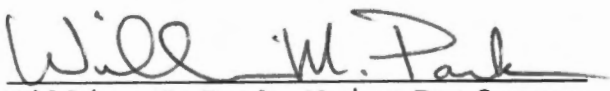
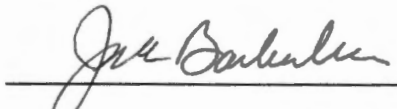
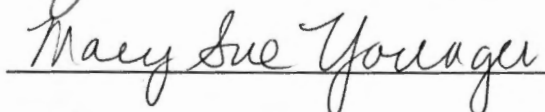


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A PILOT STUDY USING WASTEPLAN TO EVALUATE THE BENEFITS
OF REGIONALIZATION OF SOLID WASTE SERVICES
FOR THE UPPER CUMBERLAND DEVELOPMENT DISTRICT

A Thesis
Presented for the
Master of Science
Degree
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Jeffrey E. Case
August 1993

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ABSTRACT

The WastePlan computer software package was employed to estimate the potential cost savings from regionalization of some solid waste services in Middle Tennessee's Upper Cumberland Development District. This research project was undertaken with two objectives. The first of these was to explicitly estimate the cost savings that might result from multicounty cooperation through the establishment of regional facilities for processing of recyclables and landfill disposal. The other objective was to evaluate the WastePlan computer package itself in order to offer an assessment of its usefulness for solid waste management planning in rural areas. The required data were gathered from the Upper Cumberland Development District Needs Assessment.

Research revealed that substantial economies of size exist in the processing of recyclables and landfill disposal, and the economies of size associated with operation of these facilities outweigh the increased transportation costs that accompany a larger planning region. Compared to the case in which each of fourteen counties operated its own facilities, a scenario with only two regional facilities had 24% lower total system costs. In a scenario with only one of each of these facilities in the district, total costs were 30% less.

Although it is recognized that the cost estimates presented are not completely accurate, they do help to show

that there are economies of size present in the operation of solid waste management facilities. A major reason for these imprecise estimates is the fact that this research has abstracted from the very real problem of administrative costs. These type of costs arise whenever new political jurisdictions are created (as in a solid waste planning region) and are the result of the creation of a new organization or working arrangement. Since these costs are largely nonmonetary, it is difficult to compare them to the monetary costs involved with a solid waste planning region, but it can be generalized that the presence of administrative costs would reduce the most efficient region size.

WastePlan was found to be difficult to use for this type of analysis. The precision required for the inputs into the program often made them difficult to obtain and certain omissions from the software made modelling of accurate systems difficult. The fact the WastePlan is such a comprehensive planning tool makes it flexible enough to use in many situations, but it also makes a simple analysis more cumbersome. It was concluded that the WastePlan computer package is adequate for this type of analysis, but the time and effort required to employ it would preclude its use by most non-professionals.

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CHAPTER ONE

Introduction

Problem Statement

A serious problem facing rural communities in Tennessee today is that of how to manage the solid waste they produce. Until recently, most concern was focused on the portion of the state's garbage which originates in urban areas, but it has become increasingly evident that dealing with the remaining 23% produced in rural areas may represent an even greater challenge (CTAS--County Technical Assistance Service, 1991). With concern for the environment taking on a new role as a prominent issue in our time, the decisions made by managers at the local level are of increasing importance.

Rural communities face a wide array of solid waste management options as well as a complex set of regulations limiting those options. As Park (1993) points out, there are three key realities that rural communities face in planning for solid waste management in the near future.

The first reality is the increased regulatory control of local solid waste management decisions by state and federal authorities. Subtitle D of the Resource Conservation and Recovery Act mandates certain rules and procedures for the siting, design, operation, and closure/post-closure care of all municipal landfills whether they be public or private

concerns. In addition to guidelines governing landfill operations, Subtitle D calls for proof that the owner/operator of a sanitary landfill can provide adequate care and protection to the public after the landfill is closed. In most cases a bond must be purchased beforehand to assure the future financial security of the facility. The relatively high cost of compliance with these new regulations promulgated by the federal government falls ultimately on the community served by the landfill and constitutes a substantial burden for local governments, households, and businesses.

