 1988, Cerrato 1989, Kuniholm 1989).

Robinson and Robinson (1986), for example, noted that very little attention has been paid to this waste stream:

> More often than not, the problem of quantifying commercial wastes cannot be totally resolved .... The special problems with commercial and industrial waste requires knowledgeable approaches that, with few exceptions, have been woefully lacking and ignored in overall planning ....

Purpose of Study

How can more accurate quantitative and qualitative assessments of the waste stream be made? Golueke and McGauhey (1969) concluded that disposal based sampling is "inherent[ly] incomplete . . . ." This chapter will examine some of those problems. It would appear that sampling early in the process, prior to collection, would provide a truer picture of waste generation and the potential for recycling. This hypothesis warrants testing.

The purpose of this study is to determine if at-source measuring of waste provides more accurate and complete estimates of materials generated in the commercial waste stream. This will be done by comparing composition estimates of the waste stream from standard disposal based techniques with estimates created by at source of generation measurements. It develops techniques that effectively and efficiently measure waste production to reflect the total amounts of material available for practical capture and the day-to-day dynamics of sub-sector waste generation.

The heart of the problem in waste management appears to be the paradigmatical shifting of programming from a disposal-based to a generation-based orientation. Historically, the profession has assumed collection and focused on techniques for final disposal. In a recycling based management program, disposal is handled by the long established scrap and secondary materials industry. The emphasis now must turn to programs that maximize the collection of waste for its value as a commodity. This creates a completely new set of dynamics. Part of the problem is that, until recently, the waste management industry has had little experience or interest in large scale recycling programs.

Another important issue, stakeholder involvement, addresses the problem of gaining participation from the waste generators once recycling collection programs are in place. By expanding the stakeholder groups to include local government personnel as well as commercial sector management and employees, a framework can be created for program design and implementation after the analysis has been made.

Chapter IV presents the study's **hypothesis that more effective waste management programs can be planned by linking waste generation to its source,** both by geographic location and by type of generator.

The Necessity for Waste Stream Assessments

It is ironic that though most persons have a regular, if casual, relationship with solid waste, little is known about waste management from an academic or policy perspective. For too long professionals, like most other citizens, have assumed that the status quo for waste disposal was sufficient. As has been noted by Golueke and McGauhey (1969):

> In the case of solid wastes, where progress toward solution of problems has been glacier-like in its advance because of man's inability to see the problem or his disinclination to recognize it, there is little reason to fear that the answer will outrace the quest.

Little has changed in the ensuing two decades since Golueke and McGauhey (1967) undertook their major, nationally funded, multi-year study for "comprehensive studies of solid waste management." They observed then that "long experience with refuse disposal has not produced information on the composition of solid wastes in the detail now needed for management purposes." Their list of reasons is also as accurate as if it was written yesterday. These are (Golueke and McGauhey 1967):

1. Traditional concepts of management
2. Scope of concern with solid wastes
3. Dislocation of systems
4. Change in industrial technology
5. Cultural and sociological changes in America

Before solid waste can be "managed," local conditions must be analyzed. Programs and policies depend on knowing waste composition, how much of different types of materials is available, and where and by whom the waste is generated. Locally derived data are needed because community characteristics differ from one area to the next (Metropolitan Council 1988). Waste stream analyses, composition studies, or characterizations (terms used to define examination of the waste stream) are conducted as a crucial first step in providing planners and managers with answers to these questions (Golueke and McGauhey 1967, 1969, U.S. EPA 1975, U.S EPA 1979, MDEM 1985, Evans 1985, Savage et al. 1985, Brunner and Ernst 1986, MDNR 1986). A major problem arises because analyses of local waste composition do not adequately reflect the quantity, type, or source of generation of materials.

A Systems Approach to the Municipal Solid Waste Stream

The collection, transport, and disposal system for solid waste is complex, with a considerable amount of "noise" (variables ranging from source of generation to final disposal point) that is difficult to filter out in order to study specific waste sectors that comprise the municipal solid waste stream. In Minnesota, for example, researchers noted that there is "a complex, interwoven network of waste transport and disposal between county boundaries, and to a lesser degree, exported outside the TCMA [Twin Cities Metropolitan Area]." (Metropolitan Council 1988). Figure 3 indicates the various interactions that may take place between the time waste is generated by a firm within a commercial sector and the time it is finally "disposed."

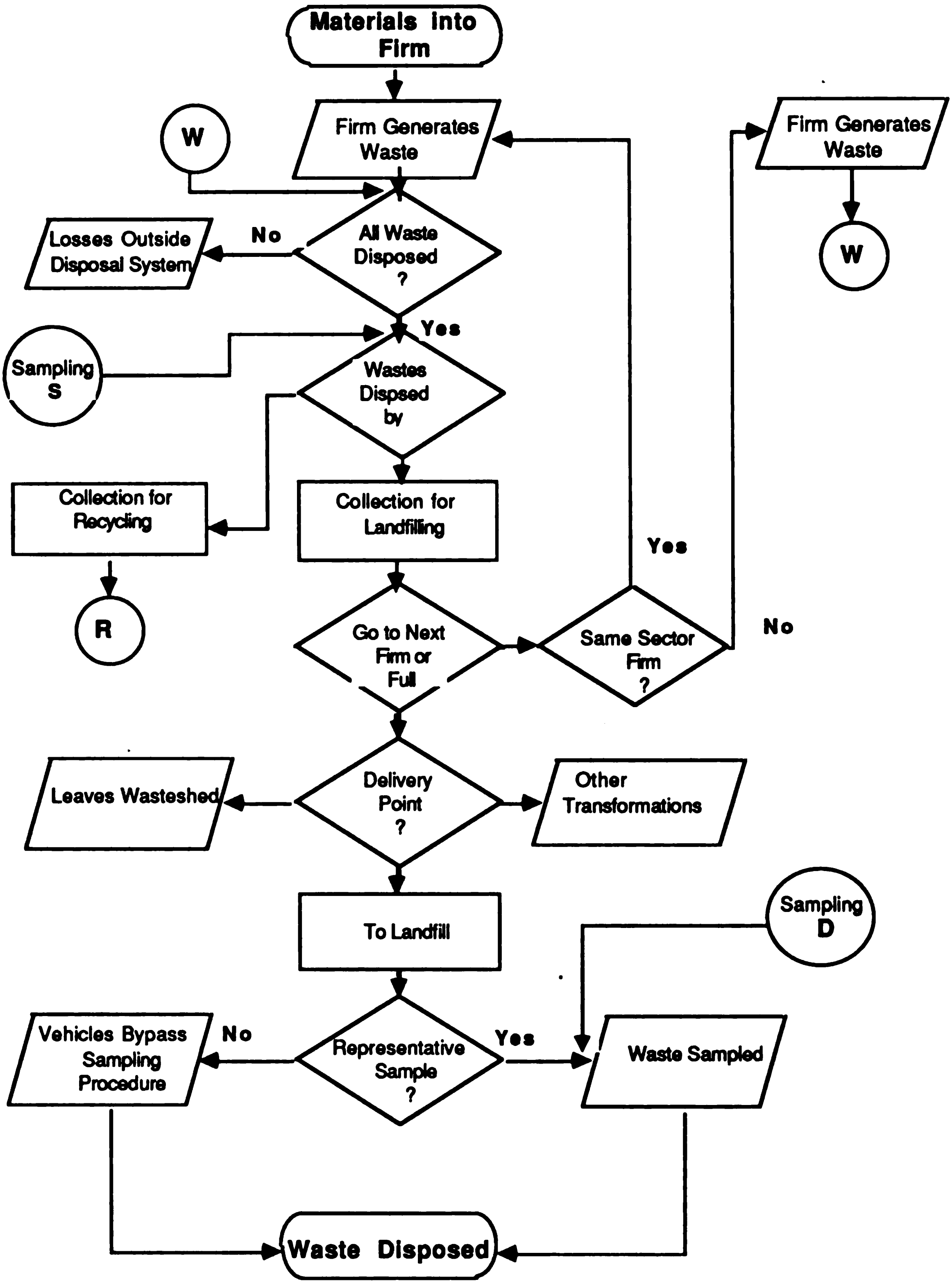


Figure 3. Waste flows through the commercial sector with alternative sampling points **S** and **D** marked.

Sampling at the point of generation (at **S** in Figure 3) could make it more likely that all available waste would be measured.

The problem with disposal-based sampling is that once material leaves an establishment a variety of things can happen to it, as depicted by Figure 3. Also, disposal practices, with the many financial and regulatory dynamics associated with it, are in a continuous state of flux, and disposal patterns change. As Metropolitan Council (1988) noted: "[c]losing landfills and changing tipping fees can create instantaneous changes in the flow of waste to any facility, thus making it even more difficult to document waste quantities generated by a particular county."

One important variable to consider is that waste may not be disposed of at all, because many commercial sector enterprises are already recycling. Westchester County (1988) found that an estimate of commercial recycling activities could not be made, because there were not sufficient data to make a determination.

Waste may leave the wasteshed (the geographic area from which all waste is disposed of in local/shared disposal facilities) and private haulers occasionally operate in different municipalities and empty their trucks at a facility outside the wasteshed. The Metropolitan Council study, for example, found that many industrial loads bypassed the processing facility, where sampling took place (Metropolitan Council 1988). The waste will almost certainly be mixed and compacted with waste from other businesses and residential sources. The load may be exclusively from within a sub-sector (e.g. all office buildings, all restaurants) or it may be completely mixed, and include wastes from multi-family residential complexes as well as a variety of businesses (Evans 1985).

If a study is being conducted at a disposal facility (sampling point **D**, Figure 3), there is no assurance that a representative sample will be taken of the waste that was **generated** within the wasteshed. Commercial and industrial loads may be missed, so that a representative sample of the entire municipal solid waste stream is not taken (Metropolitan Council 1988, MDNR 1989).

Sampling at point S (Figure 3) avoids the "noise" problems that take place once materials leave the place of generation. While measuring at the source, before waste enters the complex system, seems intuitively correct, this approach has seldom been taken in research and planning. Only a few firms, including the environmental engineering company Malcolm Pirnie, in its 1988 study of Westchester County, New York (Cerrato 1989, Kuniholm 1989), and Recovery Sciences, in its study for Sunnyvale, California (Sunnyvale 1986), have taken this approach.

Waste Generation in the Commercial Sector

There is a problem in that little is known about the dynamics of waste generation. This is especially true in the commercial sector. As late as 1989 the consulting firm Resource Integration Systems (GBCC et al. 1989) reported that "few reliable studies of commercial waste composition have been undertaken." Cal Recovery Systems (Metropolitan Council 1988), in conducting a major solid waste study for the Minneapolis-St. Paul metropolitan region, had difficulty in determining business waste totals. In their conclusion the concern was raised that:

> The quantity of waste recycled by area businesses cannot be accurately estimated due to the lack of a standard reporting system . . . . very little waste quantity data have been collected through which one may identify the geographic and generation source of the waste.

The Metropolitan Council report highlights two major problems: The **lack of data**, and (more seriously) **the lack of standard and appropriate** procedures for determining business sector waste streams.

Locally generated waste is often analyzed by local professionals who have their own methods of data collection and assessment. Communities typically act in isolation in determining their needs. There does not appear to be a central authority or set of procedures that waste management or municipal professionals can turn to in order to acquire a thorough set of methods for conducting waste stream analyses. In examining data enhancement priorities for the Metropolitan Minneapolis area, Metropolitan Council's first recommendation was to standardize definitions and test methods for collecting solid waste data. Its second recommendation was to determine the level of recycling currently taking place within the commercial and industrial sectors (Metropolitan Council 1988).

Limitations of Standard Assessment Practices

Most policies and programs are based on information derived from waste stream assessments using data collected from sampling waste at landfills, the point of disposal. Traditionally, characterization studies have focused on the complete municipal waste stream, but no community of any size has all its rubbish collected in such a general way. There is a significant problem with the standard methods employed in disposal-based sampling if they do not adequately or completely delineate the complexities or the potential of the non-residential waste streams. Waste management planners are operating under the burden of methods for determining waste stream composition that were conceived in the 1940s. It is no longer sufficient to analyze solely for overall composition of materials disposed of within the wasteshed. More detailed information is needed that reflects how waste is generated at its source.

If these methods are now outdated, they are not adequate to plan for the scale of recycling being called for and the more sophisticated micro-management now needed. If the data derived are too general, and even inaccurate, then a false picture of the dynamics of waste generation is being presented. It is the analysis of these dynamics that determines waste management policy decisions.

A problem with assessments taken of the overall municipal solid waste stream is that they can mask the fact that many commercial waste streams are homogeneous, clean, and have large concentrations of readily recyclable materials on a consistent basis. As a result, analyses of the at-landfill sampling techniques lead to the conclusion that representative and complete samples of business sector waste are not being made (McCamic 1985, Evans 1985). Significant portions of recyclable materials, chiefly office paper, mixed paper grades, and corrugated cardboard, are not being counted. The limitations of disposal-based sampling include:

1. An inability to identify the waste explicitly to the source
2. An inability to prevent contamination of materials
3. An inability to accurately measure weight or volume of materials **as generated** because of contamination and compaction inherent in the collection process
4. Limited ability to correlate demographics and social data with the waste generators
5. Limited ability to design program on the micro-level of individual or sub-sector generators
6. No involvement of waste generators
7. Orientation to centralized and large scale solutions

These limitations point out why a different system for studying waste generation is needed.

Consequences of Underestimating the Recyclable Fraction of the Waste Stream

A lack of a complete accounting of materials results in seriously underestimating the amount of materials available for recycling. This creates the problem of having programs incorrectly designed and undersized, causing emphasis to continue to be placed on standard collection systems. Diversion will then be incomplete, because equipment, staffing, and routing will be inadequate to handle all the material that is actually generated. The high levels of recycling that policy makers are mandating cannot be met if significant portions of commercial sector materials continue to be landfilled or incinerated. This can cause the related problem of having unrealistic expectations for the amount of recycling that would be needed in the residential sector to meet recycling goals (Regional Environmental Task Force 1989). If the potential for business sector diversion is not accurately assessed, calculations made for recycling in the residential sector will probably be artificially high.

An undercounting of the recyclable portion of the waste stream skews the economics and finances of the local disposal system. This creates the problem of increased management costs in three major ways:

First, the value of the resource, derived from scrap as a commodity, is lost when materials are burned or buried. The potential for recovery is lost. **Secondly**, programs will not be properly planned (MDEM 1985) and will be under budgeted and thus unable to handle the entire recycling fraction if it were to be captured. Equipment and staff will continue to be disproportionally directed toward landfilling. Programs will target larger waste generators and bypass the many smaller businesses that, collectively, make up a sizable portion of the commercial sector. Firms will not be prepared to or attempt to separate all materials, since estimates are lower than actual generation rates. Finally, uncaptured materials sent to the landfill or incinerator will add to operating costs of those facilities and shorten their life spans. Conversely, large quantities of unaccounted for materials that are captured will results in overcapacity at the processing facilities, which also increases costs (MDEM 1985, Savage et al. 1985).

Summary

Municipal solid waste is a more complex issue than commonly recognized, and its dynamics are not well understood. Today's problem in waste management appears to be the paradigmatical shifting of programming from a disposal-based to a generation-based orientation that captures materials for their market value. The new emphasis in program management is to maximize the collection of waste for its value as a commodity. This creates a completely new set of dynamics. Since programs are locally planned, each community and region has to make this adaptation on its own.

The first need is to analyze waste stream composition so that programs can be properly sized. Standard, disposal-based sampling methods are not fully assessing the amount of materials in the commercial waste stream available for recycling. Most planning continues to be based on sampling done at the point of disposal. Major new studies done for the states of Michigan (MDNR 1989) and Washington (WSDE 1988) and the Minneapolis-St. Paul (Metropolitan Council 1988) region relied on disposal-based sampling. Chapter III, the Literature Review, surveys various field studies and assesses their results. The literature review will provide a point of comparison for the standard approach and the alternative presented here for principles that support at-source measurements of materials.

CHAPTER III

REVIEW OF PREVIOUS STUDIES

Introduction

The first axiom of solid waste management waste planning is to base program design on an accurate analysis of the waste stream (Robinson and Robinson 1986). Planners and waste managers agree that data for waste composition must be locally derived to be useful for developing new program strategies (Golueke and McGauhey 1967, 1969; U.S. EPA 1979, 1989; Evans 1985; MDNR 1986; Metropolitan Council 1988, are but a few). National estimates provide an overall picture of the condition of solid waste in the United States, but local dynamics are too variable for these figures to be useful in the design of specific programs. Studies done prior to the mid-eighties have been criticized as to the "worth" of the data because of their age, the mixing of waste streams by sectors, the lack of complete measurement of the waste stream, and assumptions that were made in conducting on-paper analyses (Golueke and McGauhey 1967, McCamic 1985, Savage et al. 1985). These issues remain a concern today.

Assessing the Waste Stream

The quantity and composition of solid waste, particularly in the business sectors, need to be quantitatively evaluated within a community. These factors are "key considerations in the planning, design, and operation of solid waste management systems," according to the Michigan Department of Natural Resources (1986). In a guidebook on local planning, composition variables are called:

> Major criteria in the collection, transportation, recycling, recovery, and disposal components of a solid waste management system. The information produced by a waste stream assessment is used by designers, financiers, and decision-makers at all level of government.

In their review of alternative methods for analyzing municipal solid waste, Brunner and Ernst (1986) found:

> The importance of reliable information on the composition of municipal solid wastes (MSW) is emphasized by the following facts: (1) potentials for recycling . . . or needs for treatment and disposal capacities . . . can be identified only if information on the amount and composition of MSW is available; (2) in order to design waste treatment processes properly, the materials which are to be treated have to be well characterized; (3) emissions to the environment from waste management practices can be predicted only if the inputs of waste treatment are known.

A waste stream assessment is generally defined as any program which involves a logical and systematic approach to obtaining and analyzing data on one or more solid waste streams or sub-streams (MDNR 1986). The primary issues in determining waste composition are the classification system to define waste stream components (McCamic 1985, MDNR 1986, Metropolitan Council 1988) and the place of sampling in the flow of the waste stream (MDEM 1985, McCamic 1985, Kuniholm 1989). Both of these have changed with the new strategies emphasizing recycling of materials (McCamic 1985, Kuniholm 1989).

Research methods to conduct a project include sampling at the point of disposal, sampling at the source, and modelling (MDEM 1985, McCamic 1985). The first two take direct measurements of waste as in the field. The last consists of on-paper calculations and manipulation of secondary data. These are too far removed from actual waste generation to be meaningful (Golueke and McGauhey 1967, U.S. EPA 1979, MDEM 1985, Metropolitan Council 1988).

Field sampling in and of itself is not sufficient. The state of Washington sponsored sampling that was done at 87 sites in 1988, but the sampling period was of one and two days duration (WSDE 1988). Field measurements taken for the metropolitan region around Minneapolis, Minnesota were limited to ten days (Metropolitan Council 1988). Seldom does a study report, as the U.S EPA (1979) did, that:

> Data generated for this study were developed by limited,on-site investigations . . . assumed to be fairly representative of typical waste generation. However,until detailed waste characterization studies are done for these sources, the data must be considered an approximation. These detailed studies could significantly contribute to increasing the accuracy and utility of the applicability analysis.

Defining the Municipal Solid Waste Stream

The municipal solid waste stream (MSW) is made up of at least six major component parts: residential, commercial, industrial, institutional, construction and demolition, and agricultural (Figure 4 and Figure 5) (McCamic 1985, Cerrato 1989, Kuniholm 1989, Selke 1990). Most programmatic efforts emphasizing recycling, to date, have gone into the residential sector (Cerrato 1989).

A wide range of estimates exist for the size and material composition of the commercial-industrial-institutional waste streams. Papke (1989) estimates the range to be from 10 percent to 75 percent of a community's total waste stream. Figure 6 shows that communities report widely divergent sizes when determining their commercial waste streams. The estimates of the material make-up of waste streams also differ greatly. These composition ratios vary more than local factors would suggest. Figure 7 compares the commercial sectors of Seattle, Washington and St. Paul, Minnesota. Waste generation per capita is similar (2.5 pounds vs 2.27 pounds per day), yet sampling showed that the St. Paul area's percentage of papers in the

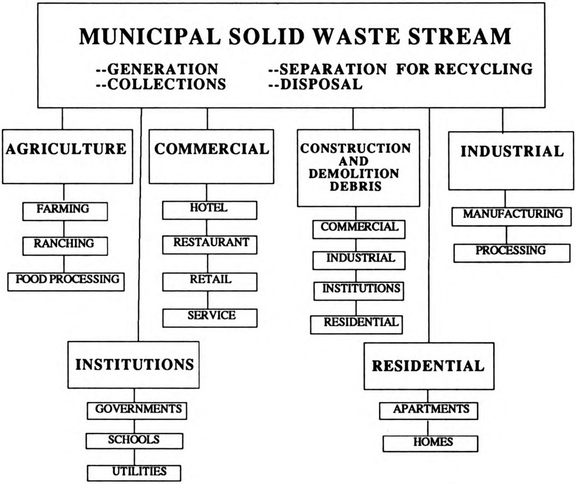


Figure 4. The municipal solid waste stream is comprised of independent sectors.

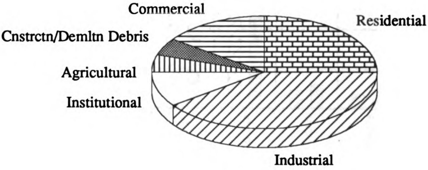


Figure 5. Sub-sectors of the municipal solid waste stream.

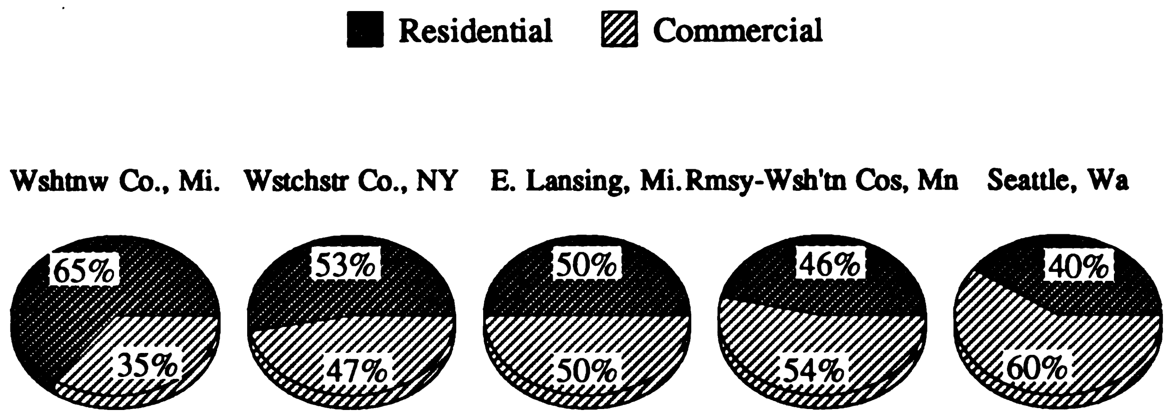


Figure 6. Commercial to residential waste stream ratios of various metropolitan areas.

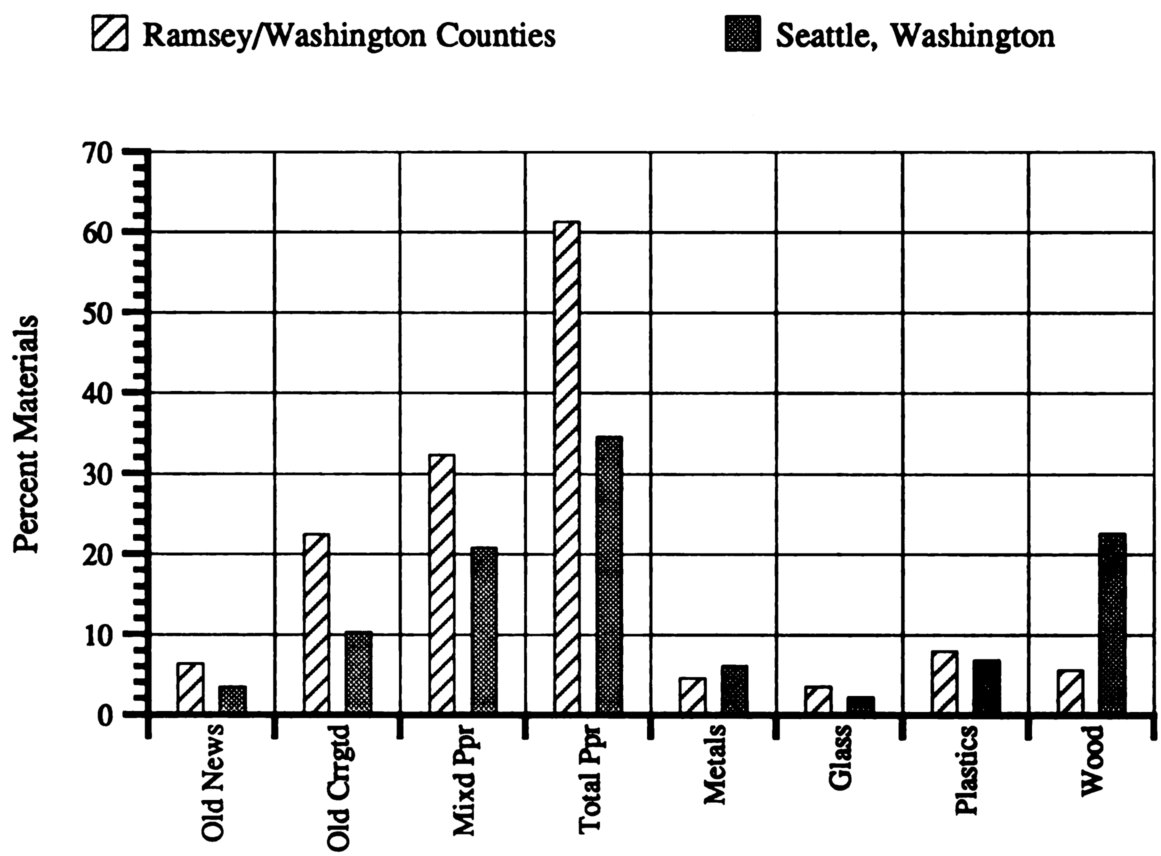


Figure 7. Comparing waste composition of two urban commercial waste streams.

waste stream was 77 percent greater than Seattle's (Seattle 1989, Metropolitan Council 1988). While waste generation is determined by local conditions, this variation is probably greater than the influence of unique circumstances.

Sub-Dividing the Municipal Solid Waste Stream

Most researchers recognize the unique nature of specific sub waste streams within the overall municipal solid waste load (St. Paul 1982, Evans 1985, McCamic 1985, Savage et al. 1985, Sunnyvale 1986, Metropolitan Council 1988, MPIRG 1988, Westchester County 1988, WSDE 1988, Cerrato 1989, Kuniholm 1989, GBCC et al. 1989, Seattle 1989). These sectors can be divided further along natural divisions of type of activity, location ("land use" in Evans 1985, and others) and materials handled (Sunnyvale 1986). The U.S. EPA (1979) defined four different types of airport operations and three different sizes of shopping centers.