In addition, the state of Tennessee has sought to exercise greater control of solid waste management by passing The Solid Waste Management Act of 1991. This act designated each development district within the state as a solid waste management planning district. Furthermore, each solid waste management planning district was required to submit a needs assessment to the State Planning Office by September 30, 1992. The law also established a goal of a 25% reduction in solid waste entering disposal facilities by 1995. This reduction is expected to come primarily from the diversion of recyclables from the waste stream. Another important aspect of the state law is the requirement that all citizens have adequate access to collection services, meaning at least one convenience center in each county. It is hoped that this will decrease the incidence of roadside dumping and move presently unmanaged waste into a solid waste management system. This problem of

unmanaged waste is an important issue in rural areas throughout Tennessee (CTAS 1991, p.11).

The general rules coming from the federal government in the form of Subtitle D combined with the more specific regulations coming from The Solid Waste Management Act of 1991 mean that garbage collection and landfill disposal are now more expensive propositions. This situation puts rural citizens in a particularly precarious position compared to larger municipalities. Rural areas have land to use for landfills but lack the tax base and fiscal resources to make full use of it.

A second key reality facing rural communities involves the increasing concern and involvement of citizens in the solid waste management process. Such an attitude change is welcomed by waste management professionals because it shows that people are beginning to understand the gravity of the challenges they face. However, popular control of solid waste decision-making can be a problem in itself. The fact that Americans regularly use and understand anagrams such as NIMBY (Not In My Back Yard) demonstrates that our collective consciousness is attuned to these particular problems.

As more citizens become concerned with these issues, communication of accurate information becomes increasingly important. The public should have opportunities to participate in the entire solid waste planning process and be given proper incentives to achieve overall goals. This means

that pressure for effective solid waste planning is coming not only from increased state and federal regulation but from the citizens themselves.

The third key reality facing rural solid waste managers is the presence of substantial economies of size with respect to certain components of solid waste management systems. By taking advantage of the potential economies of size, rural communities can often substantially reduce the cost of solid waste processing and disposal. Identification of the most cost-effective approach to meet the new regulations as well as citizen demands for services is critical given the important and competing needs at the local level.

For most rural areas, this will mean looking at a the possibility of cooperation among counties, not only for landfill disposal, but also for processing and marketing of recyclables. The potential for lower costs with regional processing and disposal facilities has been well documented by various researchers whose work will be reviewed in a later chapter. Another benefit of regionalization, which is only now being recognized for its full importance, is the presence of a larger base for the marketing of recyclables. Given the crowded market for most recycled materials, negotiations for the sale of recyclable material can be strengthened by having increased volumes gathered over a larger area.

General Objectives and Procedures

In order to comprehensively and efficiently analyze the various solid waste management options facing a county or a multicounty region within the context of these key realities, it would appear that a microcomputer based planning tool could be very helpful. WastePlan, developed by the Tellus Institute, appears to be the most promising of all the planning tools available. The Tennessee Valley Authority has purchased a site license for the distribution of WastePlan to public or non-profit entities throughout the TVA region, but so far it has been used only sparingly.

Although acknowledged as a useful software package, local users have been slow to embrace WastePlan for their particular purposes and are skeptical of suggestions arising from its use. This skepticism constrains the use of WastePlan by planners and local officials in rural areas. Reasons for this resistance could include lack of expertise, lack of computer hardware, distrust of "black box" prescriptions, resistance to change in decision-making approaches, or a lack of appreciation of how WastePlan could help them solve their problems.

To a certain extent, such distrust is warranted. No planning tool can provide perfect information because no one region can be completely modelled. Monetary costs and institutional factors can only be approximated by computer but cannot be fully replicated. Any findings arising from the use

of WastePlan (or any software package) are inherently inaccurate to some degree. In the context of this study, cost estimates are presented "to the penny," but it must be understood that such precision is most helpful in facilitating relative comparisons among various systems, not in accurately predicting absolute cost levels for any one system.

The objectives of this research were two-fold. First, use of the WastePlan computer software package was to be evaluated to assess its potential usefulness by solid waste managers at the local or regional level. The most practical way to accomplish this objective was to conduct a case study application of WastePlan for solid waste management planning in a rural area of Tennessee. This leads to the second broad objective of this research, which was to evaluate alternative levels of regionalization for a rural area of Tennessee with the hope of providing some useful information for actual decision-making in that area and perhaps other rural areas within the state. The area chosen for the case study application was the Upper Cumberland Development District (UCDD), which is described in the next section of this chapter.

Informational inputs required to run WastePlan were gathered from the UCDD District Needs Assessment and by means of interviews with interested and knowledgeable parties within the district. The District Needs Assessment (DNA) is a catalog of information called for by The Solid Waste

Management Act of 1991. It includes demographic characteristics, characteristics of the waste stream, collection and transportation systems, source reduction and recycling programs, and solid waste management facilities. (Tennessee State Planning Office, 1991). Whenever WastePlan called for data not readily available from the DNA or local officials, default data built into the program or information from similar studies were used. In such cases efforts were made to check the reasonableness of the information with knowledgeable sources.

Using the information available, two regionalization scenarios were constructed. Costs associated with these scenarios were compared with each other and with costs of a Base Scenario in which each county had its own landfill and processing center for recyclables.

Description of Case Study Area

The fourteen counties that make up the Upper Cumberland Development District have more in common than contiguous borders. Being situated on the rough terrain of the Cumberland Plateau (See Appendix A), these counties are predominantly rural with small agricultural sectors, and their remote location in relation to Middle and East Tennessee's centers of commerce (Nashville and Knoxville) limit their potential for most industrial or commercial development. The district studied is sparsely populated and relatively poor. Roughly 18% of the population within the district had incomes

below the poverty line in 1979 (Tennessee Statistical Abstract 1990, pp. 94-97).

The largest city in the region is Cookeville in Putnam County, which had a population of 21,744 in 1990 (Cleland, 1992). Due to its central location and easy access to interstate transportation, Cookeville serves as the hub of commerce in the area as well as the location of the UCDD headquarters. Putnam County is also the largest county in the region having a population of 51,373 in 1990. In fact, Putnam County, including Cookeville, makes up approximately one-fifth of the population in the entire district as of 1990. Population per county averaged 18,000, ranging from a maximum of 51,373 in Putnam County to a minimum of 4,548 in Pickett County (See Figure 1.1).

The current solid waste management situation in the UCDD can be summarized as follows. Low population densities, as indicated in Figure 1.1, make it infeasible for many households to have any sort of scheduled house-to-house pick-up of garbage. Most counties have traditionally collected rural garbage using green boxes scattered throughout the county but have no formal county collection system, while a few counties have implemented at least one convenience center. Larger cities in the district usually provide some sort of municipal curbside pick-up of garbage. Once collected, garbage is generally disposed of in landfills. A few cities and counties in the district have just recently initiated

COUNTY	POPULATION (1990)	AREA (SQ.MI.)	POP./ SQ.MI.	SOLID WASTE GENERATED ^a (TONS/YEAR)
Cannon	10,467	265.7	39.4	6,841
Clay	7,238	236.1	30.7	5,519
Cumberland	34,736	681.6	51.0	29,521
Dekalb	14,360	304.6	47.1	10,822
Fentress	14,669	498.7	29.4	10,763
Jackson	9,297	308.9	30.1	5,725
Macon	15,906	307.1	51.8	11,317
Overton	17,636	433.4	40.7	11,467
Pickett	4,548	162.9	27.9	2,953
Putnam	51,373	401.0	128.1	46,194
Smith	14,143	314.4	45.0	10,617
Van Buren	4,846	273.5	17.7	3,010
Warren	32,992	432.7	76.2	28,638
White	20,090	376.7	53.3	15,674
Total	252,301	4,997.0	50.5	198,800

Source: UCDD District Needs Assessment, 1992.