In the 1980s planners started to use the federal Standard Industrial Classification (SIC) coding system to define sub-sectors and group firms with similar waste generation characteristics. Researchers have developed their own sub-sector classification schemes, as shown in Table 1. Washington state (WSDE 1988) and Seattle (1989) used a modified SIC based classification, combining groupings to categorize eight types of commercial generators (and Washington took the same approach with the industrial sector). The Minnesota Public Interest Research Group (MPIRG 1988) reduced 33 major SIC groups to four in its survey of the Minneapolis area. There is no uniform method or standard guidelines currently available. The use of standardized solid waste definitions and field test methods is the first recommendation made by the consulting firm CRS (Metropolitan Council 1988) in its list of priorities to regional authorities for enhancing data collection.

Table 1. Waste sectors and generators examined in various studies.

	Firm Type/Category	SIC Codes	1989 1_/ Wshngtn Seattle	1988 2_/ Wshington from 9 commnties statewide	1988 2_/ Nw York Wstchstr County totals	1985 Ontario Canada Toronto	1979 3_/ U.S EPA
1	Construction	150 to 170		xx			
2	Manufacturing	200 to 290 300 to 390	xx		xx		
3	Transport, Cmmnctns., Utilities, and Sanitary Services	400 to 490	xx	xx	xx		xx
4	Wholesale	500 to 519	xx	xx	xx		
5	General Retail	520 to 549 560 to 579 and 590	xx	xx	xx	xx	xx
6	Automotive Retail	550					
7	Restaurant	580	xx	xx	xx	xx	
8	Offices		xx	xx	xx	xx	xx
	- finance	600 to 629					
	- insurance	630 to 649					
	- real estate	650					
	- other	660 to 679					
	- legal services	810					
	- government	910-970					
9	Hotel/Motel	700	xx	xx			
10	Major Services	710 to 790	xx	xx	xx		
	- social/other	830 to 890					
11	Hospitals/Health	800					xx
12	Institutional			xx	xx		xx
	-recreational	780 to 799, 840					
	- educational services	820					
	- government	910 to 970					
13	Apartment Buildings					xx	xx

1_/ Extrapolated from eight reported categories.
2_/ Extrapolated from seven reported categories.
3_/ Extrapolated from five reported categories.

In its study of small-volume waste generators, the U.S. EPA (1979) identified five sources of waste streams, with various generators within each category. There were some published studies for each generator type they examined, but they recognized an issue that has plagued waste management planners through the present:

> . . . after an extensive literature search, it was determined that relatively little or no information exists on waste composition and generation rates from the small operators . . . with the exception of hospitals, office buildings, and small cities" (U.S EPA 1979).

However, local communities have always had studies done of their municipal solid waste to meet their needs. Among the specific commercial sectors that have been closely examined are St. Paul, Minnesota (1982); Toronto, Ontario (Evans 1985); Sunnyvale, California (1986); Westchester County, New York (1988); Boston (Greater Boston Chamber of Commerce [GBCC] et al. 1989); and Seattle (1989), but these reports seldom have been made widely available or put into a publically available system. They are often proprietary. These studies have utilized questionnaires, disposal-based sampling, "pure-load" sampling of targeted packer trucks, and at-source sampling. And, as noted earlier, the composition ratio of these waste streams vary widely (Figure 6).

Emphasizing the Commercial Sector

Planners are turning to commercial wastes in order to divert large amounts of recyclable materials (U.A. EPA 1979, Evans 1985, MDEM 1985, Sunnyvale 1986, GBCC et al. 1989, Cerrato 1989). Cerrato (1989) finds the benefits of initiating recycling programs there include:

1. The commercial waste stream typically consists of a large fraction of recyclable materials, such as paper, corrugated cardboard, and wood

2. Commercial recyclables are both readily identifiable and easily separated from the commercial waste stream
3. A significant amount of commercial recycling is usually already going on and these efforts can be enhanced or used as examples for other programs
4. Due to increasing disposal and collection costs, commercial recycling becomes an economically attractive business decision
5. Commercial recycling activity will help municipalities reach mandated state recycling goals by increasing recycling rates and therefore reducing the overall commercial waste stream requiring disposal

The commercial sector may constitute as much as 75 percent of a region's waste load (Papke 1989).

Comparing Methods of Sampling the Municipal Solid Waste Stream

While a great many studies have been done on municipal solid waste streams throughout the country, a uniform set of standards for sampling the solid waste stream has not been established. Table 2 lists studies recently conducted using criteria developed for this research to compare the level of detail used in sampling the waste stream and any corresponding demographic data that were taken. Most studies have focused on field sampling of the waste stream at disposal facilities and transfer stations. The Seattle and Washington State studies conducted additional "pure load" sampling of targeted sub-sector waste streams. Both these studies also surveyed businesses using questionnaires to gain demographic data. The similarity is probably a result of the same consulting firm being used for each project.

The "pure load" sampling seems to have been done for background purposes rather than as a basis for finding commercial sector waste quantities. The Seattle (1989) study explained "an additional 24 'commercial pure' samples were sorted . . . to collect data for specific types of commercial generators . . . . These data were

Table 2. Rationales underlying protocols for various waste stream assessments examining commercial sector waste generation.

Criteria	Seattle Wshington 1989	Boston Msschstts 1989	Wshtnw C. Michigan 1989	Wschster New York 1988	Wshingtn /Ramsey Minnesota 1988	Wshington State 1988	Sunnyvle Calfrnia 1986	Toronto Ontario 1985	U.S.EPA 1979
1 samples at source/point of disposal/survey	disposal	survey	disposal	source	disposal	disposal	source	source	source
2 samples total waste stream (msw) or sub-sector	both	no sample	msw	sub	msw	both	both	sector	sub
3 prevents contamination of materials	no	n/a	no	no	no	no	no	no	no
4 accurately measures weight of materials as generated	no	no	no	no	no	no	no	no	no
5 accurately measures volume of materials as generated	no	no	no	no	no	no	no	no	no
6 sampling of demographic and social indicators	yes	yes	no	yes	limited	yes	yes	no	yes
7 recognizes role of waste generators and the need to understand their perspective and involvement	no	yes	no	yes	no	limited	yes	no	yes
8 be duplicable and the results replicable	yes	yes	yes	yes	yes	yes	yes	yes	yes

not used to calculate composition estimates." The Washington state study did have as a "task" analysis of the data to "produce waste stream composition and waste generation rates for each 'pure-load' category" (WSDE 1988). Neither effort seemed to use these sampling data to estimate municipal-wide quantities for the commercial sector.

In contrast, Westchester County's (1988) field survey "was carried out to test and qualify the results from . . . studies and surveys that had been completed or were currently underway . . . ."

The Changing Focus of Waste Stream Assessments

The recent acceptance of recycling as a major solid waste management technique changes the purpose of waste management. When the primary methods for disposing of waste were burial or incineration, it was understandable that studies used for planning solid waste programming were also less detailed (McCamic 1985).

Recycling provides a fundamentally different approach to waste management. As was pointed out in Chapter II, a paradigm shift is underway. The new model is collection-oriented, rather than disposal-based. More specific and different types of information are needed to define and then handle the "recycling fraction" of the waste stream. Material composition, rate of generation, collection and processing methods, and markets must all be considered (McCamic 1985, Kuniholm 1989). McCamic (1985) stressed "the importance of the point of view in study planning" in his call for a "meaningful classification system . . . . [that has] categories that reflect the way that materials are collected and marketed." Planning for recycling based waste management must consider the nature of this type of programming (McCamic 1985).

The intent of the project influences the choice of sampling procedures and approach. Research is done according to the purpose of a proposed project, and the hoped for outcome will determine the shape of the study (McCamic 1985). McCamic made a contribution by linking the classification system--which is a conscious choice--to "a philosophy of waste management." He stated:

> [t]he expanded classification system implies that the individual categories are subject to individual handling, and therefore supports a philosophy of source separation of the individual commodities for marketing.

McCamic suggested a more specific targeting by classifying discarded items and materials that can be re-used and repaired.

Part of the evolution of waste characterization studies is to move the sampling from the point of disposal to the point of generation. This fully recognizes, in McCamic's (MDEM 1985) term "the nature of the waste stream." Kuniholm (1989) uses a flow chart that initially identifies "waste material sources" and follows waste on two tracks, the recyclable fraction and the disposal fraction.

Sampling at the Source of Generation

McCamic (1985) suggested sampling at the source if the primary interest is recycling. To maximize recycling, emphasis will be on the point of origin, where materials are passed from generator to collector. The Massachusetts Department of Environmental Management [MDEM] (1985) found this to be an advantage because "real, rather than speculative, rates of recyclable separation and collection may be established." From here, program design will include "not only the total amount of material to be collected, but also the relative size of bins for different materials in a multimaterial collection vehicle" (McCamic 1985). Evans (1985) and Savage et al. (1985) each make the point that the geographic area of waste generation needs to be identified, and McCamic (1985) suggested the use of "well defined and very comprehensive . . . census data." Finally, several studies (U.S. EPA 1979, Sunnyvale 1986, Westchester County 1988) are in agreement with the St. Paul (1982) report, which has an explicit purpose of "education of business managers and owners regarding the issue of decreasing . . . landfill space."

More and more consultants are sampling commercial sector waste streams in this manner to provide a greater level of detail to local communities regarding the recycling potential (Sunnyvale 1986, Westchester County 1988, Cerrato 1989). Studies done on a neighborhood level (McCamic 1985) or by "land use" and type of activity (Evans 1985) have the advantage of identifying waste generation and composition by sectors of the community. Evans (1985) suggested "investigating various land uses and their contribution to the overall garbage composition." Kuniholm (1989) outlined a materials flow diagram, and targeted the waste material sources as the location for most accurately estimating the potential percent of recycling capture. McCamic (1985) discussed the "nature of the waste stream" and suggested "the waste stream may be broadly divided into waste sources, i.e. residential, commercial, office, and industrial." The point of generation is the necessary starting point for managing already-produced waste (U.S. EPA 1979).

At the end of the 1970s the U.S. EPA commissioned a "Small-Scale and Low-Technology Resource Recovery Study" to examine the applicability of recovering materials from small volume waste generators (U.S. EPA 1979). Waste composition and generation data was estimated by sampling at the source of generation. It disaggreggated the commercial sector and looked at specific "sources," or firms.

The importance of the EPA report was its recognition of examining "low technology" approaches to resource recovery systems to "specific waste streams of this nature." Consultants working for cities and counties from New York to California are now directing their clients toward these sub-municipal level waste streams. By incorporating this perspective into their protocols, they not only sample waste more accurately, but the associated level of information (demographics, attitudes) is also higher. Asking more specific questions brings more useful answers. Plans can be more efficiently and effectively drawn to maximize capture rates (St. Paul 1982, Sunnyvale 1986, Westchester County 1988, GBCC et al. 1989).

This approach to sampling is critical; as complex and variable as the municipal solid waste stream is, it requires a carefully considered procedure to assess it in a way that produces meaningful results. McCamic (1985) recommended "Protocols for Recyclers" to provide a framework that will function to gather more complete information for recycling-oriented programs.

This increase in detail leads to more sophisticated planning and program design that can maximize recycling. By considering what firms produce (in waste) based on what they do and how they are set up, recycling programs are made an integral part of their on-going operations, rather than an after-thought. The U.S. EPA (1979) had a limited point of view in assuming that responsibility for proper waste management rested with individual generators and would be principally an economic issue for them. They did not focus on social concerns, environmental aspects, or the potential of "aggregation" and cooperative efforts. Combining all the firms within a sector together increases the quantities of materials produced, making recycling more attractive economically. A waste disposal **system** includes all sub-sectors and all the members within them. Non-residential waste generators must not be looked at as independent, unrelated, and individual firms, but as parts of a whole. They can be disaggregated momentarily for data collection purposes, but for program design each firm is an important part of a larger system (Sunnyvale 1986, Westchester County 1988). Recycling programs will seek to maximize collection within an entire community, not merely individual firms (Evans 1985, Westchester County 1986, Cerrato 1989, Kuniholm 1989).

Local sampling allows parameters influencing waste generation to be defined in greater detail. While number of employees, size, and sales volumes are commonly included, some unique factors, either by sub-sector (beds in hospitals) or by an individual study (Recovery Sciences measured dumpster volumes for businesses in Sunnyvale) can also be considered (U.S. EPA 1979, Sunnyvale 1986).

Involving Waste Generators in Waste Stream Studies

In several reports to local governments, consulting firms have emphasized the need for "acceptance by local firms of the concept . . . of in-house recycling programs" (Sunnyvale 1986). They suggest that recycling be promoted by the local government to the business community (Cerrato 1989). The U.S. EPA (1979) would involve business managers in a waste characterization study to serve two purposes:

1. Educate decision makers and encourage their interest in solid waste management in . . . waste reduction . . .
2. Improve the assumptions used in determination of applicability and thereby enhance decision-makers confidence in pursuing resource recovery

Two Minnesota studies employing survey techniques had objectives of determining businesses interest in recycling and of educating owners and managers on solid waste issues (St. Paul 1982, MPIRG 1988). Gaining the generators' cooperation and participation in a study will maximize the accuracy of the data, make it more precise, and lead to a more sophisticated analysis. Bringing waste generators into the planning stages offers the advantage of enhancing program participation, which in turn assists in maximizing material recovery and minimizing contamination and later processing.

Next Steps: Building on Previous Research Efforts

This research offers a new paradigm for solid waste planning in response to the shift to recycling based program management and the problems presented by standard procedures as reviewed in this chapter. Sampling at the point of generation, as indicated by several studies, seems to consistently measure much higher quantities of recyclable materials in firms' waste than is measured with point of disposal sampling. Accurate information is needed if collection of all materials available for recycling is to occur.

This research examines as its central hypothesis the issue of the amount of recyclable materials in the waste stream as determined by measurement at the source of generation. Embedded in its design is the development of a methodology with a new procedure for field sampling. The methodology depends on stakeholder involvement to both provide a higher level of detail for planning and to enhance program participation once implementation is underway. Chapter IV details the study's hypothesis and the methodology employed to test it.

CHAPTER IV

HYPOTHESIS AND RESEARCH DESIGN

Methodology

Introduction

This chapter examines the principles and the sampling methods developed for this methodology. The procedure employed for analyzing commercial sector solid waste generation also serves as a framework for organizing recycling practices within the business community. When properly constructed, these practices can provide a means for planning recycling-driven collection programs that maximize removal of materials, for two reasons: (1) Accurate measurements properly size the amounts of materials available for recycling, and (2) Involvement of stakeholders in the planning stages enhances participation once the program is implemented (U.S. EPA 1979, McCamic 1985).

Why a New Approach for Studying Waste Composition is Needed

The limitations outlined in Chapter II (page 13) point out the need for a new approach to waste composition studies. The methodology for this study is based on the principle that waste management strategies must focus on generation and collection issues. This research addresses Ackoff's (1962) objective for the "improvement of the procedure and criteria employed in the conduct of scientific research." The limitations inherent in disposal-based sampling are resolved by moving the sampling point to the firms' back door, before collection takes place. Table 3 compares criteria met by disposal-based and at-source sampling schemes.

Table 3. Comparing disposal and at-source sampling schemes.

issue	disposal based	source based
1. Identify source of waste	No	Yes
2. Prevent material contamination	No	Yes
3. Accurately measure weight or volume of materials as generated	No	Yes
4. Correlate demographics and social data with the waste generators	No	Yes
5. Design program to target individual or sub-sector generators	No	Yes
6. Involve waste generators	No	Yes
7. Centralized and large scale orientation	No	Yes

The principles that justify the proposed methodology (after Ackoff 1962) are:

1. Waste stream study design will maximize the identification of readily available recyclable materials
2. Program design (implementation) is determined by a study's sampling approach
3. Measuring generators' waste at source allows correlation of demographics
4. Involving waste generators in the study phase encourages greater involvement and commitment for the actual program once it is in place

Hypothesis

The approach taken in planning the development of a study influences its outcome. McCamic (1985) stated that:

> [a] classification system implies a philosophy of waste management. . . . The expanded classification systems implies that the individual categories are subject to individual handling, and therefore supports a philosophy of source separation of the individual commodities for marketing.

A micro-level emphasis that examines the waste stream by sub-sector and individual firms supports a structure that can provide greater accuracy and higher levels of detail in the data. Businesses can be grouped by Standard Industrial Classification (SIC) codes or by location as means of lumping generators of similar materials. This leads to designing recycling collection programs that are reflective of the actual quantities of materials in the waste stream (Westchester County 1988).

In light of the limitations inherent in standard waste stream composition analyses, a different system for studying waste is needed. This study examines the hypothesis:

> H_1: **Significantly higher quantities of recyclable materials will be measured when sampling waste at the point of source generation and by sub-sector than found from sampling waste aggregated at the municipal level at the point of disposal.**

This tests the statistical hypothesis:

> H_o: **There is no difference in measurements between sampling waste at the point of source generation and sampling waste aggregated at the municipal level at the point of disposal.**

The hypotheses can be represented by the equations:

$$H_0: \mu_1 \leq \mu_2 \quad \text{and} \quad H_1: \mu_1 > \mu_2,$$

where μ_1 represents recyclable materials in the waste stream for at-source sampled populations and μ_2 represents recyclable materials in the waste stream for disposal-based sampled populations.

The significant difference will be shown quantitatively by comparing the study's sampling results with results from recent research presented in the literature.

Examining Waste at the Point of Generation

Figure 8 compares the two sampling options available for measuring commercial sector waste. Sampling at the diamond, before waste collection will provide complete accounting of the waste stream by counting materials before they

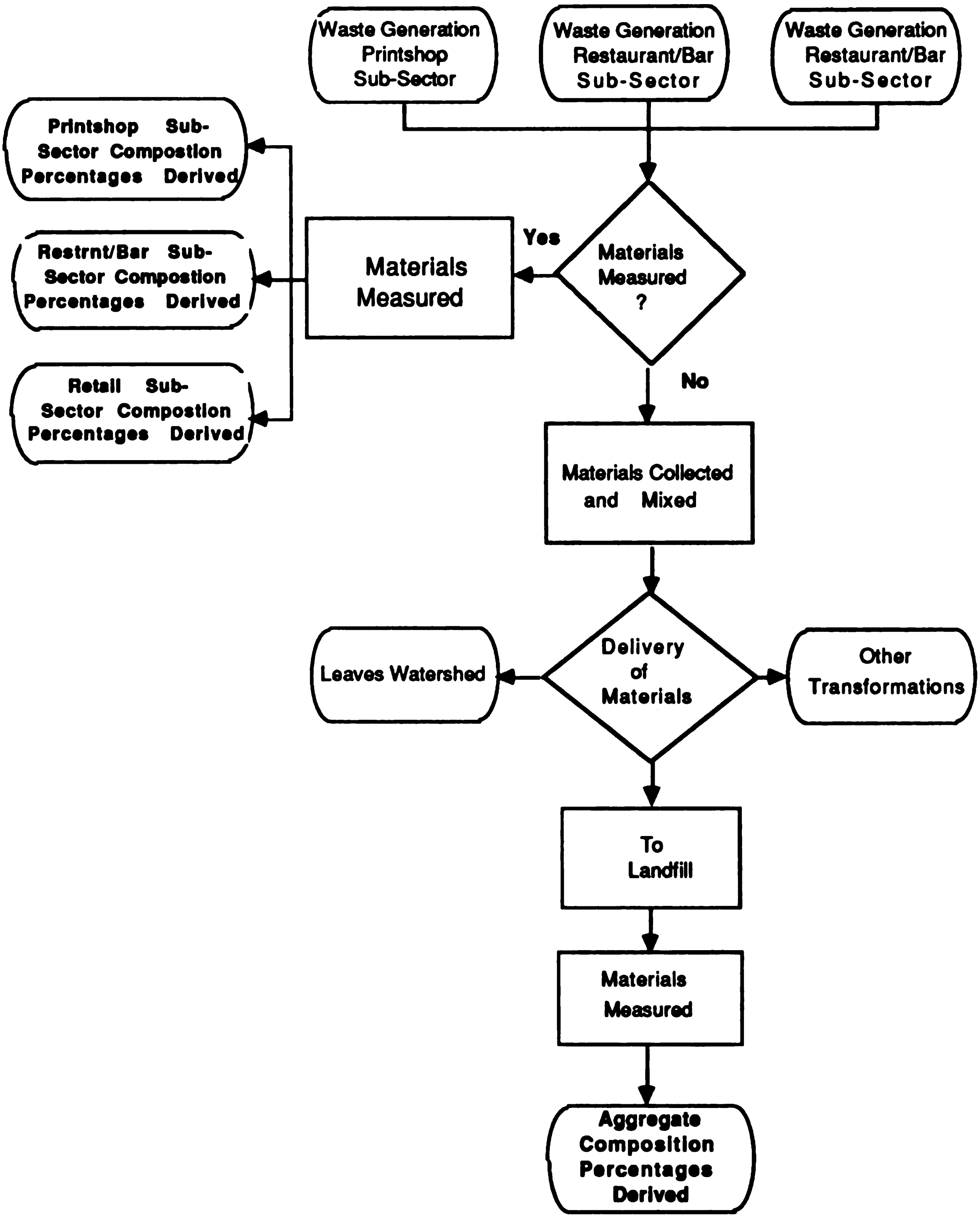


Figure 8. Alternative locations for measuring waste generation.

leave the wasteshed or are salvaged. This prevents mixing and contamination of materials.

By this approach, the commercial sector is dis-aggregated, down to specific firms defined by the federal SIC coding system. Waste is sampled on site (before the first diamond, in Figure 8). It is measured as it is generated and as it would be available for recycling. More accurate quantitative and qualitative assessments of the waste stream can be made.

Program Design as a Part of the Methodology

The specificity required by the sampling procedure is an important asset influencing program design and implementation. McCamic (1985) found:

> Recyclers will . . . want information for planning collection system specifics, including not only the total amount of material to be collected, but also the relative sizes of bins for different materials . . . .

In two ways, technically and socially, the approach taken by this research prepares waste generators and management staff for developing follow up recycling programs once the study is complete.

From a technical perspective, the analysis will show sources of material, rates, and volumes. Demographic information will indicate locations of firms, types of businesses, and possible constraints (storage, staffing). Socially, firms will be aware of waste as an issue and will be prepared to participate, having already assisted with data collection.

Since materials will have already been picked up in the area, there will be familiarity with the physical layout of the recycling program. Planning staff will have to size equipment and determine schedules, but this will now be based on the knowledge of who the generators are, the quantity and type of materials generated, and where these are located.

Lee et al. (MPIRG 1988) called this "action research," writing:

> This type of research and development has been more extensively used in the Scandinavian countries than in the United States. The basic idea is do actually "do something" . . . while generating data--and then use this data to do more in a more efficient way. Data generation and analysis is a dynamic process as the project proceeds.

In its report to Westchester County, New York (1988), Malcolm Pirnie, the environmental consulting firm, suggested "an evaluation of existing commercial program infrastructure" as the first step in developing commercial recycling programs. They began that process by surveying firms in the commercial sector.

A principle of this research methodology is to establish a framework for recycling practices within the business community as part of its procedure. Consulting firms are already using this approach. Recovery Sciences, Inc. introduced its report to the city of Sunnyvale, California (1986) with the statement:

> The purpose of this project was to determine the feasibility of expanding recycling programs to the commercial/industrial sector of the City of Sunnyvale. The first step in assessing the feasibility of such a program was to ascertain if there was a sufficient amount of recoverable materials being discarded by businesses . . . .

A St. Paul, Minnesota study was similarly designed, having as one of its purposes (St. Paul 1982) "education of business managers and owners regarding the issue of decreasing Metropolitan Area landfill space."

Methods

Introduction

It must be axiomatic that the simpler the method which is designed to solve a problem, the easier it is to compile the results and the less costly it would be to undertake and implement a program. The key components of this research project are the quantification of recyclable commercial waste by weight and volume and the determination of its composition. This was done in specified sub-sectors according to Standard Industrial Classification (SIC) codes.

This study's premise is that measurement and identification of recyclable commercial waste at the source can overcome the limitations of disposal-based sampling (see Chapter II, page 13) and enhance the recycling planning process.

I. Enlisting Institutional Support

Discussions were held with the East Lansing's City Manager and Mayor to introduce the project and request official sponsorship in April, 1987. This was granted. A letter of introduction, access to City staff, and use of City business lists, as explained below, were the primary items of support provided by the City. Before field sampling started, a meeting was held with the Police Department to inform them of the activities that would be taking place in downtown City alleys and parking lots.

II. Choosing Firms

A 1984 East Lansing City business directory listing 526 firms was used to set the sampling universe. The business community was evaluated based on the criteria presented in Table 4. The first criteria created two artificial sub-sectors: 1. firms that provide "products," such as retail goods, meals, and printing orders, and 2. firms that provide services, such as banks, hair salons, medical providers, and realtors. (East Lansing is without a manufacturing sector, and Michigan State University is considered a separate and independent jurisdiction.) This splits the traditionally defined service firms in order to separate those which offer material goods from

Table 4. Criteria for determining firms to include in waste study.

criteria	rationale
1. Fits SIC code classifications: a. Division G.--retail trade b. Ind. no. 2752--commercial printing c. Ind. no. 7334--services: photocopying	"Product" oriented firms with waste readily separated by a few employees
2. Fits SIC code classifications: a. Division H.--financial services b. Division I.--other services c. Division J.--government and schools	"Transaction" firms eliminated; firms generate discrete amounts of waste generated by many employees
3. Size of present waste bin	Upper limit set to eliminate largest firms
4. Number of pickups per week	Upper limit set to eliminate largest firms
5. On-site waste generated primarily by employees as part of business	Eliminates fast food firms
6. Customers create little waste on-site	Eliminates fast food firms
7. Recyclable waste materials commonly handled by employees	Eliminates "exotic firms and materials

those that are strict service providers.

The first group became the sample universe, while the second group was eliminated from consideration. The "product" sub-sector generates large quantities of readily identifiable types of waste that can be quickly separated out by a few employees. The "transaction" sub-sector also produces large quantities of waste, but this is produced in discrete amounts by many independent employees. Sampling these types of firms is a more difficult task.

A 1986 East Lansing list of commercial waste collection customers was used as a guideline to set parameters for size, based on size of container and frequency of pick ups per week (Table 4). (The City offers waste collection to the business district.) The sub-sectors selected for sampling included printshops, retail firms, restaurant and bars.

III. Sample Size

A stratified sampling scheme was used, with the nine represented SIC Code categories combined into three groupings: Printshops, retail stores, and restaurants and bars (Table 5). Within each grouping, the sample was chosen using a random process selection, with numbers picked from a book of tables of random numbers. Thirty-four firms were chosen to be contacted.

IV. Soliciting Firm Participation

Figure 9 outlines in flow chart form the steps taken to establish relationships with firms for the conduct of the study.

Once selected, firms were approached and requested to participate. A letter, co-signed by East Lansing's mayor, city manager, and the principal investigator was sent on City stationary to the 34 chosen firms in early September, 1987 (appendix A).

Twenty-two firms were contacted through follow up phone calls for interviews; 18 (82 percent) agreed to meet to discuss the project. Every firm that was interviewed participated in the study. Table 5 shows firm participation by sub-sector. R&Bar-1 was chosen (not randomly selected) as a pre-test to test sampling procedures in the restaurant sub-sector.

The meetings were held to show the firm managers and owners how carefully the study would be structured. Overall, the managers were supportive of investigating waste alternatives and expressed interest in recycling. Among the 10 retail stores, five volunteered to include paper separation as part of the study.

At the meeting summary outlines for the entire project and each sub-sector were provided (appendix A) and the need for assistance and the role that the firm and its employees would play was explained. To assure uniformity at these

Table 5. Demographics of East Lansing businesses participating in waste stream study, fall 1987.

SIC code	firm type & name	days open hours open	frequency of pick-up	time of pick-up	smpling period*	location of pick-up	recyclables separated**
	PRINTSHOPS: SIC Code industry numbers 2752 and 7334						
2752	Printshop-1	M-Su; 24 hrs	daily	morning	4	alley	mp, occ
2752	Printshop-2	M-Sa; 8-8	daily	morning	4	alley	wp, cp, mp, occ
7334	Printshop-3	M-F; 8:30-5:3	daily	morning	4	prkng lot	wp, cp, mp, occ
	RETAIL: Divison G, 5400 - 5999, except for food establishments						
5942	Book-1	M-Su; 8-10	daily	night	4	alley	mgz, onp, occ
5942	Book-2	M-Su; 10-10	daily	night	4	alley	mgz, onp, occ, mp
5942	Book-3	M-Su; 10-8	daily	morning	4	alley	occ
5942	Book-4	M-Sa; 10-5	twice pr wk	morning	4	street	occ, mp
5946	Camera-1	M-Sa; 10-6	once pr wk	morning	4	street	occ, mp, pls
5621	Clothing-1	M-Sa; 10-6	once pr wk	morning	4	alley	occ, mp
5411	Convnce-1	M-Su; 24 hrs	daily	night	2	prkng lot	occ
5411	Convnce-2	M-Su; 24 hrs	twice pr wk	night	2	prkng lot	occ
5993	Florist-1	M-Sa; 10-8	daily	night	2	alley	occ
5732	Stereo-1	M-Sa; vrible	once pr wk	morning	4	2nd alley	occ, mp
	RESTAURANTS/BARS: SIC Code industry number 5813						
5813	R&Bar-1	M-Su; vrible	twice pr wk	night	4	street	al, gls, tin, pls, occ
5813	R&Bar-2	M-Su; vrible	irregularly	evening	1	prkng lot	al, tin, pls, occ
5813	R&Bar-3	M-Su; vrible	twice pr wk	evening	2	prkng lot	gls, tin, pls, occ
5813	R&Bar-4	M-Su; vrible	dly-no wkend	evening	2	prkng lot	gls, occ
5813	R&Bar-5	M-Su; vrible	irregularly	evening	1	street	gls, occ
5813	R&Bar-6	M-Su; vrible	daily	evening	2	prking lot	gls, occ

* in weeks

**occ = corrugated cardboard, cp = colored paper, mp = mixed paper, wp = white paper
al = aluminum, gls = glass, tin = "tin" cans, pls = plastic

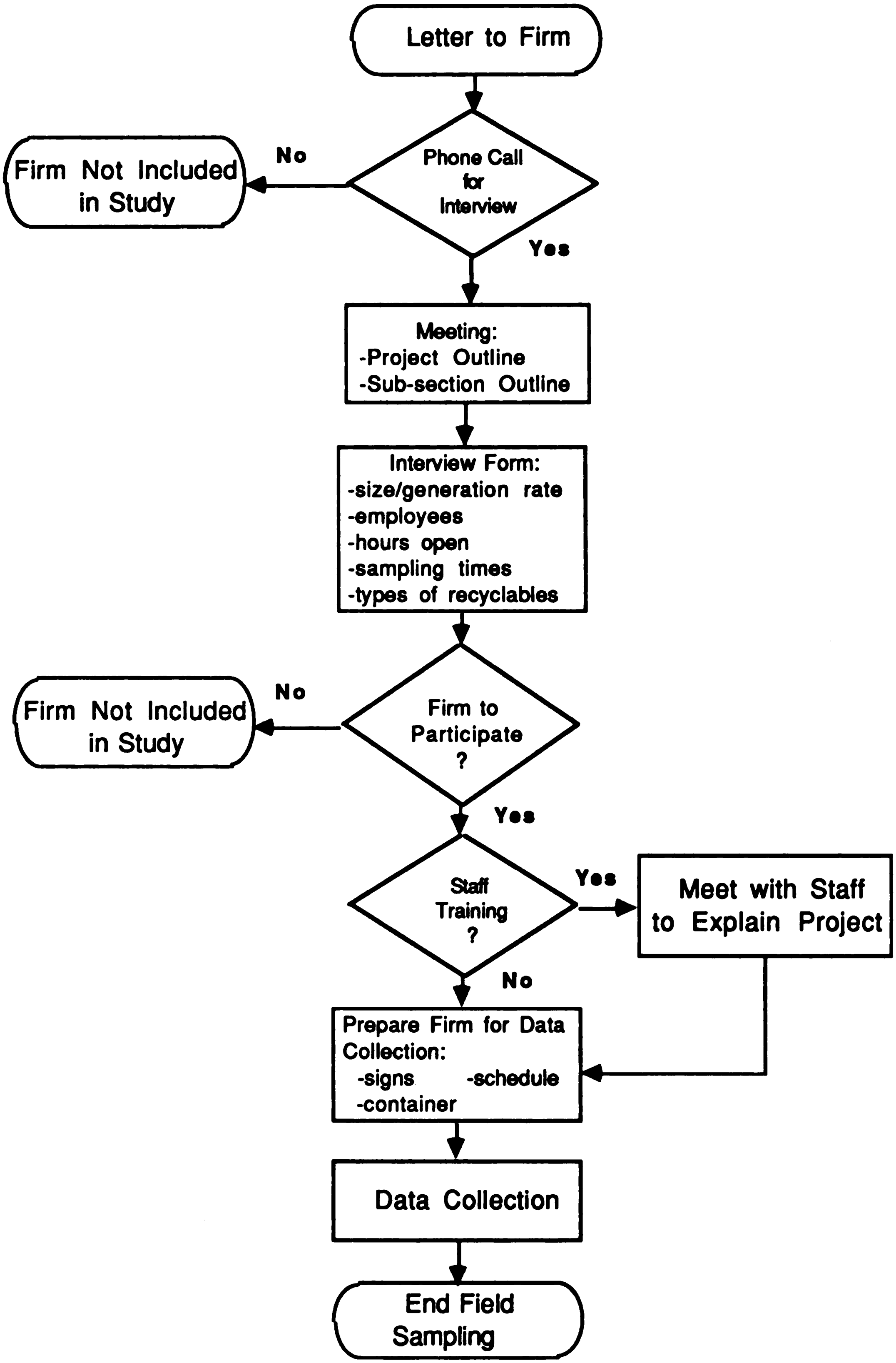


Figure 9. Steps taken to initiate involvement with firms and firm participation.

meetings, an interview form (appendix A) was filled out for each firm. Full cooperation with staff and management was pledged and the promise made that sampling would stop at the request of management (only one firm asked). Short trainings were offered to discuss the project with staff employees; fewer than half the managers requested these additional meetings.

The interview was used to obtain estimates of the size, composition, rate of generation of waste, and materials to be sampled. Storage areas and number of containers (44 gallon cardboard barrels and 30 gallon plastic bags) needed for materials were agreed upon. Some firms declined the use of barrels. Firms were given the option of an early morning (8:00 to 10:00) or late evening (9:15 to 10:30) sampling time. This was set to match opening or closing times of most establishments; this ensured that a full day's waste was measured for the firms sampled daily. The number of sampling stops needed per week was estimated for each firm and ranged from daily (some on a seven day week) to weekly (Table 5).

V. Sampling Period

Sampling started four weeks after the initial interviews. The printshops and retail stores were sampled in the four week period of October 23 to November 21. R&B-1 participated as a pre-test for the restaurants and bars concurrently. The other five restaurants and bars were sampled during the two week period of December 6 to December 21. This sampling period was shortened because of the holiday season.

Not all firms met this sampling schedule exactly. Table 5 indicates the length of participation of every firm. Although the sampling period was considerably longer than any other study reported in the literature the research was limited to one sampling period. Ideally sampling would be repeated across fall, winter, spring, and summer to assess seasonal fluctuations in waste generation.

VI. Tools and Techniques

Introduction. Variables included material composition, rate of generation, volume, and weight. This was a modified waste stream assessment in that it measured "readily recyclable materials" and "rubbish."

Collecting Materials. Material categories were based on sub-sector. Only recyclable materials frequently generated in the course of doing business were separated out (see data collection form, appendix A). Though small quantities of glass, metal, paper, plastic, and other recyclable materials are generated throughout the commercial sector, these are relatively insignificant in comparison to the corrugated cardboard, papers, and glass, metal, and plastic food containers used by the printshops, retails, and restaurants and bars, respectively. The study examined materials that would be collected in ongoing recycling programs.

Restaurants and bars did not have their entire waste stream measured. Because rubbish was not sampled, a complete assessment was not possible. The study was unable to include measurements of food wastes due to logistical and time constraints. It was, however, recognized that this is a major segment of this sub-sector's waste stream (55 percent for two restaurants, Westchester County 1988).

Corrugated cardboard was sampled at all firms. The printshops separated out white paper, colored paper, and mixed paper. The retail stores segregated materials into cardboard and rubbish, though five volunteered to separate out office paper, and the camera store separated out plastic bottles, as well. All restaurants and bars separated out corrugated, five separated glass, and three also segregated their metal and plastic food containers (Table 5). General rubbish was bagged and left by employees to be picked up for sampling.

Scheduling. Eight firms were sampled in the morning and six at night during the October-November sampling period. Printshops were sampled between 8:00 and 9:00 a.m. Retail firms were given a choice to have early morning pick-up (8:00 to 10:00) or late evening pick-up (9:00 to 10:30) to match the opening or closing time of the businesses or a more convenient time. The florist's shop closed at 8:00 p.m., prior to the start of the evening sampling period. Materials were set at the back door for the evening pick-up. Data collection was done on these two shifts daily, on a six day week. On Sunday, sampling was done at 5:30 p.m and again at 10:00. In December, the collection for the restaurants and bars were in the afternoons, from 4:00 to 5:30.

The printshops, three of the four bookstores, and the florist required daily pick-up. Two of the restaurants and bars also had daily pick-up. All other firms were able to store materials and were sampled two or three times weekly. The convenience stores and two restaurants/bars held materials outside. Sampling collection generally mirrored waste disposal collection scheduling. Table 5 lists the schedule and other sampling variables.

It took the two person research team less than two hours to collect in the morning and about 90 minutes in the evening. The number of firms being sampled on a particular shift determined the length of the sampling period. An attempt was made to measure the length of time it took to sample per firm. This was not systematic enough to be able to report results. With drive and set-up and finishing times, it took approximately 15 to 20 minutes per firm to take measurements. The entire sampling routine, from arrival to departure, could be done in as little as five minutes, although more time would be needed for larger waste loads. As anticipated, there was a direct relationship between quantity of waste generated and length of time needed to take a sample.

Downtown East Lansing has a service alley running parallel to its main street. Almost all the daily pick-ups were on the alley and as were over half of the collections made in the October sampling period (Table 5). A 1987 pick-up truck was used for sampling. At each stop the support stand would be taken out and the scale set-up adjacent to the firm's back door.

The sampling routine varied by firm. All the printshops fell into a routine of having the researchers "empty the trash." Plastic garbage cans were normally located by the printing equipment; the research team would enter the work area, remove the containers, take them out for sampling, and return the containers empty. Corrugated materials would be placed separately; this, too, would be removed.

The retail stores stored materials by category (corrugated, magazines, newspaper, office paper, plastic bottles--from the camera store). It was convenient for everyone to have the researchers enter the firm and carry the material out to the work station set up in the alley or parking lot. The two convenience stores generated so much waste that corrugated was stored next to the outside bins and the waste (mostly bagged) placed in the dumpsters. These bins would be emptied and the materials measured, then the waste returned to the bins. Corrugated that had been "thrown away" was measured as recyclable material.

Measurement Variables. Weights were taken in pound intervals and volumes measured in cubic feet. The English measurement system was used since results would be conveyed to the public (participating firms' staffs, city staff, trade journals) as well as to the scientific community. Additionally, recyclables are sold by the pound, and waste disposal prices in the Lansing area are based on cubic feet. Figure 10 illustrates the tools used for measuring the samples.

Volumes were measured using 44 gallon cardboard barrels calibrated into quarters. Two printshops had 24 and 32 gallon plastic cans; for these volume was estimated in eighths of container size. Cardboard was always flattened before measuring. A 12 foot metallic tape measurer was used to measure height, length and width dimensions. These were later converted into cubic feet. This approach guaranteed extremely conservative volume estimates, since most boxes are not flattened when thrown away. This method was chosen for two reasons: to accommodate firms that were without adequate storage space to save the material, and to assure uniformity for comparisons across the sample.

Weight was measured using a hanging spring scale and a 76 inch high metal stand. Materials were placed in the barrels, the barrels were fitted with a snap-on ring which had a small plastic ring attached to it, and then the barrel placed on the scale's hook. Printshop garbage cans full of paper were weighed directly. Corrugated that was too bulky to fit in the barrel was placed in a rope sling, secured, and then weighed.

Most firms bagged their rubbish at the close of their business day. This was left for sampling and then taken to the dumpster by the study team.

VII. The Detailed Data Sort

Measurement of all waste generated was made once during the sampling period for the printshops and retail firms. This provided a check on the cooperation level of the firms by measuring how much recyclable materials were being discarded in the rubbish. It also allowed an examination of the entire waste stream. During the week of November 12th, each printshop and retail firm's rubbish was set aside

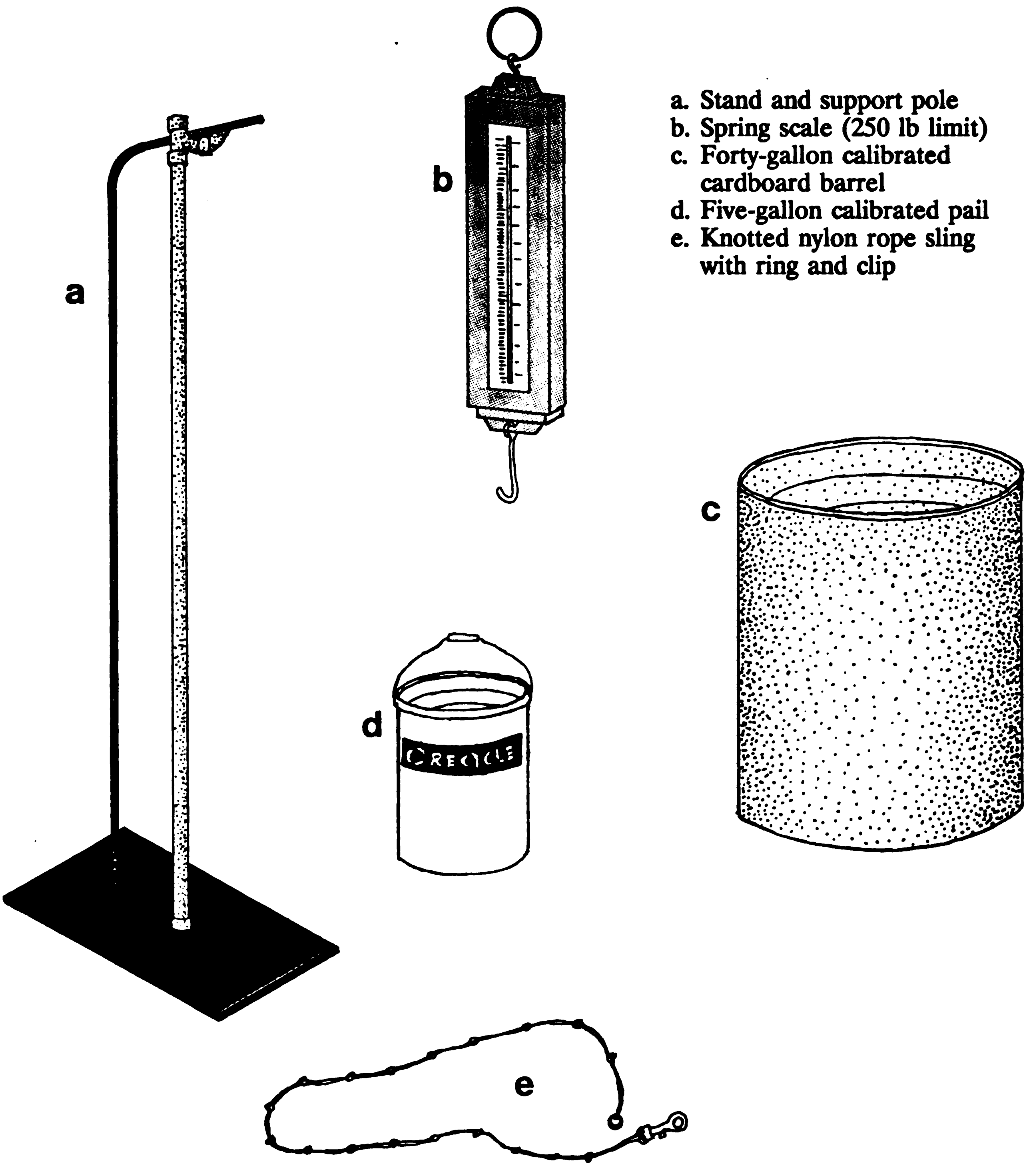


Figure 10. Tools and equipment used to conduct field sampling.

once for a detailed sort. Specific dates for taking the rubbish were picked at random; the larger waste generators had three trash bags picked at random from their entire waste load. The bags were marked and stored. They were later sorted through using a classification system modified from the MDNR's (1986) waste stream assessment manual (appendix A). Five gallon plastic buckets, calibrated in thirds, and the cardboard barrels were used as sorting receptacles. Volumes and weights were measured as described above.

VIII. Other Communications with Participating Firms

The last week of the survey firm managers were notified by memorandum and reminded through in-person visits that the sampling period was ending. An initial summary of results, for each firm, and overall, was given to the managers in November, 1988 (appendix A).

Testing the Hypothesis

Linking the East Lansing and the Westchester County Studies

The analysis of the East Lansing data was contrasted with commercial sector estimates derived from landfill based-sampling to test the study's hypothesis, $\mu_1 \geq \mu_2$, that more recyclable materials will be identified by sub-sector sampling of the waste stream. This was done by linking this analysis with a complementary study done in Westchester County, New York (1988).

To test the hypothesis, it is necessary to establish a relationship between the empirical results from East Lansing and the field sampling done in Westchester County. If East Lansing composition rates are similar (or higher) than those measured for the New York study, it can be assumed that East Lansing's aggregated commercial waste stream would also measure similarly high (or higher) levels in its overall composition.

Primary sampling was done to provide a basis for estimating commercial sector waste generation countywide (Westchester County 1988):

> The field survey was carried out to test and qualify the results from the [secondary] studies and surveys that had been completed . . . . selected business streams were weighed and separated by component to estimate waste generation quantities and composition.

Figure 11 represents the East Lansing methods as a sub-set of the system employed to determine waste composition for Westchester County. The field sampling done in New York was used as the basis to determine waste composition for the entire commercial sector. Westchester County has targeted large commercial generators of recyclable materials as participants in its recycling program based upon the results of the study (Cerrato 1989). The Westchester County study matches the research intent of this thesis, using a micro-level examination of waste generators to extrapolate to the larger municipal solid waste stream.

If the estimates from the two studies are comparable, the East Lansing methodology and results will validate and reinforce the source sampling done in Westchester County, New York. The results would then contribute to a growing knowledge base of primary data based on at-source sampling.

The link with Westchester County's county-wide estimates is based on the comparison with the County's sub-sectors. In order to compare the East Lansing results with disposal-based analyses, it must be shown that East Lansing measurements are commensurate to the Westchester County results. If this relationship can be demonstrated, East Lansing's results can be compared to other

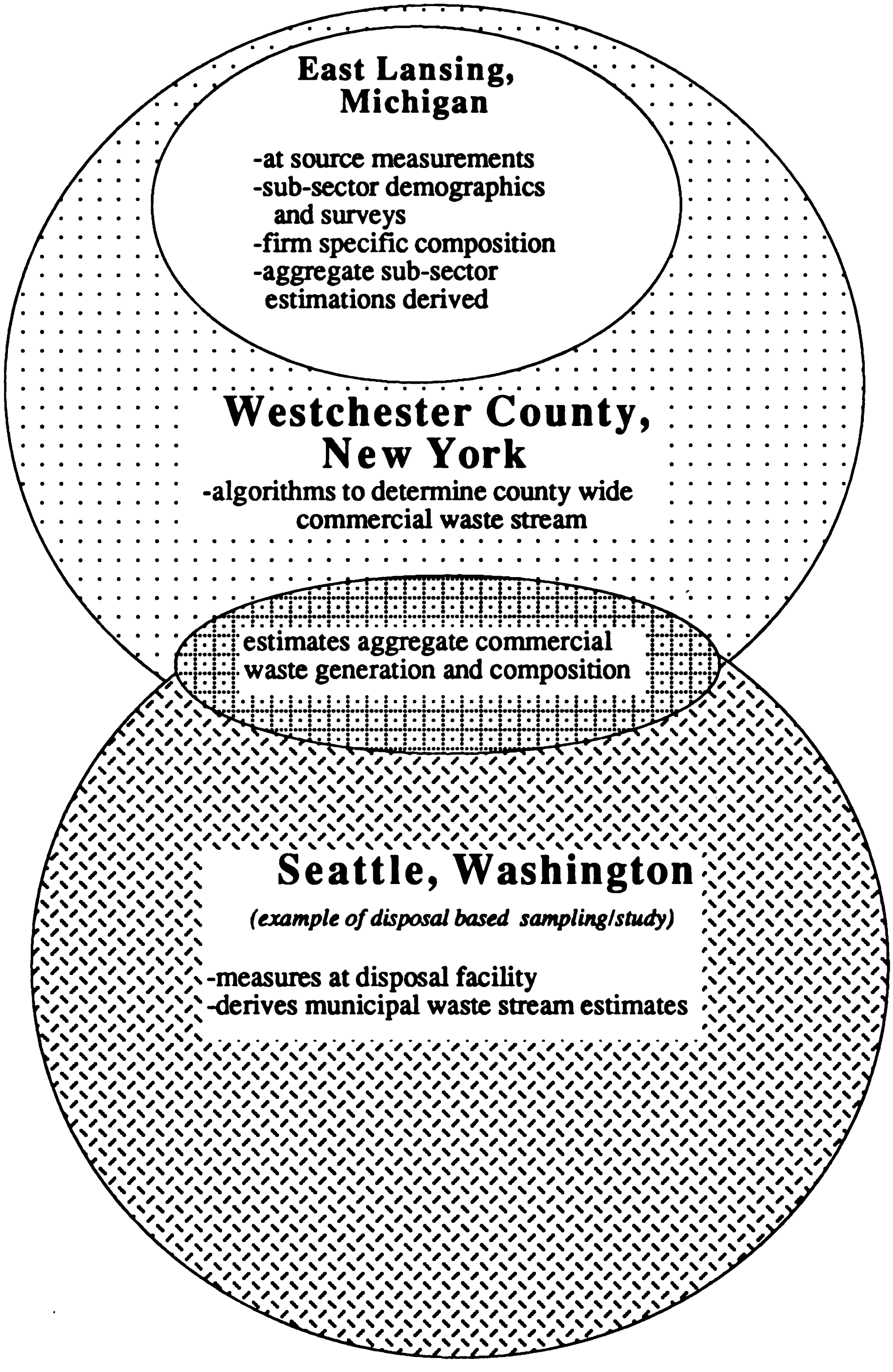


Figure 11. The Westchester County study links East Lansing to disposal based studies because both are based on at-source sampling.

disposal-based studies. This provides the link to use this research's empirical results to test the hypothesis.

Comparing the East Lansing and Westchester County Studies

The Westchester County Study

This section will summarize the methods employed to estimate the commercial sector waste stream in Westchester County. The methodology paralleled the East Lansing project in its focus on field sampling based on at-source waste generation of specific firms. In disaggregating the commercial sector nine waste generator segments were established. These were later reduced to six groupings, with selected retail, hotel and motel, and restaurant firms dropped to manage the data more effectively (Westchester County 1988). Seven SIC code divisions were included in the 26 firms that comprised the sample frame. Two of these groupings match the SIC classifications used in the East Lansing study (Table 6).

Table 6. East Lansing and Westchester County sampling parameters.

		East Lansing		Westchester County	
Business Type	SIC Code	# of firms	# of samples(1)	# of firms	# of samples(2)
Construction	150 to 170			4	1
Industrial	200 to 390			3	1
Printing	2752	3	9-27		
Office	600 to 690			3	1
Transp/Cmm/Util	400 to 490			2	1
Whlesle/Warehse	500 to 519			2	1
Retail	520 to 590	10	4-27	7	1
Restaurant/Bar	580	6	1-11	2	1
Public Insttn	910 to 970			3	1
Totals		19	27	26	1

1. Printshops and retail stores were sampled in a four week period. Bars (except R&Bar1) were sampled in a two week period.
2. Sample period was one day.

Estimates of waste production by each generator segment were based on the variable of waste generation rates per square foot of occupied floor space. Researchers followed the premise that commercial waste production is a function of the type of business activity and not the number of employees per business. Up to six separate methods were used to determine generation rates within each grouping. These included a commercial business telephone survey, a major business survey, an IBM independent survey (IBM accounts for approximately 13 percent of all occupied office floor space in Westchester County), a field survey, and the use of previous studies and national published averages.

The results of the independent surveys were analyzed and integrated into algorithms developed to determine waste generation rates for each waste generator segment. The commercial waste load was estimated for each segment. These were aggregated to determine the county's commercial waste totals. Commercial sector composition was determined from the same surveys and published reports and a breakdown of the commercial waste stream into its principal components was made.

The waste composition estimates obtained from these surveys were revised based upon the actual field data. The empirical data provided the basis for making the transformation to the final composition totals. This provided both the estimated compositional breakdown of the entire commercial waste sector and total tons of waste for the generators for each material category. These estimates were checked against other reports and found to compare favorably with 1986 estimates of commercial tonnage based on haulers records, on estimates of employee waste generation rates, and against estimates of the non-residential sector being between 60 percent and 100 percent of the residential waste stream (Westchester County 1988).

Comparing East Lansing and Westchester County Results

Field sampling done at the source of waste generation provides a primary basis for developing aggregated commercial sector waste composition estimates for Westchester County. This is a standard with which to evaluate the East Lansing results. The major difference between the two studies is that the Westchester County analysis extrapolates to the larger municipal solid waste stream, while the East Lansing research does not.

The empirical results from the East Lansing field study will be compared to comparable Westchester County sub-sector population estimates. Probability testing will be conducted to assess how the East Lansing data compare with the Westchester County data. If the East Lansing results are similar, or higher, that will indicate that the measurements are influenced by the approach taken for sampling (e.g. at point of generation vs point of disposal). Table 7 lists the percentage composition of recyclable materials reported in the Westchester County (1988) sub-streams.

The general equation to be tested is: $\mu_1 > \mu_2$, with μ_1 representing the population mean of materials composition for specific sub-sectors of East Lansing and μ_2 representing the same population mean for Westchester County's like sub-sector.

Table 7. Recyclable materials in East Lansing and Westchester County.