- a. Tons/Year were generated using WastePlan default data combined with information from the UCDD. Specific assumptions regarding generation in the UCDD are fully discussed in Chapter Four.

Figure 1.1 Demographic Information for the Upper Cumberland Development District

recycling programs with the hope that a substantial part of the required 25% reduction in waste entering landfills can be met by diverting recyclables from the waste stream.

Five counties in the district generate less than 7,000 tons of solid waste each year¹ and only three counties generate over 16,000 tons per year (See Figure 1.1 and Appendix A). Cannon, Clay, and Jackson counties presently have no landfill and thus already rely on neighboring counties for the disposal of their solid waste. Only two of the remaining eleven counties have landfills with over ten years of life remaining. Additionally, the active landfills in the district may be faced with premature closure due to Subtitle D requirements that they be in compliance before their remaining life is exhausted.

Details of the assumptions regarding future solid waste management practices employed by cities and counties in the Base and regionalization scenarios are outlined in later chapters. While the intent was to incorporate reasonable and representative activities and facilities, no attempt is made to model specific characteristics of existing activities or facilities (e.g. particular pieces of equipment in existing processing centers or the exact location of an existing landfill).

¹Specific assumptions regarding generation of solid waste in the UCDD are fully discussed in Chapter Four.

CHAPTER TWO

WastePlan

This chapter addresses the use of the WastePlan computer software package for solid waste planning. A basic description of WastePlan is followed by discussions of data needs and examples of its application in various circumstances. Finally, the specific characteristics of WastePlan which are to be evaluated in this study are noted.

Basic Description of WastePlan

WastePlan is a modified spreadsheet software program designed by the Tellus Institute to allow for modelling and analysis of various solid waste management scenarios. The User Guide (1992) describes it in this way--"a tool which enables users to analyze economic and environmental impacts associated with potential waste management strategies." WastePlan is an integrated program in that it allows for incorporation of a full range of waste management strategies including source reduction, recycling, composting, resource recovery, and landfilling. It explicitly models the interrelationships between these strategies and generates output that can be analyzed by decision-makers. As such, WastePlan can be viewed as a means to achieve increased efficiency in the management of solid wastes.

Another purported strength of WastePlan is flexibility. The software is designed to accommodate local, regional, or even state analyses. This means that it is possible to identify economies of size in management of waste for various degrees of regionalization. Such adaptability allows managers to look as possible cost reductions for entire regions as well as the likely distributional effects of regionalization on local communities.

WastePlan is not the only solid waste management modelling tool on the market today, and when compared to other popular packages may be found stronger or weaker in some respects. In a comparison by Peter Engel (1991), WastePlan was pitted against two other popular solid waste software packages (NAPCOR/Eastman Chemical model and RecycleWare). Engel (1991) found that WastePlan was strongest in identifying the effect of regional cooperation on cost. The NAPCOR model was found useful for budgeting and program development and has proven itself more helpful in larger urban areas. RecycleWare is distributed by Recycle Worlds Consulting and, as the name implies, concentrates more on the development of recycling programs than comprehensive solid waste management planning. This package is geared for the community that has a clear idea of its recycling goals and seeks only to find the most efficient means for their achievement.

Default Data and Data Needs

WastePlan comes complete with representative data for a variety of characteristics routinely needed in solid waste management planning. Such characteristics include equipment costs, waste stream composition, and typical participation rates. The program also prompts the user to enter other relevant data such as population of the area under study, applicable interest rate, and types of facilities used. Once this information has been entered in the computer, the model is ready to run.