Business Type	East Lansing %age material	Westchester County %age material
Printing	*	
Office	*	65 (1)
Retail	*	40 (2)
Restaurant/Bar	*	

* = To be determined by probability testing
1. mixed paper
2. old corrugated cardboard

The general equation to be tested is: $\mu_1 > \mu_2$, with μ_1 representing the population mean of materials composition for specific sub-sectors of East Lansing and μ_2 representing the same population mean for Westchester County's like sub-sector.

This will be tested in the retail and printshop/office complex sub-sectors. In each case, the Westchester County study's population mean for the material examined will be substituted for μ_2 (Table 7). For the retail sector the equation to be tested is:

$$\mu_1 > 40$$

The Westchester County population mean for corrugated cardboard in the retail sector is estimated as 40 percent of the overall composition, which is higher than their field results mean of 34.3 percent. This was derived from sampling seven stores.

For the printshop/office sub-sector the equation to be tested is:

$$\mu_1 > 65$$

The Westchester County population mean for mixed paper in the office sector is 65 percent of overall composition. This estimate is lower than the sample mean of 75 percent, the result of measurements taken at three office buildings.

The alpha level for testing the probability is 0.10, $a = 0.10$.

If East Lansing's results test higher than Westchester County's, the assumption will then be made that an estimate of East Lansing's aggregated commercial waste stream would be similar in composition to Westchester County's.

Comparing Disposal-based Sampling to Sub-Sector Sampling Based on the Westchester County Study

The Westchester County aggregated commercial waste stream estimates will be used to compare material composition make-up with other landfill based composition studies. An index will be created to compare the percentage of materials in each study to the like figures in the Westchester County waste stream. One (1) would be a perfect match of composition percentages. Ratios above one indicate greater quantities of the materials in the Westchester County waste stream, while numbers less than one show higher composition for that material in the other waste stream. Ratios of 1.2 and higher can be considered significant, since they indicate that Westchester County has estimated that 20 percent more of that material exists in its waste stream than the study it is being compared to.

After the relationship between Westchester County and East Lansing is demonstrated, East Lansing's results can be compared to other disposal-based studies through the Westchester County results (Figure 11). This will enable the thesis's alternative hypothesis, that sub-sector sampling at the point of generation will measure greater quantities of recyclable materials compared to sampling mixed waste at the final point of disposal, to be tested.

Objectives of Research

This study's objectives are to:

1. Explicitly link recyclable materials to sub-sectors and specific firms within each sub-sector
2. Accurately measure materials for composition, weight and volume at the waste source, as they would be specified for recycling, with little or no contamination of materials
3. Require resources for sampling that will be comparable or less than resources needed for municipal level sampling (budget, equipment, staff, time)
4. Offer conveniences that are comparable or less difficult than that needed for municipal level sampling
5. Be duplicative and the results replicable

6. Compare sub-sector derived estimates for waste composition to disposal-based estimates of sub-sector composition

Summary

As part of the methodology to support the thesis's hypothesis that sampling at the source of generation will measure larger quantities of recyclable materials, a field sampling procedure was developed. This was tested in the East Lansing commercial sector in the fall of 1987. The results of this field testing and the analysis of the data are presented in Chapter V.

CHAPTER V

RESULTS AND ANALYSIS

Introduction

The methods for conducting field measurements were tested during two sampling periods in the fall of 1987 in East Lansing, Michigan. The sampling data are listed in tables in appendix B. In this chapter the empirical results will be compared to results from the Westchester County, New York study to assess the validity of the field tests. By linking the East Lansing results to the New York study's county wide estimates, a comparison of composition results obtained by sub-sector sampling can be made with results from ten disposal-based studies. This relationship is used to test this thesis's hypothesis.

A "one-tailed" *t*-test was used to statistically determine the probability of the sample falling within the critical region of the sampling distribution created for the East Lansing results. The one-tailed test is used to specify if the sampled population means (μ_1) are greater than the comparable Westchester County population means (μ_2) for the materials measured. If the probability, or significance, is greater than alpha, a, the statistic is outside of the critical region. The equations $\mu_2 > \mu_1$, signifying that Westchester County's recyclables are a greater percentage of the waste stream than East Lansing will be rejected. If the probability is less than alpha, the test statistic falls within the critical region and the alternative equation, $\mu_1 > \mu_2$, will be accepted. Such test results would provide a high degree of confidence in assuming that the East Lansing sub-sectors have higher percentages of the sampled recyclable materials than the comparable Westchester County waste stream.

Printshops

Over 74 percent of the waste stream of the printshop sub-sector sampled were paper products (Figure 12). Individually, the total percentage of paper in their waste loads ranged from 70 percent to 81 percent (Table 8). Every sample contained over 47 percent paper, and loads were at least 75 percent paper 40 times and over 90 percent 10 times (n = 64) (Table 14, appendix B). Figure 13 shows Printshop-1's daily composition totals as one example. Overall, as much as 88 percent of materials from these printshops is comprised of recyclable papers (white, color, mixed, and corrugated) (Table 8). These are comparable to figures reported by the U.S. EPA (87 percent, 1979), Evans (95 percent, 1985), and Westchester County (90 percent, 1988) for total paper generation by office buildings. On a weight basis, large amounts of materials can be generated daily. As much as 237 pounds of white paper was discarded by Printshop-2 one day (Table 14, appendix B). By volume, firms generated as much as 36 cubic feet (1.33 cubic yards) in a single day (Table 15, appendix B). These results clearly bear out the premise raised in Chapter II: Segments of commercial waste streams are homogeneous, clean, and comprised of high levels of recyclable materials.

White paper made up over 30 percent of the load at the two printshops where this variable was measured. These figures are conservative, because large amounts of waste paper were observed to be placed in the rubbish daily. The manager of Printshop-1 estimated that over 95 percent of their paper usage was white paper

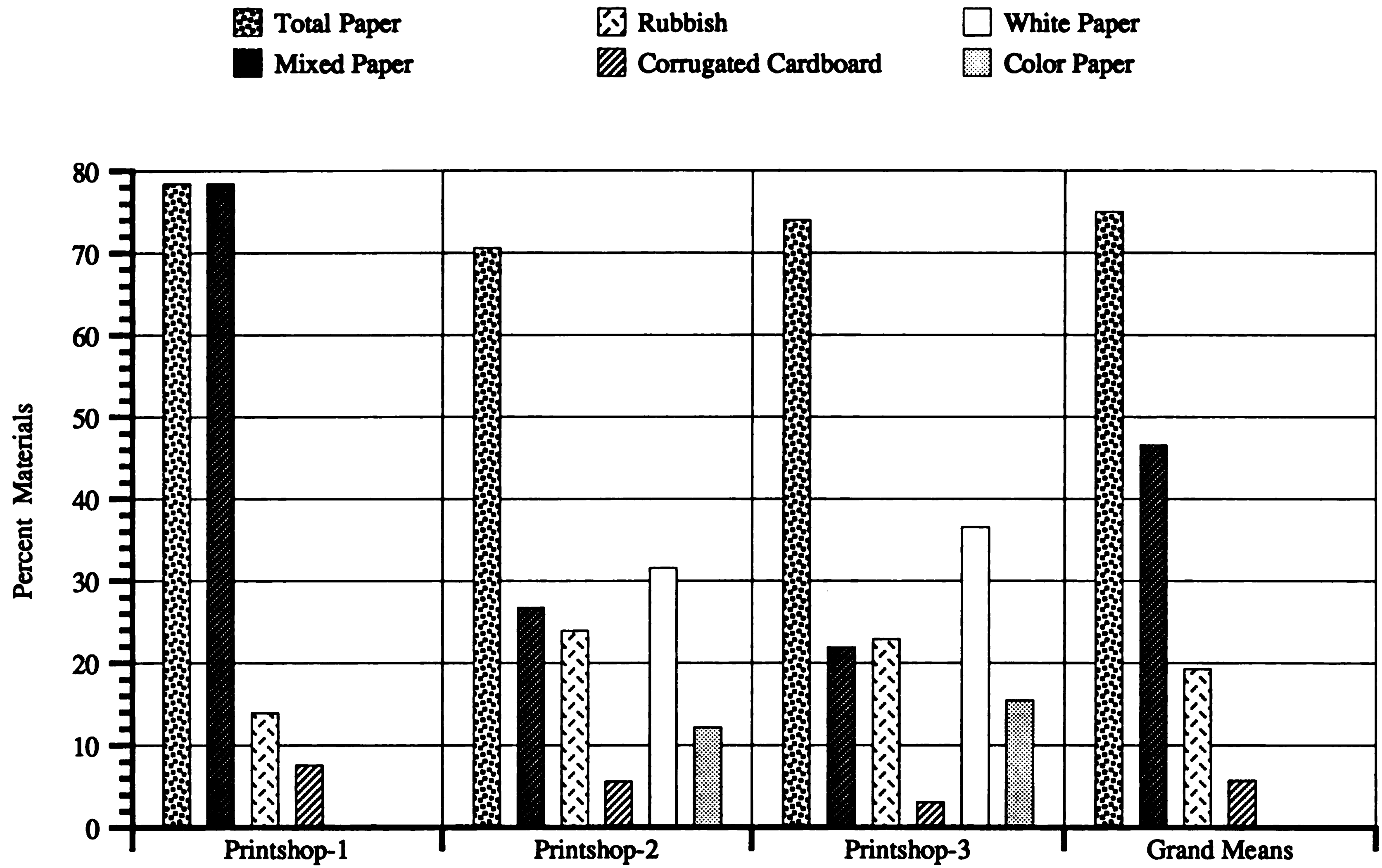


Figure 12. Waste composition from at-source sampling of three East Lansing printshops, fall 1987 (pounds).

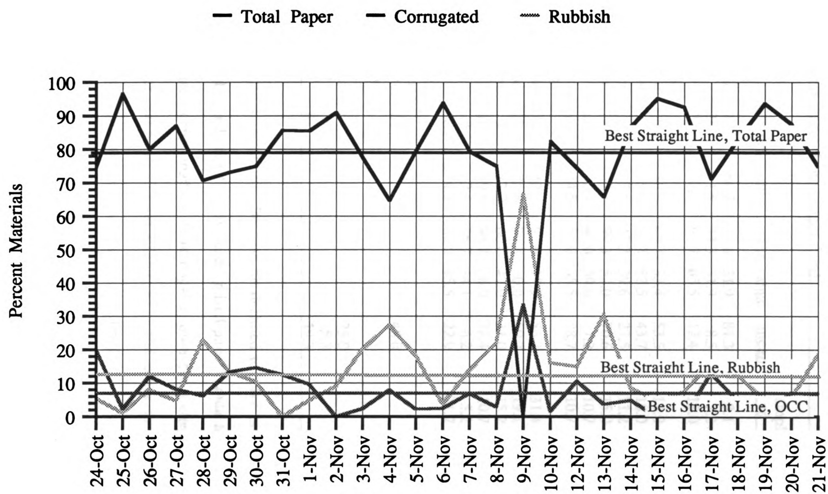


Figure 13. Daily waste composition, Printshop-1, East Lansing, Michigan (fall, 1987, weight data).

Table 8. Waste composition results, East Lansing printshops, fall, 1987 (in percentages, from weight data).

	"n" samples	min	max	range	mean	smple sd	lower c.i.	upper c.i.
Printshop-1								
mixed paper	27	64.7	96.6	31.9	81.3	9.1	78.5	84.2
cardboard	25	1.5	33.3	31.9	8.5	7.2	6.1	10.8
rubbish	27	1.1	66.7	65.5	12.4	13.0	8.3	16.5
Printshop-2								
mixed paper	9	36.3	69.7	33.4	53.5	12.0	47.0	60.1
white paper	13	15.8	68.3	52.5	43.7	18.0	35.5	51.9
color paper	8	7.6	47.2	39.6	27.5	11.2	21.0	34.0
total paper	18	47.3	99.3	52.0	70.6	15.0	64.8	76.4
cardboard	14	0.4	40.0	39.6	7.2	10.7	2.5	11.9
rubbish	15	14.5	50.0	35.5	28.7	10.7	24.2	33.3
Printshop-3								
mixed paper	7	12.7	92.6	79.9	56.3	31.4	36.8	75.8
white paper	13	20.8	20.8	0.0	50.7	19.1	41.9	59.4
color paper	9	13.0	60.0	47.0	31.0	15.2	22.7	39.4
total paper	18	59.8	95.7	36.0	78.4	10.7	74.2	82.5
cardboard	9	2.6	16.7	14.1	6.2	5.2	3.3	9.1
rubbish	18	4.5	100.0	95.5	22.9	21.7	14.5	31.3
Grand Means								
mixed paper	64				48.0			
white paper								
color paper								
total paper	64				75.0			
cardboard	64				5.8			
rubbish	64				19.3			

(personal communication). Because he declined to have his staff separate paper into the color and mixed grades, only "mixed paper" could be sampled. The 81.3 percent mixed paper load for Printshop-1 is probably a close approximate of the white paper composition ratio (Table 8). The other printshops' white paper composition ratio may be at a similarly high level.

The observed white paper data fall between the 66.9 percent estimates made by Evans (1985) for office towers in Toronto and the 42.9 percent measured by DeBell in academic and administrative buildings at the University of Colorado

(1988). These studies had the advantage of taking samples of the complete waste stream. Here, the segregated "rubbish" was bagged and measured as a homogeneous mass.

The data from the detailed waste sort provides indications that the measurement of paper products was underestimated due to paper being mixed in with rubbish. This was confirmed by numerous observations during the sampling period. When examined, the rubbish content was found to be from 17 percent to 46 percent paper by weight. Corrugated cardboard comprised five to 17 percent of the samples. Including staff-read newspapers, there was as much as 68 percent recyclables by weight in the "waste" portion of the material sampled that day (Table 19, appendix B).

In total, the printshop sub-sector waste stream may match the 95 percent paper content observed by Evans (1985) in his sampling of Toronto office towers.

The Retail Firms

The retail sector's waste stream was over 43 percent corrugated cardboard, by weight (Figure 14). Half of the 10 stores had corrugated cardboard represent more than 50 percent of their waste, and three measured more than 60 percent OCC in their waste streams. This included three of the four largest retail waste generators (Table 9). The amount of corrugated cardboard waste created was dependent on inventory deliveries, so there were tremendous fluctuations in day to day generation among the firms. Bookstore-3, as one example, averaged 64.6 percent OCC, but had as little as 14 percent in its waste (Figure 15). By weight and volume, the convenience stores were the largest steady generators of materials, discarding up to 157 pounds and 28 cubic feet of OCC on one day. All stores

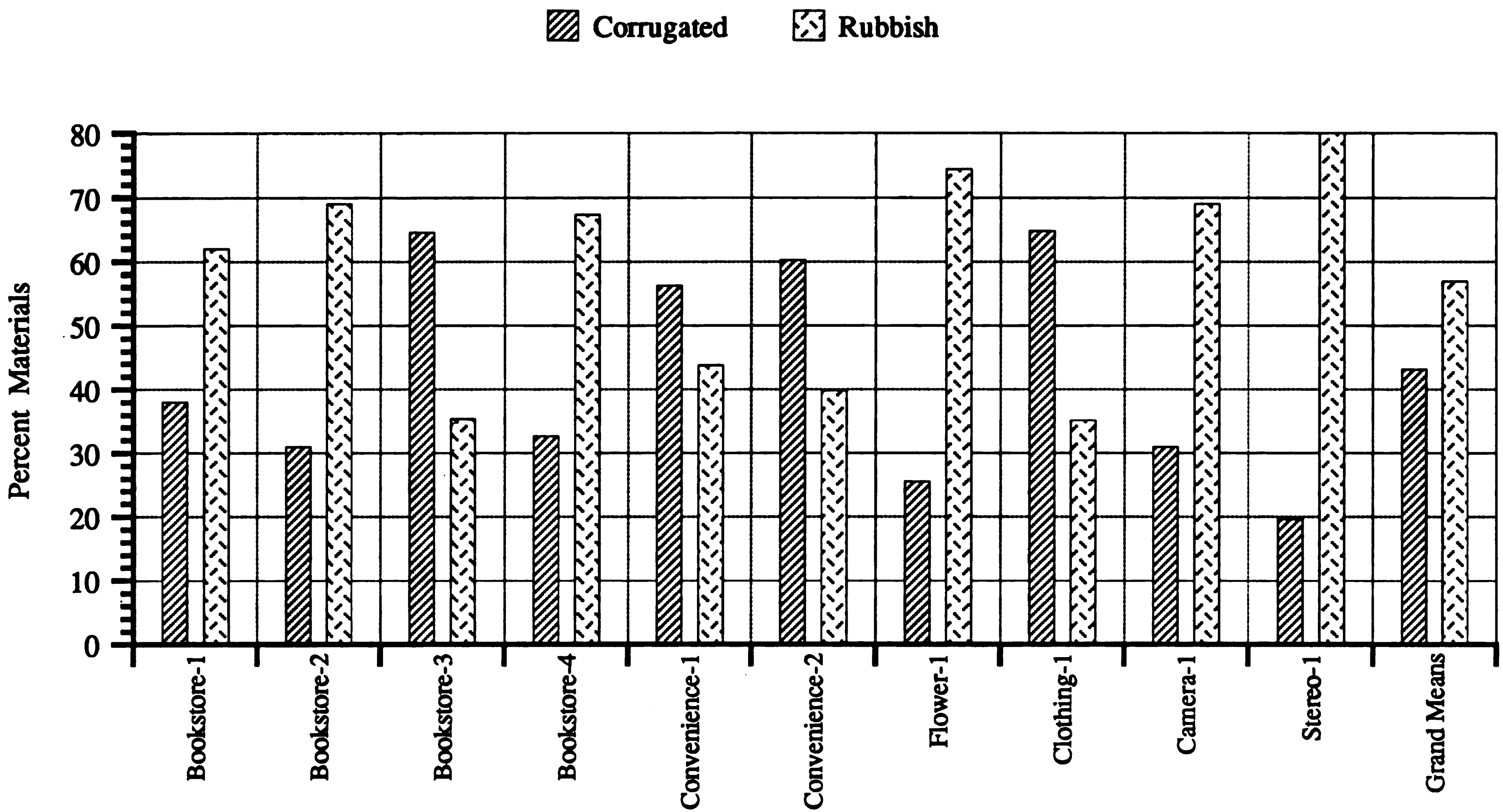


Figure 14. Corrugated composition from at-source sampling of ten East Lansing retail firms, fall 1987. (weight data).

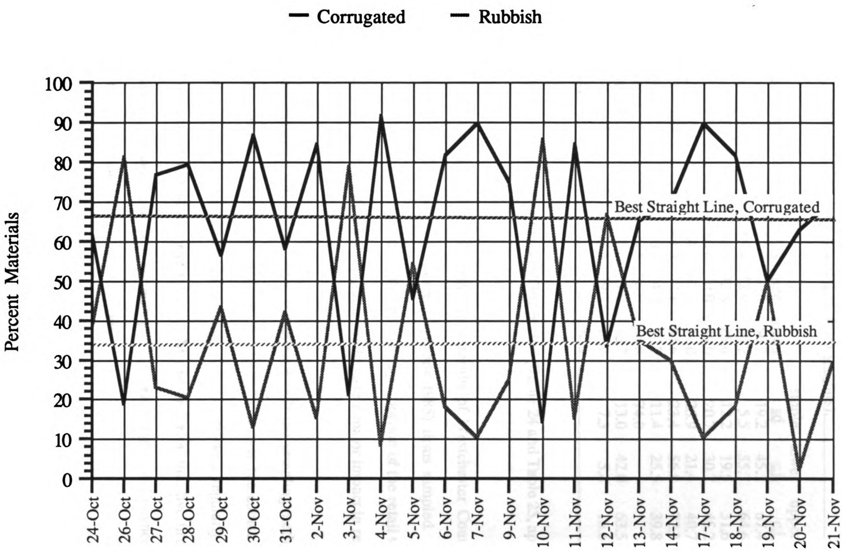


Figure 15. Daily waste composition, Bookstore-3, East Lansing, Michigan (fall, 1987, weight data).

Table 9. Percentage of OCC in waste stream, East Lansing retail firms, fall 1987 (in percentages, from weights).

	"n" samples	min	max	range	mean	smple sd	lower c.i.	upper c.i.
Convnce-1	8	17.0	77.0	60.0	56.2	19.2	45.1	67.4
Convnce-2	4	52.5	65.4	12.9	60.2	5.5	55.7	64.6
Flower-1	11	5.8	38.6	32.8	25.6	12.2	19.5	31.6
Book-1	22	10.0	80.0	70.0	38.0	20.7	30.7	45.2
Book-2	21	2.9	84.2	81.3	31.0	26.9	21.4	40.7
Book-3	25	14.3	91.7	77.4	64.6	23.4	56.8	72.3
Book-4	7	15.8	50.0	34.2	32.7	11.4	25.5	39.8
Clothing-1	4	53.6	79.6	26.0	64.8	74.0		
Camera-1	4	40.0	71.0	31.0	52.7	13.0	42.0	63.5
Stereo-1	5	3.7	23.4	19.7	11.2	7.3	5.8	16.6
Grand Mean	110				43.1			

showed large fluctuations over the sampling period (Table 24 and Table 25, appendix B).

The sub-sector mean is significantly above results of Westchester County (34 percent) (1988) and Toronto (16.5 percent) (Evans 1985) firms sampled. These studies all indicate that corrugated cardboard is a major portion of the retail sector's waste stream. Recycling collection programs would have a major impact in reducing waste loads to landfills.

The detailed waste sort showed good compliance with the sampling methods by the firms' employees. This was in contrast to observations over the course of the study, which indicated that quantities of corrugated cardboard were regularly placed in the "waste" category by almost every firm. The sample found that five firms had over 10 percent corrugated in their rubbish (n = 9; the sample for ConvnceStre-1 was lost); the highest percentage was 21.4 percent.

A Detailed Analysis of the East Lansing Results

This summary has been limited to presenting composition results for the weight data. Appendix B contains the data tables and tables of statistical analysis for measures of central tendency for weight and volume sampling of all the firms.

Comparison of the East Lansing Results with Westchester County

A one-tailed *t*-test was used to statistically compare estimates of the East Lansing population (μ_1) with the estimates made for Westchester County's population values (μ_2).

The results of the *t*-test for the printshop and retail sub-sectors are shown in Table 10 and Table 11 below. Testing was at the alpha level of 0.10, or $a = 0.10$.

Table 10. *t*- and *p*- values for mixed papers in the printshop sector, East Lansing, Michigan (from weights), $a = 0.10$.

firm	n	t value	significance	$\mu_1 > \mu_2$?
All printshops	62	8.01	<0.0005	yes
Printshop-1	27	9.38	<0.0005	yes
Printshop-2	18	1.57	0.067	yes
Printshop-3	17	5.17	<0.0005	yes

Table 11. *t*- and *p*- values for corrugated cardboard from the retail sector, East Lansing, Michigan (from weights). $a = 0.10$.

firm	n	t value	significance	$\mu_1 > \mu_2$?
All shops	110	1.36	0.089	yes
ConvnceStre-1	8	2.39	0.024	yes
ConvnceStre-2	4	7.38	0.0026	yes
FlowerShop-1	11	-3.91	1.00	no
Bookstore-1	22	-0.46	0.68	no
Bookstore-2	21	-1.53	0.93	no
Bookstore-3	24	5.13	<0.0005	yes
Bookstore-4	7	-1.70	0.93	no
ClothngStr-1	4	4.44	0.011	yes
CameraStre-1	4	1.96	0.073	yes
StereoStre-1	5	-8.83	1.00	no

Evaluation of the Equation: $\mu_1 > \mu_2$

The equation $\mu_2 > \mu_1$ was set to Westchester County (μ_2) composition ratios for the printshop/office complex and retail sub-sectors and was tested (with East Lansing represented by μ_1) as:

printshop/office complex: $\mu_1 > 65$

retail: $\mu_1 > 40$

The equation for each sub-sector states that the percentage of specific materials in the East Lansing waste stream is greater than the Westchester County materials for that sub-sector. For printshops/office complexes, mixed paper is tested at 65 percent. For retail firms, corrugated cardboard is examined at 40 percent. Testing was set at the alpha, *a*, level of 0.10.

The equations can be accepted on the basis of the significance levels shown in Table 10 and Table 11. For the printshop/office complex sub-sector, the probability, *p*, is extremely small and the equation would have been accepted even if the alpha level had been set at 0.001.

The entire retail sector *p*-value was below 0.10, indicating a low probability that East Lansing's retail sector waste composition percentage for OCC is less than Westchester County's. This is a result of the high percentages of OCC generated by the larger retail firms.

Comparing Westchester County's Commercial Sector with Disposal-based Commercial Sector Results

Chapter IV explained how the Westchester County study provides a link to contrast at-source sampling with disposal-based analyses. The probability tests showed that the East Lansing waste stream results are richer in recyclable materials than Westchester County. This provide strong evidence that the estimates made for

Westchester County's commercial sector are sound. The East Lansing results validate the Westchester County figures.

The Westchester County study will now be used as the basis to test the alternative hypothesis. In this section, the contrast between at-source sampled studies and those relying on disposal-based measurements will be made. Because the East Lansing and Westchester County results match so closely, any conclusions drawn in comparing the Westchester County waste stream with the other studies will be assumed to correlate to an overall East Lansing waste stream.

Table 12 compares Westchester County's aggregated commercial sector waste stream, by percentage of material composition, to ten disposal-based studies of commercial waste sectors (Seattle 1989, WSDE 1988, Metropolitan Council 1988, MDEM 1985, Savage et al. 1985, U.S EPA 1979). The sampling approach is the primary difference that separates this study from the others.

Westchester County's waste stream has much higher levels of recyclable paper than any other study reports. The Westchester County study targeted mixed paper and corrugated cardboard for recycling, since these two paper products made up 67 percent of the County's commercial waste stream and offered the "greatest probability in terms of physically removing them from the commercial waste stream" (Westchester County 1988). This analysis will also focus on the paper portion of the waste stream.

Table 13 makes another comparison of the composition estimates by using an index to compare Westchester County data to other waste composition percentages. A ratio (Westchester County/Disposal-based Study) was created for each study to compare relative levels of materials in the waste stream. The index shows that Westchester County estimates it waste stream has up to 2.7 times as

Table 12. Disposal based studies (except Westchester County) for commercial waste composition (weight data).

materials	1989 Wshngtn Seattle	1988 Nw York Wstchstr County totals	1988 Wshington from 9 commnties statewide	1988 Minnesota Ramsey/ Wshington Counties	1982 New Jersey Atlantic County	1982 New Jersey Passaic County	1980 New Jersey Essex, Hudson, & Union Cnty	1980 Oregon Portland Metro Rossmans	1980 Oregon Portland Metro St. John	1985 Clfornia Ben Lmnd	1985 Clforni Bna Vst
newspaper	3.48		3.37	6.40	6.80	12.40	2.96	5.90	2.90	5.30	9.40
corrugated	10.32	28.40	12.31	22.50	11.60	37.10	23.21	10.50	11.90	17.90	13.10
white paper	1.62		4.30								
mixed paper	8.64	38.40	14.54	32.30	25.10					26.00	18.30
other paper	10.53		6.80								
total paper		66.80	41.44	61.20	43.50	49.50	25.00	16.40	14.80	49.20	40.80
ferrous can	0.54		0.74	0.80							
total ferrous	3.21		5.29	3.30	5.70	2.90	6.96	5.70	3.10	5.40	5.40
aluminum cans	0.56		0.43	0.70							
misc aluminum	0.09		0.20	0.30			0.74			0.90	1.30
other non-ferrous	0.12		0.17	0.30							
total non-ferrous	0.77		0.80	1.30	1.80						
mixed metals/materi	2.19		2.19								
total metals	3.99	3.00	6.10	4.60	7.50	2.90	7.70			6.30	6.70
all metals/material	6.18		8.30								
total glass 1_/	2.30	4.00	3.89	3.50	10.80	1.80	3.63			2.90	9.90
plastic	6.88	10.90	6.80	8.00	9.30	9.80	4.35			13.00	15.50
yard waste	2.10		4.40	1.70	1.40					1.50	4.10
food waste	12.08	8.00	9.69	6.50						6.80	12.10
wood	22.64	4.00	10.26	5.60		7.50	10.31			7.70	4.50
textiles	1.87		2.93		3.10						
organic n.e.c. 2_/			0.00	5.30	16.30		35.25	71.80	78.90	8.30	4.80
inorganics n.e.c.			0.00	3.50	1.30			6.90	3.20	4.30	1.60
all else n.e.c.	11.45	4.00	11.80		6.50	28.10	12.56				
total	99.98	100.00	99.53	99.90	99.70	99.60	99.97	100.80	100.00	100.00	100.00

1_/ glass estimated (not measured) in Westchester County study.
2_/ n.e.c. = Not elsewhere classified

Table 13. Commercial waste composition, expressed as a ratio to Westchster County composition (from weight data).

materials	1989 Wshngtn Seattle	1988 Nw York Wstchstr County totals	1988 Wshington from 9 commnties statewide	1988 Minnesota Ramsey/ Wshington Counties	1982 New Jersey Atlantic County	1982 New Jersey Passaic County	1980 New Jersey Essex, Hudson, & Union Cnty	1980 Oregon Portland Metro Rossmans	St. John	1985 Clfornia Ben Lmnd	1985 Clforni Bna Vst
corrugated	2.75	1.00	2.31	1.26	2.45	0.77	1.22	2.70	2.39	1.59	2.17
mixed paper	4.44	1.00	2.64	1.19	1.53					1.48	2.10
total paper	2.15	1.00	1.61	1.09	1.54	1.35	2.67	4.07	4.51	1.36	1.64
total metals	0.75	1.00	0.49	0.65	0.40	1.03	0.39			2.10	2.23
total glass 1_/	1.74	1.00	1.03	1.14	0.37	2.22	1.10			1.38	0.40
plastic	1.58	1.00	1.60	1.36	1.17	1.11	2.51			0.84	0.70
food waste	0.66	1.00	0.83	1.23						1.18	0.66
wood	0.18	1.00	0.39	0.71		1.88	2.58			0.52	0.89
all else n.e.c. 2_/	0.35	1.00	0.34	0.45	0.62	0.14	0.32				

1_/ glass estimated (not measured) in Westchester County study.
2_/ n.e.c. = Not elsewhere classified

much corrugated cardboard and as much 4.5 times the composition of mixed paper as reported for these other communities.

Only the New Jersey Passaic County study lists a higher corrugated cardboard composition percentage. Westchester County's load of OCC in the commercial waste stream is 20 percent to 275 percent higher than the other ten studies. It is over twice as large for six of the estimates. The County estimates 28 percent of its waste is OCC, whereas only three of the ten reports list figures over 22 percent. Westchester County reports higher figures for mixed paper, from 19 percent to 367 percent higher for the six studies reporting this figure (Table 13). The Minnesota results are the closest; their 32 percent portion of the waste stream is still 18 percent below the Westchester County composition total. For the composition of total paper in the waste stream, Westchester County's estimate is at least 50 percent larger than reported by seven of the ten studies. Only Minnesota is within 10 percent of Westchester County's estimate (including newspaper). Without newspaper, the Minnesota estimates are 22 percent lower than Westchester County's (Table 12).

Comparing At-Source Results with Disposal-Based Sub-Sector Sampling

Direct comparisons can be made between "pure load" sampling of packer trucks done in Seattle (1989), for the State of Washington (WSDE 1988), and in Toronto (Evans 1985) with at-firm measurements made in Westchester County (1988), by the U.S. EPA (1979), and for this research (Figures 16, 18, and 20). In the office/printshop sub-sector, the Toronto office tower was over 95 percent paper, and contained 66.9 percent white paper, the highest measurement for each category (Evans 1985). The other two truckloads sampled reported one-third less paper, overall, and only 16 percent as much high grade papers as Toronto. The East

Lansing estimate for white paper was 30 percent lower and was within 19 percent of total paper, and the Westchester County total paper estimate almost matched, at 94 percent of the Toronto totals (Figure 16).

The great discrepancy in pure load results may be due to local conditions from time of year sampling and the small sample frames. It is also likely that these "snapshots" are not typical of the overall waste stream. No more than three samples were taken from a single site (the Washington State study had 12 samples, but seven were one-time events and individual data were not reported). In contrast, multi-week sampling was done in East Lansing. Figure 17 compares sampling parameters and shows that the East Lansing field work was much more detailed, providing a view of waste generation over an extended time frame. Total paper composition among the three printshops ranged from 70 to 80 percent, a spread of less than 10 percent (Table 8). Designers of waste composition studies stress the need for sampling periods of at least one week, and suggest seasonal sampling over a year's time (MDNR 1986, Robinson and Robinson 1986). Baird (1962) has pointed out that duplication increases the amount of information available and provides improved reliability in measurements.

Seattle reported 12.24 percent "other paper" and Washington State had 9.5 percent "non-recyclable paper" (Figure 16). It is probable that some of this is paper that became contaminated when mixed in the packer trucks, thereby decreasing the recyclable paper fraction measured.

Reports from the retail sector follow this pattern. Corrugated cardboard is the common material that will be compared here (Figure 18). The statewide Washington study reported the largest percentage of OCC in the waste stream for the pure load samples, but their total was only about half estimated by East Lansing,

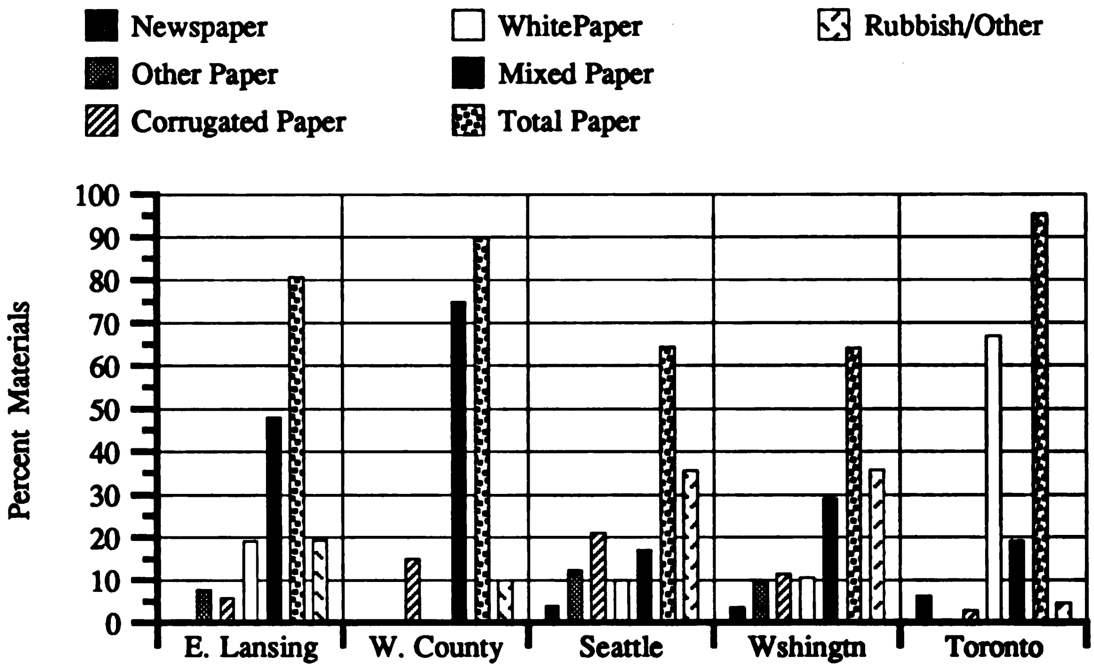


Figure 16. Paper waste composition in the office/printing sector as measured at firms and by "pure-load" sampling, for several studies (pounds).

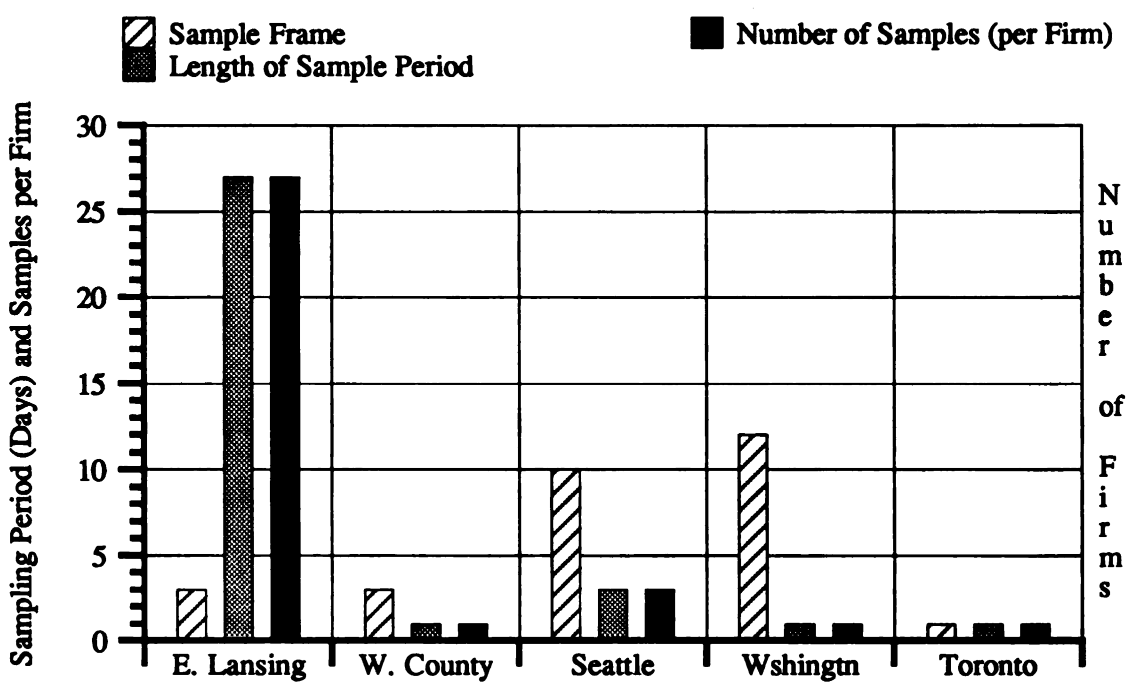


Figure 17. Office/Print sector sampling parameters for several studies.

and was almost matched by Westchester County. The U.S. EPA (1979) reported OCC composition in the 50 percent range in its examination of three different sized shopping centers. The same comparison in length of sampling period and number of samples applies. In East Lansing, 110 samples were taken in a four week period. Washington State had the most samples of the pure load studies, but only five of the 14 samples were in the same city (Figure 19). Seattle (1989), which reported 9.5 percent "other paper," also measured 30.6 percent food waste, indicating that grocery stores were probably a part of the sample frame.

The restaurant sector had more recyclable materials, with OCC dominant. The two at-source studies measured over 20 percent more corrugated than did Washington State, which had the next largest component of OCC in its waste. East Lansing had the greatest percentage of glass, over four times as much as Toronto and Washington State reported (Figure 20). The same comparison regarding sampling period and number of samples is true here. East Lansing conducted 46 samples for OCC and 29 samples for glass in its sampling periods of two and four weeks. Washington State again had 14 samples, with no more than three from a single city, and no individual data presented in its report (Figure 21).

Evaluating the Hypothesis

The sampling procedures used in this research measured greater amounts of recyclable materials in the commercial waste stream than are reported with disposal-based sampling techniques. The null hypothesis, that commercial waste measured at the source of generation in East Lansing would have smaller or equal quantities of recyclable materials than the disposal-based studies, is rejected. Instead, it is probable that East Lansing's business waste stream has higher percentages of

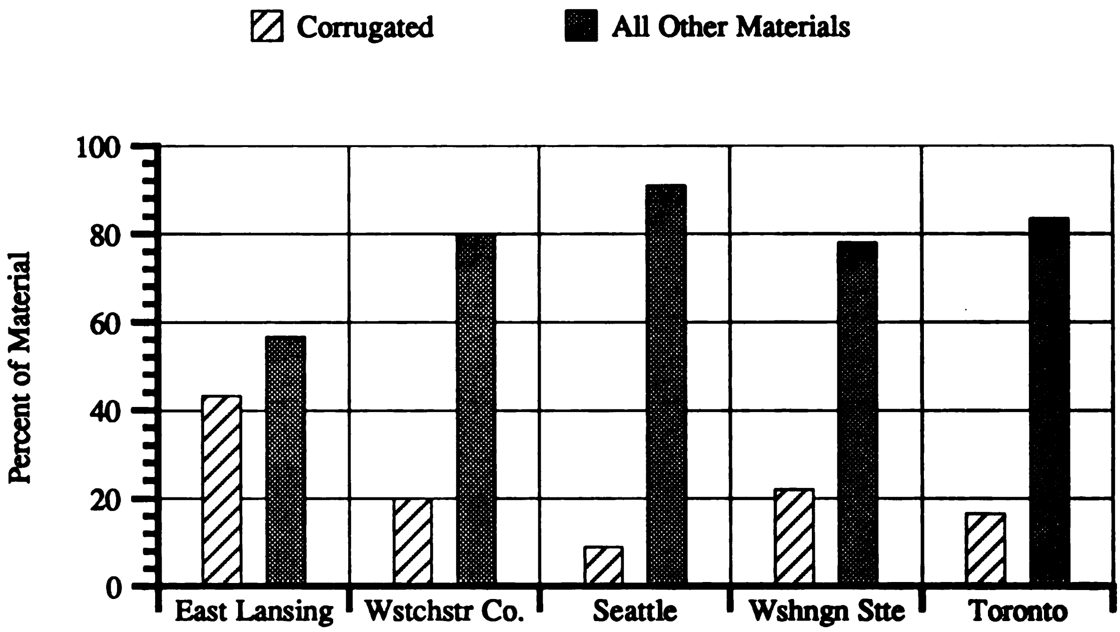


Figure 18. Corrugated paper composition in the retail sector as measured at firms and by "pure-load sampling, for several studies (pounds).

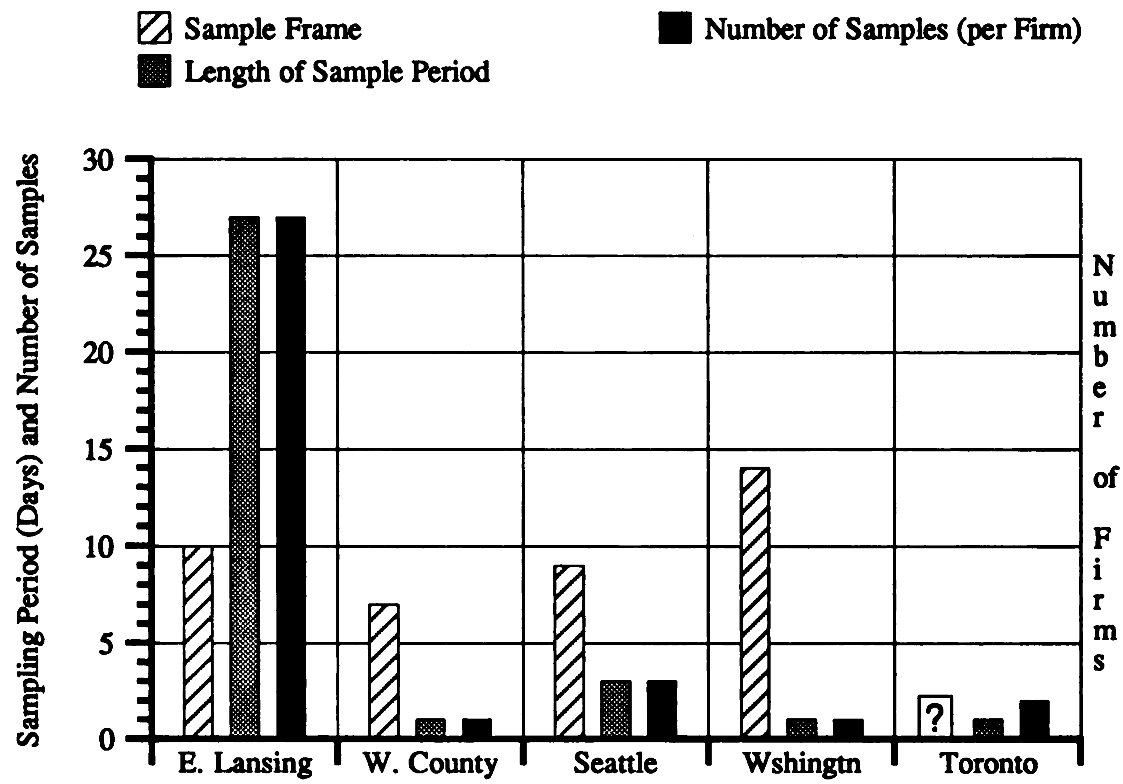


Figure 19. Retail sector sampling parameters for several studies.

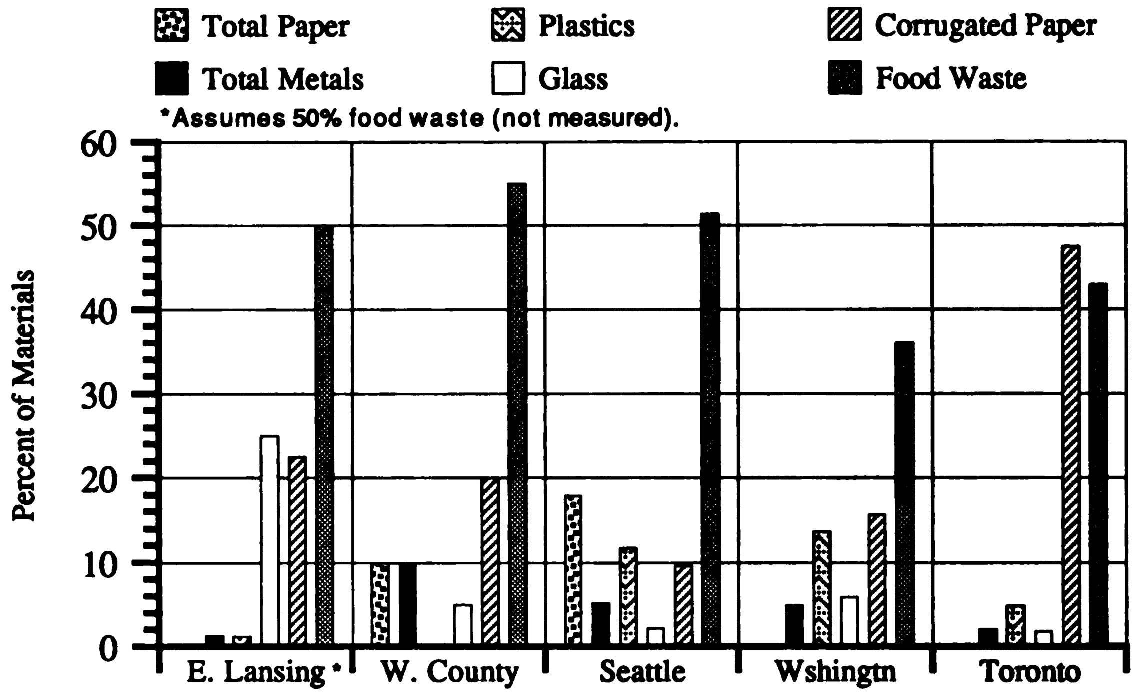


Figure 20. Waste composition in the restaurant sector as measured at firms and by "pure-load" sampling, for several studies (pounds).

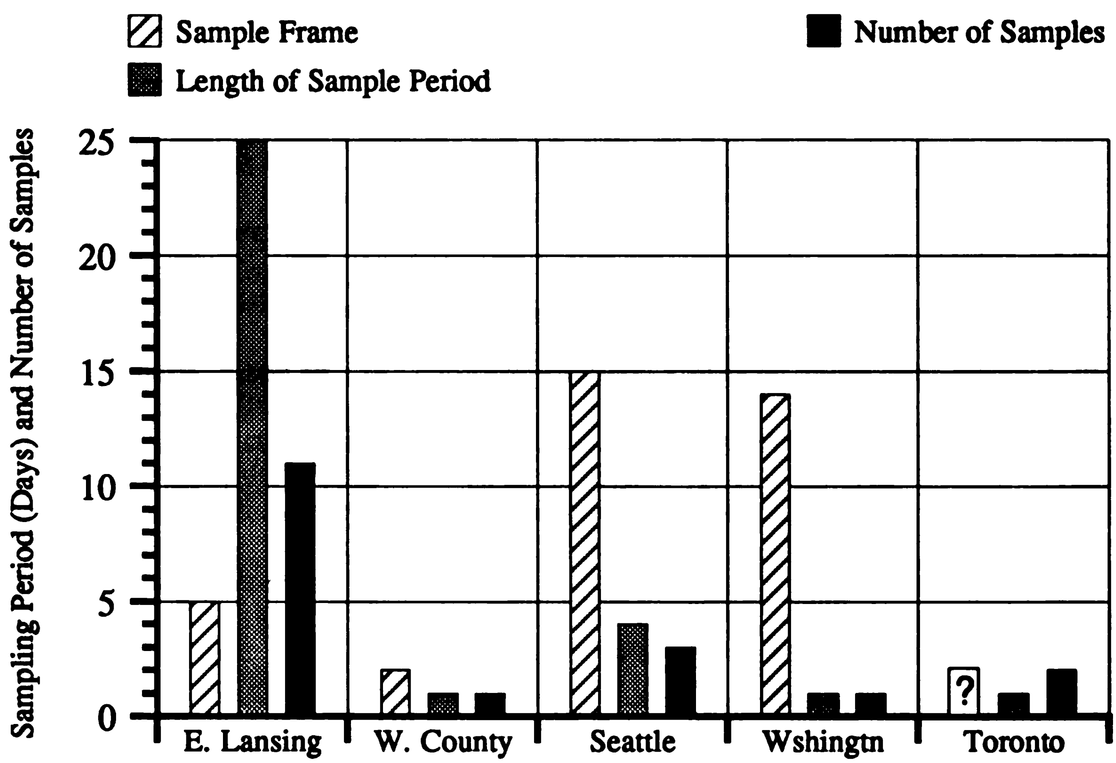


Figure 21. Restaurant sector sampling parameters for several studies.

recyclable materials than reported by the ten studies employing standard practices that are compared in this thesis. The commercial waste stream, in general, is probably significantly higher in its composition of recyclable materials than is currently being estimated. The alternative hypothesis, that there are larger percentages of recyclable materials in the commercial waste than standard methods of sampling suggest, is supported.

Rationale for Higher At-Source Sampling Results

Clearly, East Lansing and Westchester County are estimating significantly higher quantities of recyclable papers in their commercial waste streams. This was true on a direct comparison of samples taken and in the estimates of the entire commercial sector. The sampling procedures were part of a regime for examining materials before they can be contaminated. A greater level of detail is possible when materials are measured in the same condition as for collection for a recycling program. The mixing, compaction, and contamination that was described in Chapter II for transported loads is avoided. Because the sampling examined materials as they would be prepared for recycling, an accurate representation of commercial wastes for composition, weight, volume, and source of generation was made. This is the primary reason that the composition percentages of paper products is so much higher in the East Lansing and Westchester County studies. As Cerrato (1989) noted: "Commercial recyclables are both readily identifiable and easily separated from the waste stream."

The longer sampling period and many additional samples taken in East Lansing were also critical, key differences in comparison to the other studies. The sampling period could not account for seasonal variation across the year, as suggested by the MDNR (1986) and Robinson and Robinson (1986). These studies agree that "a longer program can develop more accurate flow rates . . . . a week long program will not provide reliable data and can be a misleading waste of time" (Robinson and Robinson 1986). Evaluating these factors is necessary to show the true potential of this waste stream. The East Lansing results reflect the consequences of utilizing two to four week sample periods. This longer time frame provides the opportunity to gain a more accurate picture of waste generation.

The standard collection, transportation, and disposal process alters the material to a degree that it can be said that a different "product" is measured at the final disposal site. The many possible transformations discussed in Chapter II are a series of variables and create a degree of change that cannot reasonably be factored in to make an accurate assessment of the status of materials at the front-end of the waste stream. There is a great potential for "loss," either from contamination or materials being overlooked or leaving the system. At-source sampling measures materials before they are affected by these artificial changes. The contamination factor discussed by Golueke and McGauhey (1967) is prevented from affecting the analysis.

This is true for the "pure load" samples, also. Sampling by this method is an attempt to measure recyclables on a sub-sector basis, but it continues the old paradigm of assuming collection as an inconsequential component. The focus did not change sufficiently to center on the firms as they generated materials. The Sunnyvale (1986) study, which examined full dumpsters, found that 26 percent of the bins it observed contained at least 50 percent recyclables. Sampling is best done before collection takes place if the results are to reflect business waste generation rates.

Another clue as to why more paper products are identified in the Westchester County waste stream may be found in the "other" categories of "Organic N.E.C." and "All Else N.E.C." (Not Elsewhere Classified) in the various analyses (Table 12). These categories are catch alls for materials that are unidentifiable or do not fit into another classification. Westchester County estimated that four percent of its waste was this "other." The Buena Vista and Minnesota studies almost match that, reporting 4.8 percent and 5.3 percent, but no other study is close. The combined totals for the two categories range from 8.3 percent to 78.9 percent in the other eight reports. It is probable that much of the organic fraction is contaminated or unidentifiable paper that is not suitable for being recycled. If this is so, the contamination is a direct result of the procedure on which the sampling methods are based. Loads that have been thoroughly mixed, compacted, and transported before being sampled have a sizable fraction of their materials contaminated. At-source sampling avoids these problems by providing a detailed representation of waste as it would generated be for a recycling collection program.

Summary

The correlation of the Michigan and New York results shows a strong relationship that can be used to compare East Lansing's results with disposal-based studies. The East Lansing waste stream is significantly higher in its percentage of recyclable paper products than commercial waste streams measured by disposal-based sampling methods are. This supports the rejection of the study's null hypothesis, that there is no difference in measurements between sampling waste at the point of source generation and sampling at the point of disposal. A comparison with "pure load" sub-sector sampling found similar results.

Analyses based on at-source sampling methodologies provide greater details and make more information available to planners than do disposal-based methodologies. This creates a waste generator based perspective that will be necessary in the design and implementation of materials collection programs.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary of the Thesis

Recycling is being developed as a primary technology for handling the nation's waste in the solid waste management field. Waste composition studies are a necessary first task planners and waste management professionals must undertake in order to quantify the municipal solid waste stream. But the switch to recycling oriented waste management is hampered by a continued reliance on planning tools based on the conventional paradigm that depends on centralized disposal technologies, chiefly landfills.