Potential users of WastePlan have expressed misgivings about the use of default data for analysis in Tennessee, and such concern is justified. The default data built into the model comes from comprehensive studies done in Michigan, contacts with officials throughout the country, and national averages. It is understandable that waste managers are concerned about the possible error resulting from using Michigan data in Tennessee, but that contingency is addressed by the Tellus Institute. First, Tellus personnel strongly urge using local data whenever possible and acknowledge that their built-in default data is not meant to be a substitute for local figures. Second, the Tellus Institute has published a Default Data Report (1989) which details the compilation and relevant assumptions used in the gathering of default data in the model. This report references the default data present,

explains local influences, and serves as a reference for the use of WastePlan itself.

WastePlan Applications

WastePlan has been used in several states to evaluate solid waste management strategies. One such example is the study of solid waste management in Vermont (Tellus, 1991). In this study WastePlan was employed to model the effects of regional cooperation among different numbers of waste management districts and the costs associated with each option. The model evaluated options involving eleven waste planning districts, four waste planning districts, and two waste planning districts. The trade-offs between processing and transportation costs were explicitly determined and economies of size were identified. Through the use of WastePlan, costs and outcomes were projected for each of the different options, and the least-cost number of districts was identified as four. Due to the flexibility inherent in the WastePlan model, it was possible to perform an extensive sensitivity analysis to identify factors affecting determination of the lowest cost option.

In Tompkins County, New York, WastePlan was used to evaluate a new municipal solid waste management system (Ditz and Velicer, 1991). In this case local data available for use were rather incomplete, so it was necessary to rely heavily upon default data. The relevant problem was to determine the proper sizing of recycling facilities under different

collection scenarios and capture rates. In reality, the task was much like the analysis done in Vermont which was mentioned earlier--to identify possible savings associated with different participation rates and facility sizes. The case in Tompkins County demonstrates a very practical approach to waste management issues. By making budget costs of various options explicit, a more holistic determination of the optimal decision could be achieved while keeping in mind important political and distributive considerations.

A case study of WastePlan's module for the collection and recycling of yard waste and compost material was also undertaken in this New York study. The format of WastePlan's reports also facilitates the determination of avoided costs of landfill diversion as well as strict nominal monetary values associated with cost savings from economies of size. This proved particularly useful in evaluating total benefits (actual benefits + avoided costs) for the different options studied.

Evaluation of WastePlan in this Study

A major objective of this research was to provide a critical analysis of WastePlan as a local solid waste management tool. Possible reasons for skepticism or resistance to the use of WastePlan were mentioned earlier and relate primarily to uncertainties about WastePlan characteristics and performance. Basic questions that need to be answered include the following:

- 1) What kind of equipment is needed to run this program?
- 2) Is this program "user friendly?"
- 3) How much technical knowledge of solid waste management is required?
- 4) What kind of local data is needed as inputs into the program and how difficult is it to obtain?
- 5) How reliable is the default data?
- 6) Is WastePlan flexible enough to adapt to different types of analyses?
- 7) Do the reports provide the type of information that is really needed?

Sound answers to these important questions should help to reduce the uncertainty surrounding WastePlan's potential usefulness for local solid waste management.

CHAPTER THREE

Basic Economic Theory and Review of Literature

In this chapter basic economic theory related to regionalization of solid waste services is outlined and placed within the context of the broad array of benefits and costs associated with multicommunity cooperation. Secondly, previous research dealing with potential cost savings from regional cooperation is reviewed.

The Economics of Regionalization in Solid Waste Management

Previous studies of regional cooperation in solid waste management have focused on the possible benefits from taking advantage of economies of size in the processing of recyclables and the disposal of garbage. Before a discussion of the potential for reducing costs by exploiting economies of size in those activities can be attempted, it is necessary to clarify exactly what economies of size are and why they exist.

"Economies of size" refers to the reduction in average cost per unit that generally occurs when the quantity of solid waste handled is increased. A solid waste management system that handles 20,000 tons of solid waste per year can be expected to have a lower cost per ton than a system that handles 10,000 tons, which in turn can be expected to have a lower cost per ton than a system handling 5,000 tons per year.