Recycling in the commercial sector will be a major component of municipal solid waste management programs. Several empirical studies were cited to show that there are discrepancies in the estimates of composition and quantities of materials available for recycling and that sampling methods for assessing the commercial waste stream are evolving. Composition ratio estimates are not accurate because the sampling schemes are not detailed enough to account for the many varied factors that contribute to the complexity of the municipal solid waste stream.

This research presented a new methodology that is based on disaggregating the commercial sector into sub-sectors and sampling at the point of generation. It is based on the principle that greater accuracy and a higher level of detail can be obtained by sampling at the source of generation. This represents a paradigm shift that places the emphasis on collection of materials. This requires involvement of the waste generators, a stakeholder group whose role has previously been assumed.

This study supports McCamic's (1985) call for a "new philosophy of waste management." Commercial firms need to be defined by the recyclable materials in their waste streams. Approaching the commercial solid waste system this way will mirror the recycling programs that will collect materials from these businesses. This allows the structuring of sampling methods that addresses the "dilution" effect and the "noise" problem inherent in assessing the overall municipal waste stream. Collection programs for recycling are highly discriminatory; the methodology that is used to develop these plans must also be highly selective. This study analyzed waste stream composition and volume at the generation source, thus avoided the mixing, compaction, contamination, and transporting of waste that is inherent in disposal-based studies.

The alternative hypothesis, that higher quantities of recyclable materials are found in the waste stream when measurements are taken at the point of generation, is supported. Recyclable materials comprised a larger portion of the commercial waste stream than previously assumed in the printshop, retail, and restaurant sub-sectors in East Lansing, Michigan. As much as four times as much paper wastes were found in the printshops than in office sector sub-streams analyzed elsewhere. Over 70 percent of the printshops' waste consisted of paper products. Corrugated cardboard (OCC) comprised over 40 percent of the East Lansing retail sector waste stream; this was also four time more than measured by "pure load" sampling. In the restaurant and bar sub-sector, corrugated cardboard and glass each totaled over 20 percent of the restaurants' waste stream. These were also four times the level found in other studies. The findings support Cerrato's (1989) observation that "commercial recyclables are both readily identifiable and easily separated from the waste stream."

The East Lansing results were linked to a study done in Westchester County, New York, where county wide composition estimates were made of the entire commercial waste stream. Westchester County estimated that 67 percent of this waste stream is comprised of recyclable papers (28.4 percent corrugated, 38.4 percent mixed papers). This analysis is significantly higher than estimates reported by 10 disposal-based studies done around the country. The Westchester estimates were 20 percent to 400 percent higher.

Findings

1. The printshop sub-sector is extremely rich in high grade, high value paper wastes. Printshops may have as much as 95 percent paper content available for recycling
2. Corrugated cardboard (OCC) is the primary packaging material in the retail sector and represents 43 percent of the waste generated
3. All firms that handle food (convenience in retail, restaurants and bars) are major generators of OCC, which comprised up to 55 percent of these firms wastes. Food is primarily packaged in corrugated; since the products are high turnover items, food providing-firms have inventories of corrugated packaged products they constantly replenish. This could be as much as 150 pounds once a week
4. Comprehensive recycling that covers all firms in the commercial sector will have a major impact, perhaps over 25 percent in reducing waste, because of the volume reduction that universal participation will achieve
5. Separation of materials into readily recyclable categories before collection links waste generation to its source. This is a successful strategy for identifying and quantifying the commercial waste stream
6. Four week sampling periods increases the size of the database and provides repeatability, improving the estimate of the precision of the measurements taken (Baird 1962) and reducing the standard deviation in the print samples to about 12.5 percent. In the retail sector, the standard deviations ranged from six to 26 percent
7. On a countywide basis, corrugated cardboard may be 28 percent of the commercial sector's waste, and mixed papers may comprise 38 percent. These estimates are four time larger than reported by disposal-based analyses

Implications

There is a distinct advantage to dividing the business community by SIC codes to examine sub-sector waste streams. It is probable that an examination of businesses in the service, financial, academic, and government sectors would show similar high levels of recyclable goods. An SIC code-based sampling scheme can be very specific and allows firms to be defined by activity and type of waste generation. For example, grocery stores and floral shops (two retail codes) could be grouped together on the basis of the large organic fraction of waste that these businesses generate. A further refinement might include restaurants and bars (also in the retail division) and hotels, convention centers, school cafeterias, and other entities involved in large scale food production and serving activities. Business activities that generate low amounts of recyclable materials (e.g. barbershops, laundromats) could be grouped together to ensure a complete representation of the entire commercial sector and at the same time avoid diluting the estimates of waste streams that are much richer.

Program planners will gain a more accurate assessment of the materials available in local waste streams if they do sampling at the source of generation. Source-based sampling can provide the basis for estimating the aggregated, overall waste stream. When waste composition is estimated in this way, program plans can be designed to maximize the amount of recycling possible in the waste stream.

This approach prevents indiscriminate sampling that would place a burden on developing an analysis to maximize recycling without an appraisal of the dynamics of the commercial sector. Resource rich sub-sectors are masked when sampling is based on aggregated loads. The economic potential and cost savings from diverting the material will continue to be lost if these waste streams are not completely identified and quantified. Smaller waste generators, such as those represented by East Lansing businesses, may be considered of secondary importance and not adequately targeted. Disposal-based sampling will perpetuate centralized and large scale programming, since that is the conventional planning perspective.

Plans based on the paradigm of disposal orientation tend to conclude that it is more difficult to achieve the high goals set for waste reduction and recycling activities because they are inherently undercounting the quantity of material available and not accurately assessing its source of generation or the condition in which it would be made available. Malcolm Pirnie, estimated that two-thirds of Westchester County's commercial waste stream was paper products and was 41 percent of the municipal solid waste stream, but then advised that only 19 percent of the commercial waste stream could practically be recovered. The firm suggested that "32 percent of waste reduction through recycling is optimistic, since it is greater than that achieved and sustained by any community the size of Westchester County in the United States" (Westchester County 1988). A shift away from this viewpoint will also make it easier to assess current levels of commercial sector recycling, which is not easily analyzed using current methods (Metropolitan Council 1988, Westchester County 1988).

Because this methodology recognizes the central role business employees have in maximizing diversion of materials, greater participation in collection programs will probably ensue. If much higher rates of participation and collection occur than are typically estimated, **waste reduction levels may be as much as 50 percent to 100 percent higher than currently targeted. This could occur throughout all segments of the commercial sector if emphasis is placed on separation of recyclables at the point of generation.**

The sub-sector based assessment is less costly for sampling and analyzing the waste stream (Westchester County 1988, Cerrato 1989, Kuniholm 1989). This approach has the potential to make additional resources available and has the positive feedback effect of providing for larger sampling frames, longer sampling periods, and sampling across a year's time to account for seasonal changes. Greater attention to these variables will increase the accuracy of the estimate of waste stream composition and quantity for the entire commercial sector. Follow-up program planning will more accurately size the true recycling potential of the commercial waste stream.

Recommendations

1. Divide the commercial waste stream into sub-sectors of well defined SIC code groupings based on firm activity **and** type of wastes generated
2. Expand the materials classification system to include film plastic, polystyrene, polyethylene teraphalate, colored high density polyethylene, and wood
3. Examine the organic fraction in floral and grocery businesses in the retail sector to determine amount available for composting
4. Sample complete restaurant and bar waste stream to include food wastes
5. Separate glass by color in the restaurant and bar sub-sector
6. Develop plans for sampling financial, service, academic, and government sub-sectors by having wastes separated within buildings before measurements are taken
7. Spread sampling into periods throughout the year to assess variability in waste generation
8. Conduct supplemental surveys for demographics, including number of employees, square feet in firm, gross sales, hours of operation, materials currently being recycled, size of bin, and frequency of waste pick-up
9. Assess if collection program participation is greater because stakeholders are involved during the planning and data gathering stages when this methodology is employed

Limitations of the Study

As an empirical study, the analysis was strictly subject to the limitations of the data. The separation of material was dependent on the cooperation and reliability of the firms' employees. Because all materials were not always separated out, more frequent checking of compliance through the use of the detailed waste sort would strengthen the study.

Only "product"-oriented sub-sectors within the business community were included in this research, rather than a representative cross-section of the entire commercial sector population. This prevented a direct extrapolation to the entire commercial sector from being made.

No direct check was made with waste sampled at the site of disposal for this business community. Sampling the population both at the source of generation and the disposal site would have allowed for direct comparison of the two planning methodologies. This, however, would have large costs associated with it.

Because food wastes were not measured in the restaurant and bar sub-sector, complete analysis of this waste stream was not possible. A representative sample of waste generation would have to include the food portion of the waste stream.

As an empirical study, this is an initial attempt to examine some of the causal factors that determine waste composition analysis. It focused on several relevant variables that are at the foundation of waste generation, collection, and disposal. Future research can advance the comparisons made here, continue the evaluation of the disposal-based paradigm, and further develop and critique the collection-oriented model suggested as its replacement.

APPENDIX A

CORRESPONDENCE AND DATA SHEETS USED IN FIELD SAMPLING

410 Abbott Road
East Lansing, Mi 48823

Telephone
(517) 337-1731

September 25, 1987

Mr. Peter Erdman, General Manager
Mr. Alec Gores, President
Executive Business Systems, Inc.
241 East Saginaw, Suite 1
East Lansing, Michigan 48823

Dear Mr. Erdman and Mr. Gores,

We are writing to you to ask for your cooperation in a masters research project being conducted by Kenneth Stern, a student at Michigan State University. Ken is conducting a waste stream assessment, an examination of the types and amounts of garbage generated by commercial firms in East Lansing.

We in the City of East Lansing are supporting Ken in his efforts and are looking forward to reviewing his results. We believe that this study can lead to the reduction of waste that must be taken to the landfill. If this is true, there may be some saving of monies by recycling those materials that are readily recyclable.

Ken's project is titled "Recycling as an Alternative Solid Waste Practice for the Business Community of East Lansing, Michigan. The attached outline summarizes his project. His premise is that businesses generate a considerable amount of "clean" waste that can readily be recycled. He believes that the combination of high densities of firms, with many businesses in close proximity to one another, and the high volume of waste generated by constant turnover by the nature of these enterprises, will provide sufficient quantities of materials to make a recycling program feasible.

Recycling can have specific benefits to firms in the commercial sector, as well as to the larger community. If recycling materials brings a substantial reduction in the amount of waste generated, there ought to be some reduction in waste disposal costs, also. Previous research indicates that recyclable materials in business districts make up to 65 percent of the waste generated, both in volume and weight. Removing these items from the waste stream can reduce disposal costs to businesses as well as relieve pressure on area landfills.

Ken's study will quantify the amount of garbage generated and analyze the data collected. If the results match his hypotheses, the Recyclers of Ingham, Eaton, and Clinton Counties will work toward establishing a commercial pick up route in 1988.

Your firm's name has been chosen by a random selection process to be a possible participant in the study. Ken would like to follow up this letter with a meeting to explain his project in greater detail. Your support will enable Ken to make a more thorough examination of the waste generated by East Lansing businesses. We hope you will cooperate with Ken fully as he proceeds with his research.

Please direct any comments or questions to Ken at 351-3757.

Sincerely,

John Czarnecki
Mayor

Tom Dority
City Manager

Kenneth Stern
Resource Development

PROJECT OUTLINE

Title: Recycling as an Alternative Solid Waste Management Practice for the Business Community of East Lansing, Michigan

Purpose: To conduct a waste stream assessment of randomly selected businesses in East Lansing to determine the size, nature of composition, and frequency of generation of their waste and to assess the potential for recycling of marketable materials.

Objectives:

1. Develop a process for conducting a waste stream assessment of business on the level of the individual firm.

2. Divide the business community by type and measure the waste generated by each for its recyclable components:
   A. the three sectors are: 1. retail, 2. offices (here copy centers), and 3. restaurants and bars

   B. The recyclable components (by sector) are:
      1. retail: corrugated cardboard, newspaper (if sold)
      2. offices: cardboard, paper (white, color and computer)
      3. restaurants and bars: cardboard, glass, and metal and plastic food containers

   C. Measurements are for weight (in pounds) and volume

3. Correlate waste generated to firm specific characteristics and determine if generalizations can be made between waste stream and firm characteristics

Primary Hypothesis: Can waste stream composition and generation rates be linked to firm specific characteristics, including
1. type of firm
2. size of firm (a. floor space, b. revenues)
3. number of employees
4. time of year

Timeline: Sampling will be done from mid-September through Mid December. Nine, week long sampling runs will be made

Sampling Procedure:
1. Pre-collection interview and survey done to estimate collection needs, pick up frequency, storage area, and number of containers needed
2. Short (half hour) training and discussion with employees to explain project and employee assistance needed
3. Pick up route established according to individual firms requirements
4. Collection period starts
5. Sampling procedure re-evaluated for modifications as needed; on going communications with firms to assess progress
6. Collections take place for nine weeks out of twelve

Analysis: Study write up January - June, 1988. Additional time as needed

Approximate Pick-up time______________

Pick-up days____________________________

PREPARING MATERIALS FOR COLLECTION

1. Separate recyclable materials from "garbage"
2. Recyclable components are: --cardboard --office paper
   --other____
3. Break down cardboard and stack
4. Place paper(s) in container(s): --white --colored
   --newspapers and magazines (if sold)
   NO: --CARBONS --NEWSPAPERS (unless separated) --GLOSSY(magazines)
5. Garbage is: --not readily recyclable materials
   --please dispose of liquids before adding cups
6. Place garbage in plastic bags; secure with twist-ties
7. I will measure (weigh and estimate volume) both the recyclable materials and the "trash"
8. Recyclable materials will be stored and then taken to brokers
9. I will toss the garbage bags in the dumpster
10. I will be back to pick up again on____
11. This will continue until mid-December

My Pledge to You:

1. I will come by regularly, at about the same time
2. I will stay out of the way of your business, both customers and staff
3. I will not ask for help during my collection
4. I will neither create nor leave a mess
5. I am very grateful for your assistance

Project Summary: My thesis, titled, "Recycling as an Alternative Solid Waste Management Practice for the Business Community of East Lansing, Michigan," has as its field data collection component a waste stream assessment. From mid-October to mid-December 15 businesses in East Lansing will have their garbage sorted to examine the recyclable components. Variables are material type, weight, volume, and type of business. The study is being conducted on the unit level of the individual firm. In house assistance from employees/staff is essential to the study's success. Your participation is extremely vital and valuable. Thank you for your help.

Questions, Problems, Ideas: Call Ken, 351-2438 before 8:00 a.m.
evenings till midnight
355-3414 messages
373-2190 dire emergencies, only

PRE-COLLECTION INTERVIEW SHEET

DATE ______________

INTERVIEWER ______________

FIRM ______________________________________

ADDRESS ______________________________________ PHONE# ______________________

MANAGER/OWNER ____________________________

PRIMARY CONTACT PERSON ____________________

TYPE OF FIRM ______________________________

METHODS OF CHARGING FOR COLLECTION SERVICES:

__IN RENT __PROPERTY TAX __CONTRACT WITH WASTE HAULER __DON'T KNOW

__SHARED ARRANGEMENT (WITH _________________________________)

WASTE STREAM
COMPONENT(S) ____

DO YOU RECYCLE NOW? ______________

WHAT MATERIAL(S)? ____

HOW MUCH
(AND RATE) ____________________

WHO PICKS UP
THE MATERIAL? __________________

LOCATION OF PRESENT BIN ____

WASTE HAULER __________________________ SIZE OF BIN ______________

IS WASTE BIN SHARED? __________________ WITH: ____________________________

OF PICK-UPS/WEEK (AND DAYS) ______________________________

TIME OF PICK-UP ______________ RATE OF ACCUMULATION (SLOW-FAST) ______

FREQUENCY TRASH TAKEN OUT ____________ TIME TRASH TAKEN OUT ____________

STOCKING DAYS ____

COMMENTS ____

____

PAGE 2
PRE-COLLECTION FORM (CONTINUED)

NUMBER OF EMPLOYEES INVOLVED IN WASTE COLLECTION AND DISPOSAL:__________

SIZE OF SHOP (APPROXIMATE SQ. FT.):__________

NUMBER OF EMPLOYEES:__________

SUGGESTED FREQUENCY OF PICK UP (DAILY, WEEKLY, ETC):__________

TIME (RANGE, IF POSSIBLE) OF PICK UP__________

PRE-PICK UP COLLECTION AREA:__________

NUMBER OF BARRELS NEEDED (ESTIMATE):__________

RACK/CORRAL FOR CARDBOARD:__________

DATE TO BRING CONTAINERS:__________

DATE FOR TRAINING:__________ TIME__________

NUMBER OF EMPLOYEES TO BE TRAINED:__________

TIME OF EMPLOYEE TRAINING:__________

COMMENTS__________

DATA COLLECTION FORM

Location on Route________________________Day & Date__________________

Approximate pick-up time ________________Collector(s)_________________

Time of Arrival_______________Weather Conditions______________________

Time Done__________________Pick Up Days (of seven)__________________

Time at Stop________________Firm Type____________________________

Firm___________________________________Phone #____________________

Address______________________Primary Contact Person__________________

			No.	Weight in Lbs. Gross	- Tare	= Net	Dimensions Vol	= Ft3
1.	Cardboard a.	(small)	____	____	____	____	____	____
	b.	(med)	____	____	____	____	____	____
	c.	(large)	____	____	____	____	____	____
		# of boxes	____					
2.	Glass a.			____	____	____	____	____
	b. Plastic			____	____	____	____	____
	c. Metal			____	____	____	____	____
3.				____	____	____	____	____
4.				____	____	____	____	____
5.	Rubbish			____	____	____	____	____
	TOTALS					NET		VOL

Comments/Problems____

____

____

____

DETAILED SORT FOR WASTE STREAM ASSESSMENT

FROM: WEEK OF NOVEMBER 16TH - 21ST

Firm________________________ Page____

Type of Firm________________ of_____

Component	gross weight	-	tare weight	=	net weight	total	percent
1. Newspaper							
2. Office paper							
2a. Other paper (wrappings)							
3. Corrugated							
4. Textiles							
5. Plastic, returnables							
6. Plastic, rigid							
7. Plastic, film							
8. Glass, returnable							
9. Glass, non-returnable							
10. Ferrous							
11. Non-ferrous							
12. Yard waste							
13. Plant cuttings							
14. Food waste							
15. Other organics							
16. Paper food containers							
17. Styrofoam food containers							
18. Plastic food containers							
19. Other food containers							
20. Styrofoam popcorn (packing)							
21. "Packing" paper							
22. Office supplies (pens, etc.)							
23. Other inorganics							
24. Fines							
25. Special items							
Totals							

Total sample weight____lb.

Date of Pick up__________

Prepared by_____________

Comments____

SUMMARY OF DATA COLLECTED, SELECTED COMMERCIAL FIRMS, EAST LANSING, MICHIGAN, FALL, 1987

printshops

This is a careful measurement of how much paper three specific printshops were generating. Most important are the composition ratios: By weight, 81 percent of the material is readily recyclable; by volume, 69 percent (breakdowns are in the tables). It is not very refined--the higher value white paper was not accurately (completely) sampled. White paper could easily be twice as much as shown here. Printshop1 is a copy center, and almost all of their paper use is on white stock. With structure and training, reduction at printshops could be on the order of 90 percent. Future studies need: 1. periodic measurements of the "waste" as a check, and 2. more uniform cooperation by all staffs. Most of what printshop2 calls waste was "good" paper. Some of that is true for Printshop3, also, though not as much.

On volume, paper falsely boosted the waste figures. All the printshops threw paper into their "waste" receptacles, and that skewered to the high side their waste data. Well over 80 percent of your waste is probably readily recyclable materials. As is, 70 percent of what fits (volume) in your dumpsters could be recycled.

retails

Cardboard predominates in the retail sector. Over 40 percent of the waste is cardboard by weight; by volume it is about 44 percent. The two convenience stores show again that cardboard packaging follows food supplies. The data here are very good, except for the gross nature of the "waste" category not providing any clues as to what is in it (but again, my assumption was that staff would separate out all "readily recyclable materials"). Additional samplings of the convenience stores that did not measure the waste are not included in the summaries. These data show cardboard as a percentage of the complete waste stream. No other type of firm matched the convenience stores for waste generation, except the flower shop. No store had as much cardboard, though all were regular generators of some quantity.

Bookstore2 reused boxes, storing and taking them back to the warehouse. Bookstores "1" and "2" sold newspapers and magazines; an interesting sideline, but to make picking up those materials make sense, much more would have to be generated or they would have to be supplementing a residential program. Caution is needed to generalize from the clothing and camera stores. These seemed to be typical waste loads. While small, they are regular and steady generators of cardboard. The stereo shop was probably my one worst participant. They were remodeling--which happens--and I weighed a lot of floor tiles and cement. Those data are not representative at all. The flower shop was perhaps the most interesting firm of all. From 30 to 50 percent of that is flower cuttings. Commercial composting (with restaurants, hotels, and institutions) may be the most intriguing future waste management strategy to develop.

page 2
East Lansing Commercial Firms
Solid Waste/Recycling Summary

restaurant and bars

A complete waste assessment was not done, because I did not have the resources (time, money, staff) to tackle the food portion of the waste stream. That is an extremely interesting problem to solve, but it will have to wait for someone else.

The six bars and restaurants, while small in size, were oriented to MSU students, and large in business. Management and staff cooperated to varying degrees. The two best firms were R&B1 and R&B3. These both make some attempt at feeding people, with R&B3 having the larger kitchen. R&B5 also provided good data, but I only could sample for cardboard and glass there. Overall, by weight of 100 percent of the recyclables, cardboard was 57 percent (with a range of 33 to 81 percent) and glass was 36 percent (range from 21 to 67 percent, but one shop with no glass brought down overall average). Using percentages is misleading, since not all waste was measured and some firms did not always participate. With the same warnings, the volume numbers show cardboard averaging 80 percent of the recyclable waste (range of 68 to 92 percent) and glass averaged 12 percent (range of 6 to 27 percent). The data are too scattered and insufficient to say anything about plastic or metal food containers, but an observation: All the places were willing to separate these materials, so potential exists, socially, for recycling all food containers from the kitchens. The savings here would be more in avoided costs from volume reduction rather than revenue.

1st draft: data summary
november 4, 1988

firm: COPYGRAPH

Introduction

In the fall of 1987 a waste stream assessment--an examination of waste generated--was made of 19 firms in East Lansing. Firms were randomly selected. This was the field work for Kenneth Stern's masters program thesis "Waste Generation and the Potential for Recycling in the Business Community of East Lansing, Michigan. The study was conducted on the unit level of the individual firm. Variables measured were composition (material type), weight, and volume. Firms were divided into the categories of printshops (three participants), retail stores (ten), and restaurants and bars (six). Sampling for the printshops, retail stores, and one bar took place from October 23rd through November 19th. The remaining restaurants and bars were sampled during the two week period of December 6th through 20th.

Your Firm

Copygraph generated the second most waste of the three printshops, over 1600 pounds, by weight, and over 300 cubic feet, by volume. Cooperation by staff and management was good, with support provided throughout. There was some regular mixing of paper and cardboard into the waste containers and so the numbers reported here are conservative: Copygraph produces more paper and less "pure" waste than these figures indicate. Still, 70 percent of this printshop's "waste," by weight, was measured to be paper, and 39 percent of that is white paper (again, lower than actually).

Only 26 percent is genuine waste, and that portion is probably lower, since paper (41.9 percent, by weight, and 27.6 percent by volume) and cardboard (seven and 18.4 percent, each) were found in Copygraph's garbage in the one detailed sample taken of that printshop's "trash" in November.

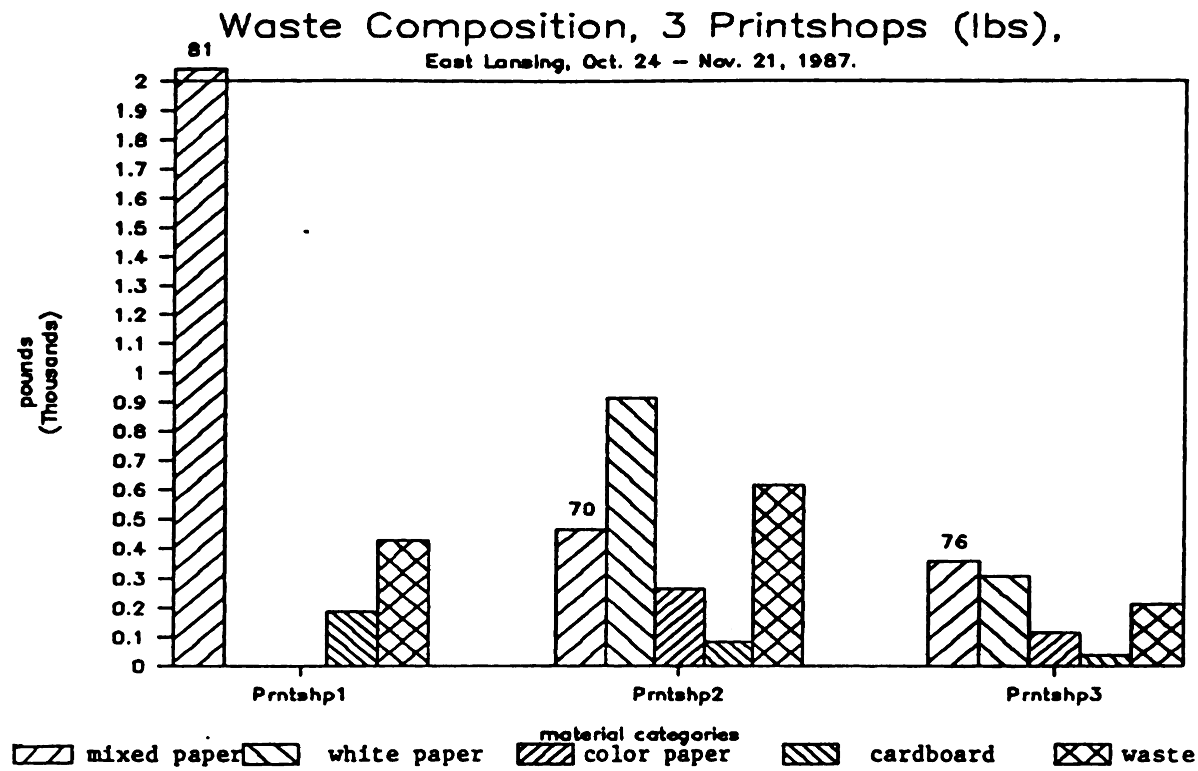
By volume the numbers are 59.7 percent recyclables, at 42 percent, all papers; 19.8 percent mixed papers, 14.1 percent white paper, 6.2 percent color papers, and 18.5 percent cardboard. By volume, 41.3 percent of the material is actual waste, and again the figure is probably less than that, since paper and cardboard were sometimes thrown away.

The one detailed waste sort found only 51 percent, by weight, and 54 percent, by volume, of the total discarded materials to be of "trash" components that are not recyclable.

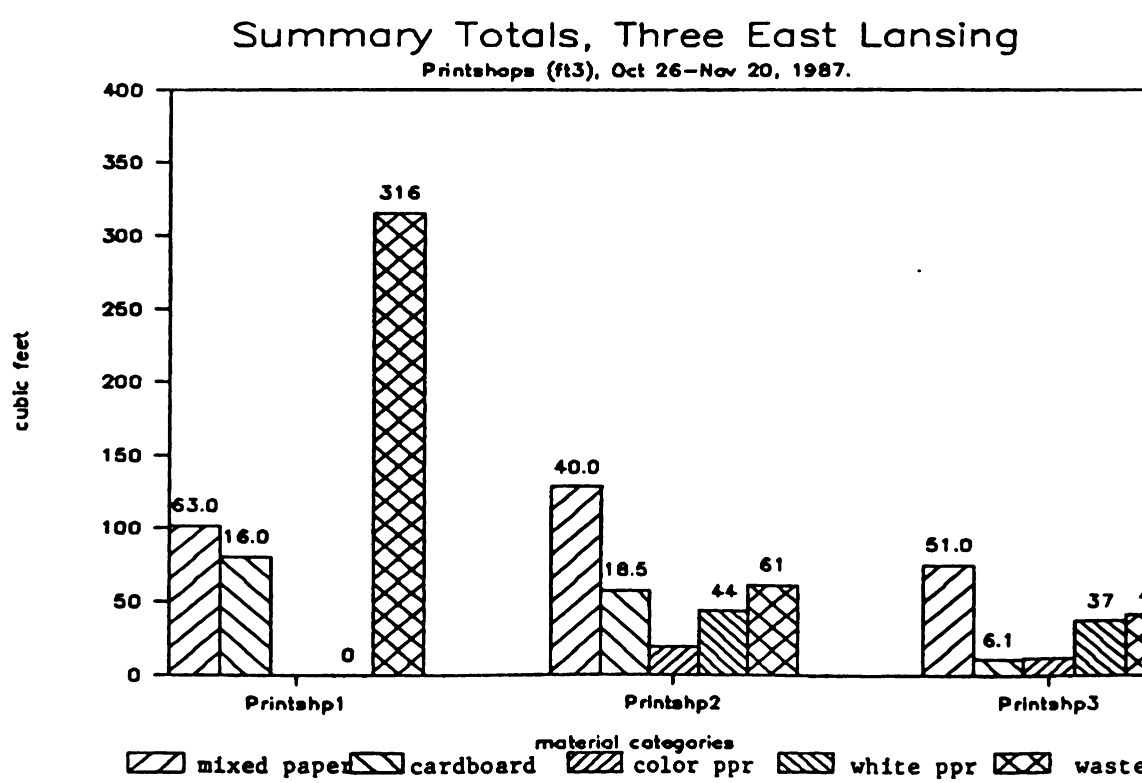
The average daily weight of the 18 samples was 130.5 lbs. The most waste generated on a single day was 368 lbs., the least 10 lbs. Nine times over 100 lbs was generated, and five times that total was over 150 lbs (and three times over 200 lbs). Paper comprised as much as 99.3 percent of the waste but never went below 47.3 percent, by weight.

By volume, the waste averaged 17.2 cubic feet. The largest load was 36.5 cubic feet, the smallest 2.3 cubic feet. Only four times were less than 10 cubic feet of materials produced; eight times it totaled more than 20 cubic feet.

copygrph.sum/11-4-88

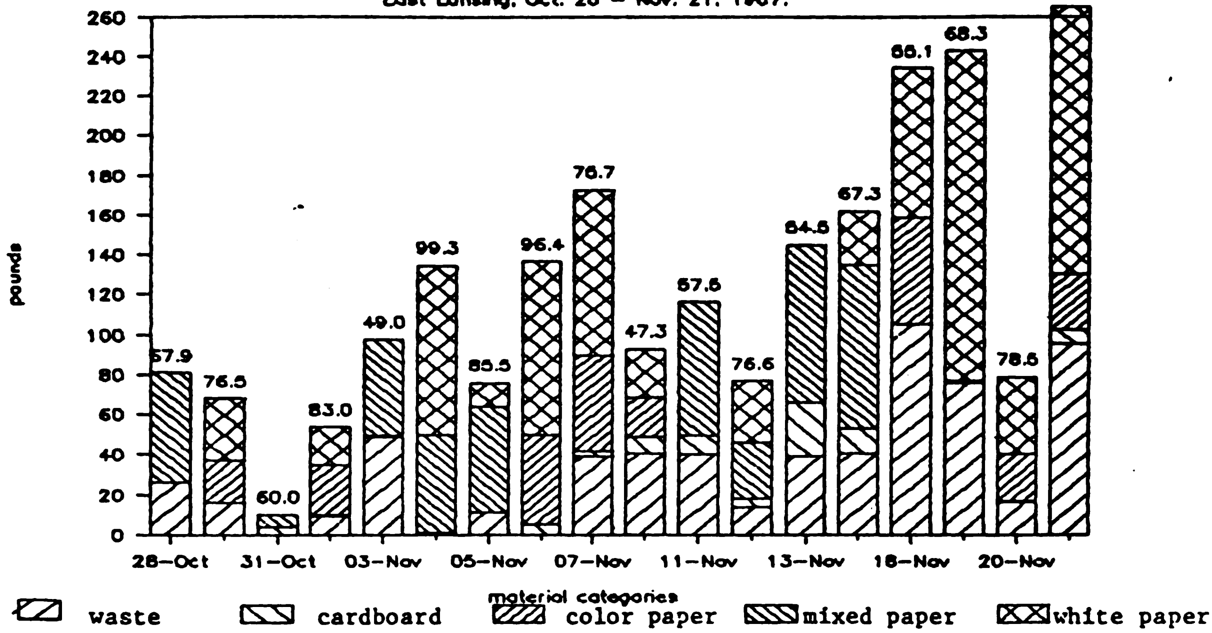


Numbers represent percentage of total paper at that printshop



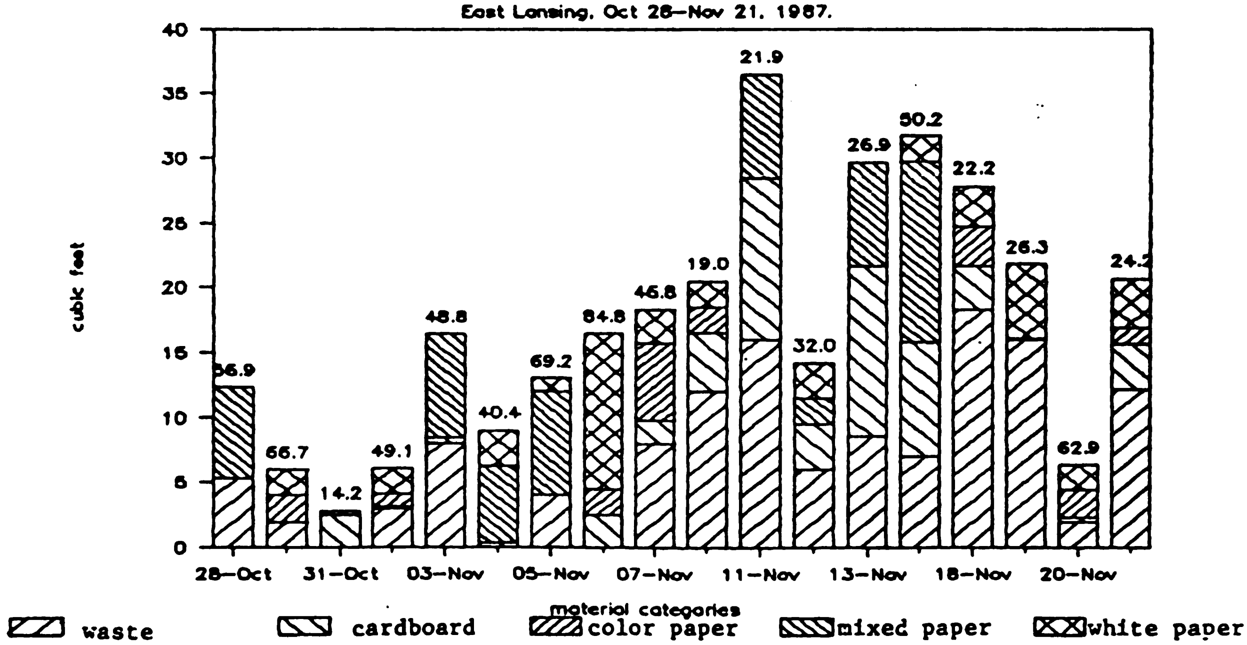
1st number: percentage of total paper
2nd number: percentage of cardboard

Waste Composition, Printshp2 (lbs),
East Lansing, Oct. 28 – Nov. 21, 1987.



Numbers are total percentage of recyclable papers (without cardboard).

Waste Composition, Printshop2 (ft3),
East Lansing, Oct 28–Nov 21, 1987.



Numbers are total percentages of recyclable papers (without cardboard).

APPENDIX B

FIELD SAMPLING DATA TABLES AND RESULTS

Table 14. Waste stream composition, by weight, of three East Lansing printshops, October 24 - November 21, 1987 (in pounds).

firm:	PRINTSHOP 1				PRINTSHOP 2							PRINTSHOP 3						
date	mxd ppr	crdb	rbsh	TOTL	mxd ppr	whte ppr	color ppr	crdb	rbsh	TOTL	TOTL PAPR	mxd ppr	whte ppr	color ppr	crdb	rbsh	TOTL	TOTL PAPR
24-Oct	41	11	3	55														
25-Oct	170	4	2	176														
26-Oct	20	3	2	25								0	19	3	0	1	23	22
27-Oct	74	7	4	85								0	0	0	0	9	9	0
28-Oct	46	4	15	65	55	0	0	0	26	81	55							
29-Oct	60	11	11	82								104	0	0	4	33	141	104
30-Oct	36	7	5	48	0	31	21	0	16	68	52	25	0	0	1	8	34	25
31-Oct	24	4	0	28	6	0	0	4	0	10	6							
01-Nov	53	6	3	62														
02-Nov	101	0	10	111	0	19	25	1	9	53	44	0	47	25	3	11	86	72
03-Nov	100	3	26	129	48	0	0	1	49	98	48	0	12	7	0	9	28	19
04-Nov	95	12	40	146	49	85	0	1	0	135	134	7	41	0	0	7	55	48
05-Nov	105	3	24	132	53	12	0	0	11	76	65	107	0	0	14	16	137	107
06-Nov	151	4	6	161	0	87	45	5	0	137	132	0	19	10	0	4	33	29
07-Nov	127	11	22	160	0	83	48	3	39	173	131							
08-Nov	132	5	39	176														
09-Nov	0	4	8	12														
10-Nov	154	3	30	187	0	24	20	8	41	93	44	28	67	0	0	64	159	95
11-Nov					67	0	0	10	40	117	67	0	12	20	1	6	39	32
12-Nov	119	17	24	160	28	31	0	4	14	77	59	75	0	0	0	6	81	75
13-Nov	71	4	33	108	79	0	0	27.0	39	145	79	0	14	30	0	6	50	44
14-Nov	144	8	14	166	82	27	0	12	41	162	109							
15-Nov	137	0	7	144														
16-Nov	50	0	4	54								0	20	10	1	5	36	30
17-Nov	155	28	35	218								0	16	6	1	12	35	22
18-Nov	107	6	16	129	0	75	54	0	105	234	129	11	5	0	4	4	24	16
19-Nov	191	3	10	204	0	166	0	1	76	243	166	0	27	0	4	4	35	27
20-Nov	112	9	7	128	0	39	23	1	16	79	62	0	9	5	0	6	20	14
21-Nov	113	10	28	151	0	237	28	7	96	368	265							
Totals	2688	186	428	3302	467	916	264	85	618	2349	1647	357	308	116	33	210	1024	781
"n"	27	25	27		9	13	8	14	15		17	7	12	9	9	16		17
Mean*	99.6	7.4	15.9		51.9	70.5	33.0	6.1	41.2		96.9	51.0	23.7	12.9	3.7	11.7		45.9
% Mtrl	81.4	5.6	13.0		19.9	39.0	11.2	3.6	26.3		70.1	34.9	30.1	11.3	3.2	20.5		76.3

mxd ppr = mixed paper, crdb = cardboard, rbsh = rubbish, TOTL = total materials, whte ppr = white paper, color ppr = color paper, TOTL PAPR = all papers combined

* Mean is total weight divided by number of samples taken, not length of sampling period.

Table 15. Waste stream composition, by volume, of three East Lansing printshops, October 24 - November 21, 1987 (in cubic feet).

	PRINTSHOP-1				PRINTSHOP-2							PRINTSHOP-3						
date	mxd ppr	crdb	rbbsh	TOTL	mxd ppr	whte ppr	color ppr	crdb	rbbsh	TOTL	TOTL PAPR	mxd ppr	whte ppr	color ppr	crdb	rbsh	TOTL	TOTL PAPR
24-Oct	10.0	2.3	0.5	12.8														
25-Oct	13.6	1.8	1.2	16.6														
26-Oct	6.0	1.3	1.2	8.5									2.0	1.0		0.5	3.5	3.0
27-Oct	12.0	1.5	1.2	14.7								0.0	0.0	0.0	0.0	1.5	1.5	0.0
28-Oct	10.0	3.2	2.5	15.7	7.0	0.0	0.0	0	5.3	12.3	7.0							
29-Oct	8.0	3.0	2.4	13.4								12.0			1.4	3.5	16.9	12.0
30-Oct	13.3	9.7	1.2	24.2	0.0	2.0	2.0	0	2.0	6.0	4.0	4.0			0.1	2.8	6.9	4.0
31-Oct	9.0	1.5	1.2	11.7	0.3	0.0	0.0	2.5	0.0	2.8	0.3							
01-Nov	14.0	3.1	1.2	18.3														
02-Nov	11.0	0.1	2.0	13.1	0.0	2.0	1.0	0	3.0	6.1	3.0		6.0	2.0	2.5	4.0	14.5	8.0
03-Nov	12.0	1.3	4.8	18.1	8.0			0	8.0	16.4	8.0		2.0	0.5		5.1	7.6	2.5
04-Nov	13.0	8.7	10.6	32.3	6.0	2.7		0.3		9.0	8.7	2.0	4.0			4.3	10.3	6.0
05-Nov	12.5	2.2	3.6	18.3	8.0	1.0		0	4.0	13.0	9.0	8.0			2.2	7.0	17.2	8.0
06-Nov	12.5	1.5	2.4	16.4		12.0	2.0	3		16.5	14.0		3.0	1.0		2.0	6.0	4.0
07-Nov	11.0	0.4	5.9	17.3		2.6	6.0	2	8.0	18.4	8.6							
08-Nov	12.0	3.6	7.3	22.9														
09-Nov	0.0	1.5	0.0	1.5														
10-Nov	16.0	1.7	9.5	27.2		2.0	2.0	5	12.0	20.5	4.0	4.0	6.0			25.3	35.3	10.0
11-Nov					8.0			12	16.0	36.5	8.0		1.0	4.0	0.5	1.1	6.6	5.0
12-Nov	9.1	5.0	8.0	22.1	2.0	2.7		4	6.0	14.2	4.7	10.0				1.7	11.7	10.0
13-Nov	13.5	2.7	9.6	25.8	8.0			13.2	8.5	29.7	8.0		2.0	2.0		3.0	7.0	4.0
14-Nov	12.0	2.3	2.4	16.7	14.0	1.9		8.8	7.0	31.7	15.9							
15-Nov	12.5	0	1.2	13.7														
16-Nov	8.5	0.8	1.2	10.5											0.6	1.7	2.3	0.0
17-Nov	12.0	6.9	6.0	24.9									4.0	1.0	1.7	5.2	11.9	5.0
18-Nov	12.4	4.3	3.6	20.3		3.2	3.0	3.4	18.3	27.9	6.2	1.0	1.0		0.5	3.0	5.5	2.0
19-Nov	15.2	2.9	3.6	21.7		5.7		0.1	16.0	21.8	5.7		4.0		1.3	1.7	7.0	4.0
20-Nov	12.0	4.1	3.6	19.7		2.0	2.0	0.4	2.0	6.4	4.0		2.0	0.5		1.7	4.2	2.5
21-Nov	12.5	3.0	4.1	19.6		3.8	1.2	3.5	12.2	20.7	5.0							
Totals	315.6	80.4	102.0	497.9	61.3	43.7	19.2	57.4	128.3	309.9	124.2	41.0	37.0	12.0	10.8	75.1	175.9	90.0
"n"	27	27	27		9	13	8	13	15		17	7	12	9	9	18		23
Mean*	11.7	3.0	3.8		6.8	3.4	2.4	4.4	8.6		7.3	5.9	3.1	1.5	1.2	3.6		5.6
% Mtrl	63.4	16.1	20.5		19.8	14.1	6.2	18.5	41.4		40.1	23.3	21.0	6.8	6.1	42.7		51.2

mxd ppr = mixed paper, crdb = cardboard, rbbsh = rubbish, TOTL = total materials,
whte ppr = white paper, color ppr = color paper, TOTL PAPR = all papers combined

* Mean is total weight divided by number of samples taken, not length of sampling period.

Table 16. Summary statistics from daily sampling, weight data, East Lansing printshops, fall, 1987 (in pounds).

	total mtrls	"n" smples	min	max	range	mean*	smple sd	lower c.i.	upper c.i.	% mtrls
Printshop-1										
mixed paper	2688	27	0	191	191	99.6	46.8	84.8	114.4	81.4
cardboard	186	25	0	28	28	7.4	5.8	5.5	9.4	5.6
rubbish	428	27	0	40	40	15.9	12.4	11.9	19.8	13.0
Printshop-2										
mixed paper	467	9	0	82	82	51.9	23.9	38.8	65.0	19.9
white paper	916	13	0	237	237	70.5	65.7	40.5	100.4	39.0
color paper	264	8	0	54	54	33.0	13.7	25.0	41.0	11.2
total papers	1647	18	6	259	253		59.9			
cardboard	85	14	0	27	27	6.1	7.0	3.0	9.2	3.6
rubbish	618	15	0	105	105	41.2	29.9	28.5	53.9	26.3
Printshop-3										
mixed paper	357	7	0	107	107	51.0	43.3	24.1	77.9	34.9
white paper	308	13	0	67	67	23.7	17.8	15.6	31.8	30.1
color paper	116	9	0	30	30	12.9	9.7	7.6	18.2	11.3
total papers	781	18	0	107	107	43.4				76.3
cardboard	33	9	0	14	14	3.7	4.1	1.4	5.9	3.2
rubbish	210	18	1	64	63	11.7	14.8	6.0	17.5	20.5
ALL PRINTSHOPS -- GRAND MEANS										
total paper	5116	63				81.2				
cardboard	304	48				6.3				
rubbish	1256	60				21.0				

* Means are total weights for each category divided by number of samples taken, not length of sampling period.

Table 17. Summary statistics from daily sampling, volume data, East Lansing printshops, fall, 1987 (in cubic feet).

	total mtrls	"n" smples	min	max	range	* mean	smple sd	lower c.i.	upper c.i.	% mtrls
Printshop-1										
mixed paper	315.6	27	6	16.0	10.0	11.7	2.2	11.0	12.4	63.4
cardboard	80.4	27	0.1	9.7	9.6	3.0	2.3	2.3	3.7	16.1
waste	102.0	27	1	10.6	10.1	3.8	3.0	2.9	4.7	20.5
Printshop-2										
mixed paper	61.3	9	0.3	14.0	13.7	6.8	3.9	4.7	8.9	19.8
white paper	43.6	13	1	12.0	11.0	3.4	2.8	2.1	4.6	14.1
color paper	19.2	8	1	6.0	5.0	2.4	1.6	1.5	3.3	6.2
total paper	124.1	17				7.3				40.0
cardboard	57.7	13	0	13.2	13.1	4.4	4.3	2.5	6.4	18.6
waste	128.3	15	2	18.3	16.3	8.6	5.3	6.3	10.8	41.4
Printshop-3										
mixed paper	41.0	7	1	12.0	11.0	5.9	4.2	3.3	8.5	24.7
white paper	37.0	12	1	6.0	5.0	3.1	1.7	2.3	3.9	22.3
color paper	12.0	9	0.5	4.0	3.5	1.5	1.2	0.9	2.1	7.2
total paper	90.0	16				5.6				54.2
cardboard	10.8	9	0.1	2.5	2.4	1.2	0.8	0.7	1.7	6.5
waste	65.1	18	0.5	15.3	14.8	3.6	3.4	2.3	4.9	39.2
ALL PRINTSHOPS										
total paper	529.7	60				8.8				
cardboard	148.9	49				3.0				
waste	295.4	60				4.9				

* Means are total volumes for each category divided by number of samples taken, not length of sampling period.

Table 18. Summary statistics from daily sampling, volume composition data, East Lansing printshops, fall, 1987 (in percentages).

	"n" smples	min	max	range	mean	smple sd	lower c.i.	upper c.i.
Printshop 1								
mixed paper	27	40.3	91.2	51.0	66.5	13.2	62.3	70.7
cardboard	27	0.6	100.0	99.4	18.5	18.3	12.7	24.3
waste	27	3.9	37.2	33.3	18.7	10.2	15.4	21.9
Printshop-2								
mixed paper	9	11.8	66.7	54.9	39.1	21.0	27.6	50.7
white paper	13	6.0	72.7	66.7	23.6	18.4	15.2	31.9
color paper	8	5.7	33.3	27.6	19.0	11.6	12.3	25.7
total paper	17	11.8	84.9	73.0	42.3	21.1	33.9	50.8
cardboard	13	0.0	88.2	88.2	19.2	18.4	10.8	27.6
waste	15	22.1	73.4	51.3	44.7	14.5	38.5	50.9
Printshop-3								
mixed paper	7	11.3	85.5	74.2	44.2	28.8	26.3	62.1
white paper	12	15.2	57.1	42.0	37.8	14.0	31.1	44.4
color paper	9	0.0	60.6	60.6	19.5	18.1	9.5	29.4
total paper	16	28.3	85.7	57.4	57.2	17.2	50.1	64.3
cardboard	9	1.9	25.8	23.9	12.8	7.2	8.9	16.7
waste	18	14.3	100.0	85.7	42.7	23.4	33.6	51.8
ALL PRINTSHOPS								
total paper	60				57.2*			
cardboard	49				17.7*			
waste	60				32.4*			

* Numbers do not add to 100 percent due to rounding error.

Table 19. Detailed waste sort, by volume and weight, of printshops participating in waste stream study, November, 1987, East Lansing, Michigan (in percentages, cubic feet, and pounds).

waste category	Printshop-1 volume	Printshop-1 %age volume	Printshop-1 weight	Printshop-1 %age weight	Printshop-2 volume	Printshop-2 %age volume	Printshop-2 weight	Printshop-2 %age weight	Printshop-3 volume	Printshop-3 %age volume	Printshop-3 weight	Printshop-3 %age weight
newspaper 1_/	2.0	27.0	6.0	17.1								
office paper	2.0	27.0	16.0	45.7 2_/	3.0	27.6	18.0	41.9 3_/	0.5	14.3	1.0	16.7
other paper	1.0	13.5	2.0	5.7					0.5	14.3	1.0	16.7
corrugated crdbrd					2.0	18.4	3.0	7.0	0.5	14.3	1.0	16.7
plastics, film	0.3	4.5	1.0	2.9	0.3	3.0	1.0	2.3				
plastics, rigid	0.2	2.2	1.0	2.9								
glass, non-rtrnble												
plant cuttings												
food waste	0.0	0.4	1.0	2.9								
paper food cntnrs	1.0	13.5	2.0	5.7								
plstc/styrfm cntn	0.3	4.5	4.0	11.4	0.5	4.8	2.0	4.7 4_/				
styrofoam packing												
packing paper					3.0	27.6	3.0	7.0 5_/				
office supplies												
rubbish	0.5	7.0	1.0	2.9	2.0	18.4	16.0	37.2	2.0	57.1	3.0	50.0
other												
1 piece of metal	0.0	0.0	1.0	2.9								
totals	7.4	99.6	35.0	100.0	10.9	100.0	43.0	100.0	3.5	100.0	6.0	100.0

1_/ includes brown bags and wrapping paper
2_/ includes mostly white paper
3_/ includes mixed white and color papers
4_/ combines paper, plastic, and styrofoam food containers
5_/ includes newspaper
6_/ includes chipboard

Table 20. Modified waste stream composition, by weight, of ten retail firms, East Lansing, Michigan, October 23 - November 21, 1987 (in pounds).

	BOOKSTORE 1					BOOKSTORE 2						BOOKSTORE 3			BOOKSTORE 4			
date	crdb	magz	news	rbsh	TOTL	crdb	news	magz	rbsh	ppr	TOTL	crdb	rbsh	TOTL	crdb	ppr	rbsh	TOTL
23-Oct											0							
24-Oct				8	8				4		4	21	13	34				
25-Oct				7	7				10		10							
26-Oct				8	8	21			7		28	3	13	16				
27-Oct	17			8	25	16			3		19	20	6	26	5	2	3	10
28-Oct	4			10	14	12	15	35	10		72	27	7	34				
29-Oct	7	6	17	5	35	17		7	5		29	13	10	23				
30-Oct	4			4	8	18			6		24	20	3	23	8	12	7	27
31-Oct				4	4	1			10		11	11	8	19				
01-Nov	2			12	14				6		6							
02-Nov	6			17	23	4	1	60	14		79	11	2	13				
03-Nov	15			22	37	24			36		60	12	45	57				
04-Nov	9			21	30			24	10		34	11	1	12	2		7	9
05-Nov	7	31	14	11	63				11		11	5	6	11				
06-Nov	9			3	12	5			13		18	9	2	11	3	4	1	8
07-Nov	4			5	9			25	5		30	26	3	29				
08-Nov				15	15				11		11							
09-Nov	13	5	6	10	32	19			9		28	3	1	4				
10-Nov	6	3	5	8	22	3	8	12	9		32	1	6	7				
11-Nov	2			4	5	7			9	21	37	11	2	13	3	11	5	19
12-Nov	11			8	19	2			12		14	5	10	15				
13-Nov	7			11	18	2	14		50	3	69	13	7	20	4	5	1	10
14-Nov	8			2	10	2			5		7	14	6	20				
15-Nov	2		2	5	9				4		4							
16-Nov	2	5	5	8	20	12			10		22	11		11				
17-Nov			38	5	43	4			13		17	35	4	39				
18-Nov			11	3	14	5	13	37	8		63	27	6	33	5	7	3	15
19-Nov	3			8	11	1			7		8	9	9	18				
20-Nov	9			4	13	5	38	25	29	5	102	27	1	28		2	2	4
21-Nov	1			3	4	1			4		5	19	8	27				
Totals	147	50	97	238	532	181	89	225	330	29	854	364	179	543	30	43	29	102
"n"	22	5	8	29	29	21	6	8	29	3	30	25	24	25	7	7	8	8
Mean*	6.7	9.9	12.1	8.2	18.3	8.6	14.8	28.1	11.4	9.7	28.5	14.6	7.5	21.7	4.3	6.1	3.6	12.8
% Mtrl	27.6	9.30	18.2	44.6		21.2	10.4	26.4	38.6	3.4		67.0	33.0		29.4	42.2	28.4	

crdb = corrugated cardboard, magz = magazines, news = newspaper, rbsh = rubbish, TOTL = all materials, ppr = total papers.

* Mean is total weight divided by number of samples taken, not length of sampling period

Table 20 (continued).