There are two reasons why economies of size occur in solid waste management: (1) the possibility of utilizing fixed inputs to full capacity in the short run (2) the long run ability to use advanced technological developments and/or larger machines which do the same work at a lower unit cost (Leftwich, p. 211). In the short run all inputs used in the solid waste management process are fixed, so no economies of size due to technological changes can occur in the short run. This means that any economies of size exploited in the short run are the result of increased efficiency given the same equipment. Therefore, economies of size in the short run are generally the result of more efficient utilization of unused capacity in existing equipment.

The second reason for economies of size derives from using the most advanced technology to lower the unit cost of operation. Operating cost for producing almost any output can be lowered by automation, but automation can occur only in the long-run where inputs into the solid waste management process are flexible. In addition, doubling output capacity by the purchase of new technology usually doesn't require a doubling of the initial investment. Hence, a large piece of equipment with a given capacity will have a lower operating cost per unit than two smaller pieces of equipment summing to the same capacity. The fact that inputs in the solid waste management process are variable in the long-run allows for a reduction in cost per ton for the entire system.

Both of these types of economies of size are evident in the processing of recyclables. An example would be use of a baler for the compaction of cardboard. If this baler isn't being utilized to its full capacity, increasing the volume of cardboard to full capacity would make the process more efficient and lower the cost per ton for baling of cardboard. This takes advantage of economies of size resulting from full use of capacity in the short run. If the volume of cardboard coming to the processing plant were larger than could be handled by the original baler, investment in a larger, more efficient, baler could occur. Because of economies of size from technology, a larger baler could generally handle the volume of cardboard more efficiently. Lower unit cost resulting from the investment in a new baler would result from taking advantage of economies of size associated with new, more efficient, technology in the long run.

These same economies of size also occur to different degrees in landfill disposal. A landfill is generally constructed to be operational for a certain period of time before it is closed, but if that period of time elapses before capacity is reached, the space can still be utilized. In the case of a baler for cardboard, capacity not utilized in the present is lost forever (disregarding wear and tear saved). This difference means that economies of size in the short run aren't an important factor in explaining why larger landfills have a lower unit cost.

However, economies of size derived from technological factors account for lower costs of larger landfills. For example, the projected cost per ton for a landfill in Tennessee handling 25 tons per day is \$69.03, a landfill handling 50 tons per day, \$44.69, and a landfill handling 200 tons per day, \$22.55/ton² (CTAS, Appx. D). Cost per ton for landfill disposal decreases as volume increases because doubling a landfill's capacity doesn't necessitate a doubling of all costs associated with it. For example, total construction and development cost for a 25 ton per day landfill is \$710,000 while the same cost is \$2,650,000 for a 200 ton per day landfill. A landfill with eight times the capacity is constructed and developed for less than four times the expense. The same thing occurs for equipment costs. For the 25 ton per day landfill the cost is \$171,000, but for the 200 ton per day landfill, the equipment cost is \$312,500. Less than twice the cost is needed for a landfill with eight times the capacity.

The lower costs arising from economies of size associated with regional processing and disposal may be fully or partly offset by the increased cost of transportation associated with moving materials to a regional facility. This is especially important for rural areas with low population densities, because transportation costs may increase rapidly as the area

²These estimates assume a composite liner and public debt financing.

served is expanded. A point exists at which the increased cost of transportation completely offsets the potential cost reduction resulting. This is illustrated in Figure 3.1, in which the sum of processing/disposal costs and transportation costs yields a cost function with a minimum point at Q' tons of solid waste, which would correspond to a region of a particular size.

Up to this point in the discussion of regionalization, some very important factors have been ignored. There are costs associated with solid waste regionalization over and above the costs associated with processing and disposal solid waste. Some costs, such as those associated with the initial collecting of solid waste at the local level, would not vary much with the size of the region. However, other costs may vary greatly with the size of the region.