	CONVNCESTRE 1				CONVNCESTRE 2				FLOWERSHOP 1				STEREO SHOP 1					CAMERA SHOP 1						CLOTHING STORE 1			
date	crdb	rbsh	TOTL	X	crdb	rbsh	TOTL	X	crdb	rbsh	TOTL	X	crdb	ppr	rbsh	TOTL	X	crdb	ppr	plst	rbsh	TOTL	X	crdb	ppr	rbsh	TOTL
23-Oct													18	18	41	77											
24-Oct	39																										
25-Oct			0																								
26-Oct	22	24	46																								
27-Oct	16																	22.0	2.0	1.0	6.0	31					
28-Oct	16	78	94																								
29-Oct	47																										
30-Oct	74	60	134										1.0		26.0	27.0		12.0		1.0	11.0	24		35	1.0	8.0	44.0
31-Oct	31																										
01-Nov	38																										
02-Nov	60	39	99																								
03-Nov	51																										
04-Nov	54	16	70		102	54	156						16	8	135	158											
05-Nov	154																										
06-Nov	140	146	286																					26		13	39
07-Nov	63																										
08-Nov	60				138		138																				
09-Nov	92	35	127						18	54	72																
10-Nov	26								34	66	100																
11-Nov	19				82	52	134		24	40	64		12	2	106	120		22	6	1	26	55					
12-Nov	157	63	220						12	123	135																
13-Nov									5	81	86													22	2	13	37
14-Nov																											
15-Nov					170	154	324																				
16-Nov									18	29	47																
17-Nov									18	81	99																
18-Nov					88	55	143		27	43	70							13	2		11	26					
19-Nov									41	102	143																
20-Nov									7	47	54		5	5	47	57								15	3	11	28
21-Nov									35	70	105																
Totals	1159	461	1076		580	315	895		239	736	975		52	33	354	439		69	10	3	54	136		98	6	45	148
"n"	19	8	9		5	4	5		11	11	11		5	4	5	5		4	3	3	4	4		4	3	4	4
Mean*	61.0	57.6	119.5		115.9	78.8	178.9		21.7	66.9	88.6		10.4	8.1	70.8	87.7		17.3	3.3	1.0	13.5	34.0		24.5	1.8	11.1	37.0
% Mtrl									24.5	75.5			11.9	7.4	80.7			50.7	7.4	2.2	39.7			66.2	3.7	30.1	

crdb = corrugated cardboard, magz = magazines, news = newspaper, rbsh = rubbish, TOTL = all materials,
ppr = total papers.

* Mean is total weight divided by number of samples taken, not length of sampling period

Table 21. Modified waste stream composition, by volume, of ten retail firms, East Lansing, Michigan, October 23 - November 21, 1987 (in cubic feet).

	BOOKSTORE 1						BOOKSTORE 2				whte			BOOKSTORE 3				BOOKSTORE 4			
date	crdb	magz	news	rbsh	TOTL	X	crdb	magz	news	rbsh	ppr	TOTL	X	crdb	rbsh	TOTL	X	crdb	ppr	rbsh	TOTL
23-Oct																					
24-Oct	4				4					2		2		9	6	14					
25-Oct										2		2									
26-Oct							4			2		6		1	4	5					
27-Oct	8			2	9		1			4		7		8	8	16		1	1	1	3
28-Oct	2			4	6		1	1		4		6		7	5	12					
29-Oct	2	0	1	4	7		1	0		4		5		5	6	11					
30-Oct	3			2	5		0			4		4		5	2	7		2	1	2	4
31-Oct							0.01			4		4		2	4	6					
01-Nov	1			4	5					2		2									
02-Nov	3			6	9			3		3		7		4	2	6					
03-Nov	6			2	8		10			8		18		8	8	16					
04-Nov	5			2	7			1		3		4		3	1	4		1	0	3	4
05-Nov	2	2	2	4	10					4		4		3		3					
06-Nov	2			3	5		1			3		4		2	2	4		0.4	1	1	1
07-Nov	2			2	3			2		3		4		8	1	9					
08-Nov				4	4					3		3									
09-Nov	3	1	1	5	9		4			4		8		1	1	2					
10-Nov	2	1	1	4	7		1	1	1	4		6			4	4					
11-Nov	1			2	3		2			3	1	6		6	2	8		2	2	1	5
12-Nov	6				6					2		2		1	2	3					
13-Nov	4			4	8				0	6	0	6		2	4	6		2	2	1	4
14-Nov	2			1	3		2			2		5		4	4	8					
15-Nov	1		1	4	6					2		2									
16-Nov		1	1	4	5		3			4		7		4	4	8					
17-Nov	3		2	4	9					4		5		12	4	16					
18-Nov			0	3	3		1	1	1	4		7		12	4	16		2	1	1	3
19-Nov	1			4	5		1			2		3		4	6	10					
20-Nov	4			2	6		2	1	2	5	1	10		11	1	11		0	1	1	1
21-Nov	1			3	4					2		2		4	11	14					
Totals	65	4	7	78	154		33	8	4	98	1	148		124	94	214		9	7	9	26
"n"	23	5	8	24	26		16	8	4	29	3	29		24	24	25		8	8	8	8
Mean*	2.8	0.7	0.9	3.2			2.1	1.0	0.9	3.4	0.5			5.2	3.9			1.2	0.9	1.1	
% Mtrl	42.0	2.4	4.6	50.5			23.1	5.7	2.6	67.6	0.7			57.0	43.3			36.4	28.7	35.3	

crdb = corrugated cardboard, magz = magazines, news = newspaper, rbsh = rubbish, TOTL = all materials, whte ppr = white paper, ppr = total papers, plst = plastic.

* Mean is total volume divided by number of samples taken, not length of sampling period

Table 21 (continued).

	CONVNCESTRE 1			CONVNCESTRE 2			FLOWERSHOP 1			STEREO SHOP 1				CAMERA SHOP 1					CLOTHING STORE 1			
date	crdb	rbsh	TOTL	crdb	rbsh	TOTL	crdb	rbsh	TOTL	crdb	ppr	rbsh	TOTL	crdb	ppr	plst	rbsh	TOTL	crdb	ppr	rbsh	TTLS
23-Oct										4	2	5	11									
24-Oct	8.8		9																			
25-Oct	5.0		5																			
26-Oct	9.1	8.0	17				10		10													
27-Oct	5.7		6											7	0.5		6.5	14.1				
28-Oct	7.4	21.0	28																			
29-Oct	12.3		12																			
30-Oct	17.2	9.4	27							0.4		8.0	8.4	5		0.7	8.0	13.9	17	4.0	4.0	25.0
31-Oct	9.7		10																			
01-Nov	11.3		11																			
02-Nov	6.3	17	23				1		1													
03-Nov	12.7		13																			
04-Nov	15.4	8	23	20	16	36				7	2	9	18									
05-Nov	22.0		22																			
06-Nov	28	55	83																8	6	2	16
07-Nov	18		18																			
08-Nov	10		10	36	4	40																
09-Nov	12	10	22				7	11	18													
10-Nov							14	12	26													
11-Nov	8		8	13	11	23	3	8	11	7	0	8	16	7	4	0		11.3				
12-Nov	21	24	45				7	25	33													
13-Nov							1	19	21										7	6	6	19
14-Nov																						
15-Nov				39	42	81																
16-Nov							8	8	16													
17-Nov							2	22	24													
18-Nov				12	16	28	5	8	13	2	1	7	9	7	1		12	19.5				
19-Nov							6	18	24													
20-Nov							3	6	9										6	3	6	15
21-Nov							19	19	38													
Totals	239	152	294	120	88	208	87	157	233	16	3	32	43	26	6	1	27	59	38	19	18	75
"n"	19	8	19	5	5	5	13	11	13	5	4	5	5	4	3	2	3	4	4	4	4	4
Mean*	12.6	19.0		23.9	17.6		6.7	14.3		3.2	0.8	6.4		6.5	1.8	0.3	8.8		9.5	4.8	4.5	
% Mtrl	61.2	38.8		57.6	42.4		35.5	64.3		31.1	5.9	62.7		44.4	9.4	1.7	45.1		50.7	25.3	24.0	

crdb = corrugated cardboard, magz = magazines, news = newspaper, rbsh = rubbish, TOTL = all materials, whte ppr = white paper, ppr = total papers, plst = plastic.

* Mean is total volume divided by number of samples taken, not length of sampling period

Table 22. Summary statistics from daily sampling, weight data, East Lansing retail firms, fall, 1987 (in pounds).

	total crdbd	total waste	"n" samples crd/wst*	-----cardbrd------- min	max	range	mean	------crdbrd------ smple sd	lower c.i.	upper c.i.
Convnce-1	615	461	8/8	16	157	141	76.9	50.9	47.3	106.5
Convnce-2	359	315	4/4	82	170	88	89.8	31.2	64.1	115.4
Flower-1	239	736	11/11	5	41	36	11.7	11.1	6.2	17.2
Book-1	147	239	22/29	0	17	17	6.7	4.4	5.2	8.2
Book-2	181	329	21/29	0	24	24	8.6	7.6	5.9	11.3
Book-3	364	179	25/24	0	35	35	14.6	8.9	11.6	17.5
Book-4	30	29	7/8	0	8	8	6.1	2.0	4.9	7.4
Clothing-1	98	44	4/4	15	35	20	24.5	8.4	17.6	31.4
Camera-1	69	54	4/4	12	22	10	17.3	5.5	12.7	21.8
Stereo-1	52	355	5/5	1	18	17	10.4	7.2	5.1	15.7
GRAND MEAN			111				18.5			

* First number is for OCC samples, second number is rubbish samples.

Table 23. Summary statistics from daily sampling, volume data, East Lansing retail firms, fall, 1987 (in cubic feet).

	total crdbd	total waste	"n" smples crd/ws*	--------cardboard-------- min	max	range	mean/ smple	smple sd	lower c.i.	upper c.i.
Convnce-1	115.0	152.0	8/8	5	28.0	23.0	14.4	7.5	10.0	18.8
Convnce-2	120.0	89.0	5/5	13	39.0	26.0	24.0	12.8	14.6	33.4
Flower-1	75.0	156.0	11/11	1	19.0	18.0	6.8	5.4	4.1	9.5
Book-1	68.0	79.0	23/24	1	8.0	7.0	3.0	1.9	2.3	3.6
Book-2	34.0	99.0	15/29	1	10.0	9.0	2.3	2.4	1.2	3.3
Book-3	126.0	96.0	24/24	1	12.0	11.0	5.3	3.4	4.1	6.4
Book-4	10.4	11.0	7/8	0.4	2.0	1.6	1.5	0.7	1.1	1.9
Clothing-1	38.0	18.0	4/4	6	17.0	11.0	9.5	5.1	5.3	13.7
Camera-1	26.0	26.5	4/4	5	7.0	2.0	5.2	3.0	2.7	7.7
Stereo-1	20.4	37.0	5/5	5	9.0	4.0	4.1	3.0	1.9	6.3
GRAND MEAN			106				5.9			

* First number is for OCC samples, second number is rubbish samples.

Table 24. Material composition results for East Lansing retail firms participating in waste stream study, fall, 1987 (in percentages, from volume).

	"n"*	cardboard						
	smples	min	max	range	mean/ smple	smple sd	lower c.i.	upper c.i.
Convnce-1	8/8	26.1	65.8	39.8	46.6	15.9	37.4	55.9
Convnce-2	5/5	42.8	91.2	48.4	58.4	19.0	44.4	72.4
Flower-1	11/11	7.2	53.7	46.5	32.3	16.1	24.3	40.3
Book-1	23/24	11.4	81.1	69.7	42.2	22.7	34.4	49.9
Book-2	15/29	5.9	65.5	59.6	31.0	17.9	23.3	38.6
Book-3	24/24	21.8	95.4	73.6	55.1	19.4	48.5	61.6
Book-4	7/8	24.5	54.3	29.8	37.0	9.3	31.2	42.7
Clothing-1	4/4	37.6	68.0	30.4	48.8	13.7	37.5	60.1
Camera-1	4/4	33.3	50.3	17.0	40.4	8.8	33.1	47.7
Stereo-1	5/5	4.8	46.2	41.5	28.3	17.1	15.7	40.9
GRAND MEAN	106				42.8			

*First number is for OCC samples, the second for rubbish samples.

Table 25. Detailed waste sort, by volume and weight, of retail firms particpating in waste stream study, November, 1987, East Lansing, Michigan (in percentages, cubic feet, and pounds).

waste category	Bookstore-1 volume	Bookstore-1 %age volume	Bookstore-1 weight	Bookstore-1 %age weight	Bookstore-2 volume	Bookstore-2 %age volume	Bookstore-2 weight	Bookstore-2 %age weight	Bookstore-3 volume	Bookstore-3 %age volume	Bookstore-3 weight	Bookstore-3 %age weight	Bookstore-4 volume	Bookstore-4 %age volume	Bookstore-4 weight	Bookstore-4 %age weight
newspaper 1_/	0.50	16.67	2.00	22.22	2.50	27.47	7.00	30.43								
office paper	1.00	33.33	1.00	11.11	0.81	8.90	2.00	8.70	0.49	10.60	1.00	10.00	0.33	21.85	1.00	10.00 2_/
other paper					0.49	5.38	1.00	4.35								
corrugated crdbrd	0.49	16.33	1.00	11.11	2.16	23.74	3.00	13.04	0.48	10.40	4.00	40.00 3_/	0.16	10.60	2.00	20.00 3_/
plastics, film	0.04	1.33	1.00	11.11	0.65	7.14	1.00	4.35	2.00	43.29	1.00	10.00	0.04	2.65	1.00	10.00
plastics, rigid	0.16	5.33	1.00	11.11	0.04	0.44	1.00	4.35	0.16	3.46	1.00	10.00				
glass, non-rtrnble					0.33	3.63	3.00	13.04					0.08	5.30	1.00	10.00 4_/
plant cuttings																
food waste					0.33	3.63	1.00	4.35					0.04	2.65	1.00	10.00
paper food cntnrs													0.33	21.85	1.00	10.00
plstc/styrfm cntnrs	0.16	5.33	1.00	11.11	0.98	10.77	2.00	8.70	0.49	10.60	1.00	10.00	0.16	10.60	1.00	10.00
styrofoam packing																
packing paper									1.00	21.64	1.00	10.00				
office supplies													0.04	2.65	1.00	10.00
rubbish	0.65	21.67	2.00	22.22	0.81	8.90	2.00	8.70			1.00	10.00	0.33	21.85	1.00	10.00
other																
totals	3.00	100.0	9.00	100.0	9.10	100.0	23.00	100.0	4.62	100.0	10.00	100.0	1.51	100.0	10.00	100.0

notes

1_/ includes brown bags and wrapping paper
2_/ includes other papers, including newspaper and office paper
3_/ includes chipboard
4_/ non-returnable glass

Table 25 (continued).

waste category	Convencience Store-2- vol	%age vol	wght	%age wght	Florist Shop-1 vol	%age vol	wght	%age wght	Camera Store-1 vol	%age vol	wght	%age wght	Clothing Store-1 vol	%age vol	wght	%age wght	Stereo Shop-1 vol	%age vol	wght	%age wght	
newspaper 1_/	3.39	25.1	3	10.7	2.00	12.4	1	2.0					0.65	13.1	1	6.3	0.49	4.5	2	6.5	
office paper	0.33	2.4	1	3.6	0.49	3.0	2	3.9					0.49	9.9	1	6.3	1.00	9.1	4	12.9	
other paper	0.65	4.8	1	3.6					0.50	9.3	1	8.3					0.49	4.5	2	6.5	
corrugated crdbrd	4.49	33.3	6	21.4	2.00	12.4	3	5.9					0.16	3.2	1	6.3	2.00	18.3	3	9.7	
plastics, film	1.14	8.5	1	3.6	3.00	18.6	2	3.9	3.00	56.0	5	41.7	0.49	9.9	1	6.3	0.33	3.0	2	6.5	3_/
plastics, rigid	0.49	3.6	1	3.6	1.30	8.1	1	2.0					0.49	9.9	1	6.3					
glass, non-rtrnble					0.08	0.5	1	2.0	0.03	0.6	1	8.3									
plant cuttings					6.00	37.3	33	64.7													
food waste	0.17	1.3	4	14.3									0.03	0.7	1	6.3					
paper food cntnrs	0.16	1.2	2	7.1	0.65	4.0	1	2.0	0.49	9.1	1	8.3	1.00	20.2	2	12.5	0.98	8.9	2	6.5	
plstc/styrfm cntnr	0.81	6.0	1	3.6	0.08	0.5	1	2.0	0.33	6.2	1	8.3	0.44	8.9	1	6.3	5.00	45.7	1	3.2	
styrofoam packing					0.33	2.1	1	2.0					0.16	3.2	1	6.3			1	3.2	4_/
packing paper																					
office supplies																					
rubbish	0.98	7.3	4	14.3	0.08	0.5	2	3.9	0.98	18.3	2	16.7	1.00	20.2	5	31.3					
other																					
--ferrous metal	0.04	0.3	1	3.6					0.03	0.6	1	8.3	0.03	0.7	1	6.3					
--rtrnble popcan	?		1	3.6																	
--rtrnable glass	0.83	6.2	2	7.1																	
--textiles							1	2.0													
--wood					0.08	0.5	1	2.0													
--aersol can and lightbulb							1	2.0													
--carpet																	0.33	3.0	2	6.5	
--1 gallon paint can																	0.33	3.0	12	38.7	
totals	12.7	100.0	28	100.0	16.1	100.0	51	100.0	5.36	100.0	12	100.0	4.95	100.0	16.00	100.0	10.95	100.0	31	100.0	

1_/ includes brown bags and wrapping paper
2_/ includes chipboard, also
3_/ includes rigid plastic, also
4_/ includes paper packing, also

Table 26. Waste stream composition, by weight, of six East Lansing restaurants and bars, October 20 - November 21 and December 6 - 20, 1987 (in pounds, food wastes not included).

	R&BAR-1						R&Bar-2					R&BAR-3					R&BAR-4			R&BAR-5			R&BAR-6		
date	crdb	glass	plst	alum	tin	TOTL	crdb	alum	tin	plst	TOTL	crdb	glass	tin	plst	TOTL	crdb	glass	TOTL	crdb	glass	TOTL	crdb	glass	TOTL
20-Oct	14	38				52																			
23-Oct	39	24				63																			
25-Oct	35	83				118																			
28-Oct	14	42	3	1	10	70																			
30-Oct	44	17	11			72																			
21-Nov		11				11																			
02-Nov	72	58				130																			
06-Nov	8	36			3	47																			
09-Nov	70	57				127																			
13-Nov	9	101				110																			
16-Nov	83	36			8	127																			
07-Dec	14	38				52	22		17		39	37	3	8	0	48							11		11
08-Dec	39	24				63	27	1	2	6	36						44		44	14		14	12	25	37
09-Dec	35	83				118	25				25						27	36	63					28	28
10-Dec	14	42	3	1	10	70	14				14	24	0	7	32	63	32		32				28	30	58
11-Dec	44	17	11			72					0						54		54				46		46
12-Dec		11				11						36	27	0	0	63							14		14
13-Dec	72	58				130																	14		14
14-Dec	8	36			3	47						40	0	11		51	27		27				18		18
15-Dec	70	57				127											38		38	51	114	165	8	50	58
16-Dec	9	101				110											17		17				16		16
17-Dec	83	36			8	127	26				26	47	19	0		66	24		24				14	16	30
18-Dec																	56		56	14	41	55	12	13	25
19-Dec																									0
20-Dec												18	67	5	2	90		47	47	28	67	95	21	11	32
Totals	776	1006	28	2	42	1854	114	1	19	6	140	202	116	31	34	381	319	83	402	107	222	329	214	173	387
"n"	20	22	4	2	6	22	5	1	2	1	6	6	6	6	4	6	9	2	10	4	3	4	12	7	14
Mean*	38.8	45.7	7.0	1.0	7.0	84.3	22.8	1.0	9.5	6.0	23.3	33.7	19.3	5.2	8.5	63.5	35.4	41.5	40.2	26.8	74.0	82.3	17.8	24.7	27.6

crdb = corrugated cardboard, glass = all glass, plst = rigid HDPE, alum = aluminum, tin = steel food cans, TOTL = all materials

* Mean is total weight divided by number of samples taken, not length of sampling period

Table 27. Waste stream composition, by volume, of six East Lansing restaurants and bars, October 20 - November 21 and December 6 - 20, 1987 (in cubic feet, food wastes not included).

	R&BAR-1						R&Bar-2					R&BAR-3					R&BAR-4			R&BAR-5			R&BAR-6		
date	crdb	glass	plst	alum	tin	TOTL	crdb	alum	tin	plst	TOTL	crdb	glass	tin	plst	TOTL	crdb	glass	TOTL	crdb	glass	TOTL	crdb	glass	TOTL
20-Oct	4.5	2.0				6.5																			
23-Oct	11.1	2.0				13.1																			
25-Oct	10.2	4.0				14.2																			
28-Oct	4.8	3.0	2.0	0.4	1.0	11.2																			
30-Oct	9.7	0.5	1.1			11.3																			
21-Nov		0.5				0.5																			
02-Nov	20.4	4.0				24.4																			
06-Nov	4.4	2.0			0.5	6.9																			
09-Nov	16.7	4.0				20.7																			
13-Nov	3.8	6.7				10.5																			
16-Nov	31.5	2.0			0.5	34.0																			
08-Dec							5.8	0.5	1.0	4.0	11.3						10.1		10.1	3.5		3.5	2.8		2.8
09-Dec							7.2				7.2						5.5	2.0	7.5						
10-Dec							1.7				1.7	9.5		2.0	2.0	13.5	9.4		9.4				8.1		8.1
11-Dec											0.0						14.9		14.9				10.5		10.5
12-Dec												7.4	2.0			9.4							5.1		5.1
13-Dec																							5.2		5.2
14-Dec												9.5		4.0	0.5	14.0	0.0		0.0				5.5		5.5
15-Dec																	8.1		8.1	10.5	5.5	16.0	2.3	4.2	6.5
16-Dec																	4.1		4.1				9.0		9.0
17-Dec							10.0				10.0	10.6	1.0			11.6	6.9		6.9				5.4	1.0	6.4
18-Dec																	18.6		18.6	4.8	2.0	6.8	4.6	1.2	5.8
19-Dec																									
20-Dec												3.0	4.0	2.0	2.0	11.0		3.0	3.0	9.1	3.0	12.1	7.1		7.1
Totals	117	31	3	0	2	153	25	1	1	4	30	40	7	8	5	59	78	5	83	28	10	38	66	6	72
"n"	10	11	2	1	3	11	4	1	1	1	5	5	3	3	3	5	9	2	10	4	3	4	11	3	11
Mean*	11.7	2.8	1.5	0.4	0.7	13.9	6.1	0.5	1.0	4.0	6.0	8.0	2.3	2.7	1.5	11.9	8.6	2.5	8.3	7.0	3.5	9.6	6.0	2.1	6.5

crdb = corrugated cardboard, glass = all glass, plst = rigid HDPE, alum = aluminum, tin = steel food cans, TOTL = all materials

* Mean is total volume divided by number of samples taken, not length of sampling period

Table 28. Summary statistics from daily sampling, volume data, East Lansing restaurants and bars, fall, 1987 (in cubic feet).

	"n" samples	min	max	range	mean	smple sd	lower c.i.	upper c.i.
R&Bar-1								
cardboard	10	3.8	32	27.7	38.8	28.2	24.2	53.4
glass	11	0.5	7	6.2	45.7	27.4	32.1	59.3
"tin"	3	0.5	1	0.5	7.0	3.6	3.6	10.4
aluminum	1	0.4	0	0.0	1.0	0.0	1.0	1.0
plastic	2	1.1	2	0.9	7.0	5.7	0.4	13.6
R&Bar-2								
cardboard	5	1.7	7	5.5	22.8	5.3	18.9	26.7
"tin"	2	1.0	3	1.9	9.5	10.6	-2.8	21.8
aluminum	1	0.5	1	0.0	1.0	8.0	-17.6	19.6
plastic	1	4.0	4	0.0	6.0	0.0	6.0	6.0
R&Bar-3								
cardboard	6	3.0	11	7.8	33.7	10.7	26.5	40.9
glass	4	1.0	4	3.0	29.0	27.2	6.6	51.4
"tin"	4	2.0	4	2.0	7.8	2.5	5.7	9.8
plastic	2	0.5	2	1.5	17.0	21.2	-7.7	41.7
R&Bar-4								
cardboard	9	17.0	56	39.0	35.4	13.6	28.0	42.9
glass	2	36.0	47	11.0	41.5	7.8	32.5	50.5
R&Bar-5								
cardboard	3	14.0	51	37.0	31.0	18.7	13.3	48.7
glass	3	41.0	114	73.0	74.0	37.0	38.9	109.1
R&Bar-6								
cardboard	12	8.0	46	38.0	17.8	10.3	12.9	22.7
glass	7	11.0	50	39.0	24.7	13.4	16.4	33.0
GRAND MEANS								
cardboard	45				29.5			
glass	27				40.6			
"tin"	9				7.9			
aluminum	2				0.8			
plastic	5				10.8			

* Means are the total volume for each category divided by number of samples taken, not length of sampling period.

Table 29. Summary statistics from daily sampling, weight data, East Lansing restaurants and bars, fall, 1987 (in pounds).

	"n" samples	min	max	range	mean	sample sd	lower c.i.	upper c.i.
R&Bar-1								
cardboard	10	8.0	83.0	75.0	38.8	28.2	24.2	53.4
glass	11	11.0	101.0	90.0	45.7	27.4	32.1	59.3
"tin"	3	3.0	10.0	7.0	7.0	3.6	3.6	10.4
aluminum	1	1.0	1.0	0.0	1	0	1.0	1.0
plastic	2	3.0	11.0	8.0	7	6	0.4	13.6
R&Bar-2								
cardboard	5	14.0	27.0	13.0	22.8	5.3	18.9	26.7
"tin"	2	2.0	17.0	15.0	9.5	10.6	-2.8	21.8
aluminum	1	1.0	1.0	0.0	1.0	8.0	-12.2	14.2
plastic	1	6.0	6.0	0.0	6.0	0.0	6.0	6.0
R&Bar-3								
cardboard	6	18.0	47.0	29.0	33.7	10.7	26.5	40.9
glass	4	3.0	67.0	64.0	29.0	27.2	6.6	51.4
"tin"	4	5.0	11.0	6.0	7.8	2.5	5.7	9.8
plastic	2	2.0	32.0	30.0	17.0	21.2	-7.7	41.7
R&Bar-4								
cardboard	9	17.0	56.0	39.0	35.4	13.6	28.0	42.9
glass	2	36.0	47.0	11.0	41.5	7.8	32.5	50.5
R&Bar-5								
cardboard	3	14.0	51.0	37.0	31.0	18.7	13.3	48.7
glass	3	41.0	114.0	73.0	74.0	37.0	38.9	109.1
R&Bar-6								
cardboard	12	8.0	46.0	38.0	17.8	10.3	12.9	22.7
glass	7	11.0	50.0	39.0	24.7	13.4	16.4	33.0
GRAND MEANS								
cardboard	45				29.5			
glass	27				40.6			
"tin"	9				7.9			
aluminum	2				1.0			
plastic	5				10.8			

* Means are the total weight for each category divided by number of samples taken, not length of sampling period.

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