Shaffer (1992) has suggested that a "multicommunity collaborative effort" such as joining in a solid waste planning region requires a "new organization or working arrangement" which "entail costs for time, travel, and political capital. In addition, activities formerly done as volunteer efforts may now be monetized by hiring staff, conducting meetings and having a formal budget." Furthermore, handling problems from the perspective of a multicounty region can be quite different from the perspective of a single county, so decision criteria and accepted "rules of thumb" which were applicable for a single county may no longer apply

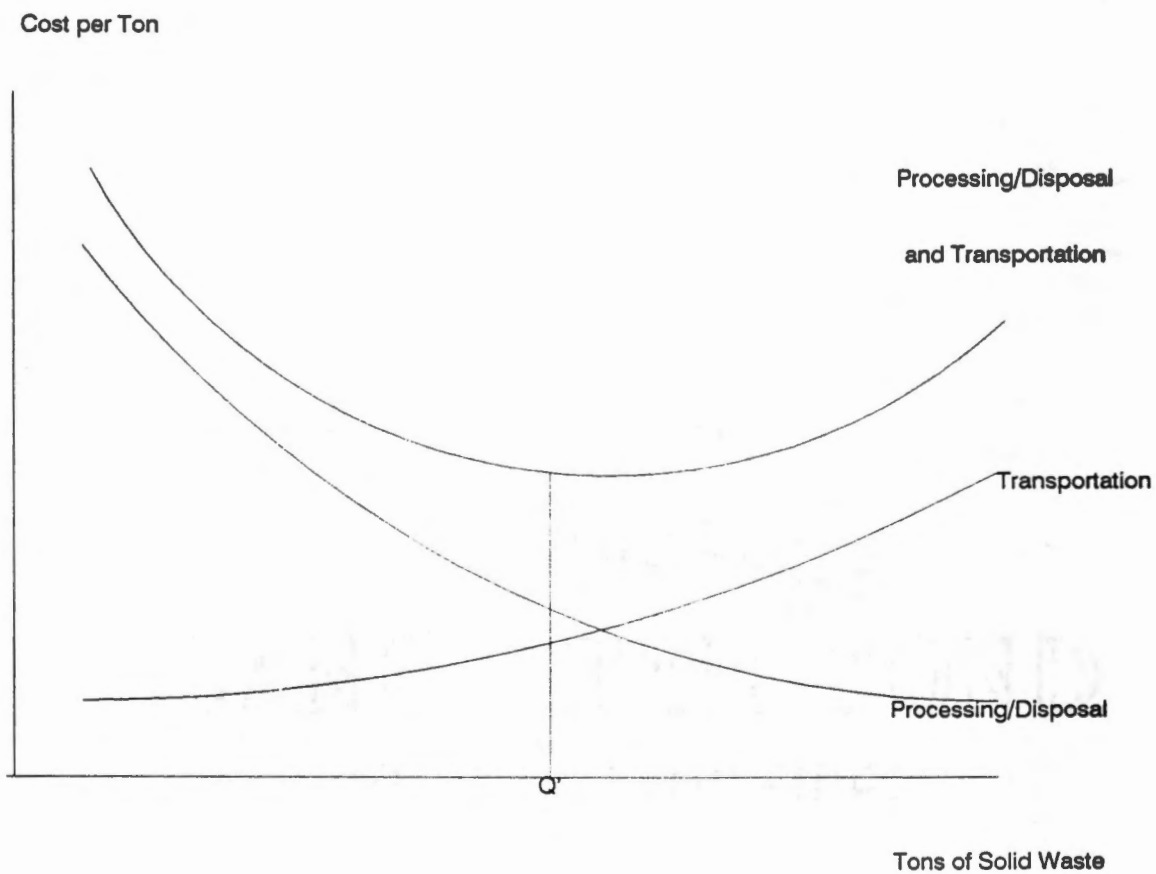
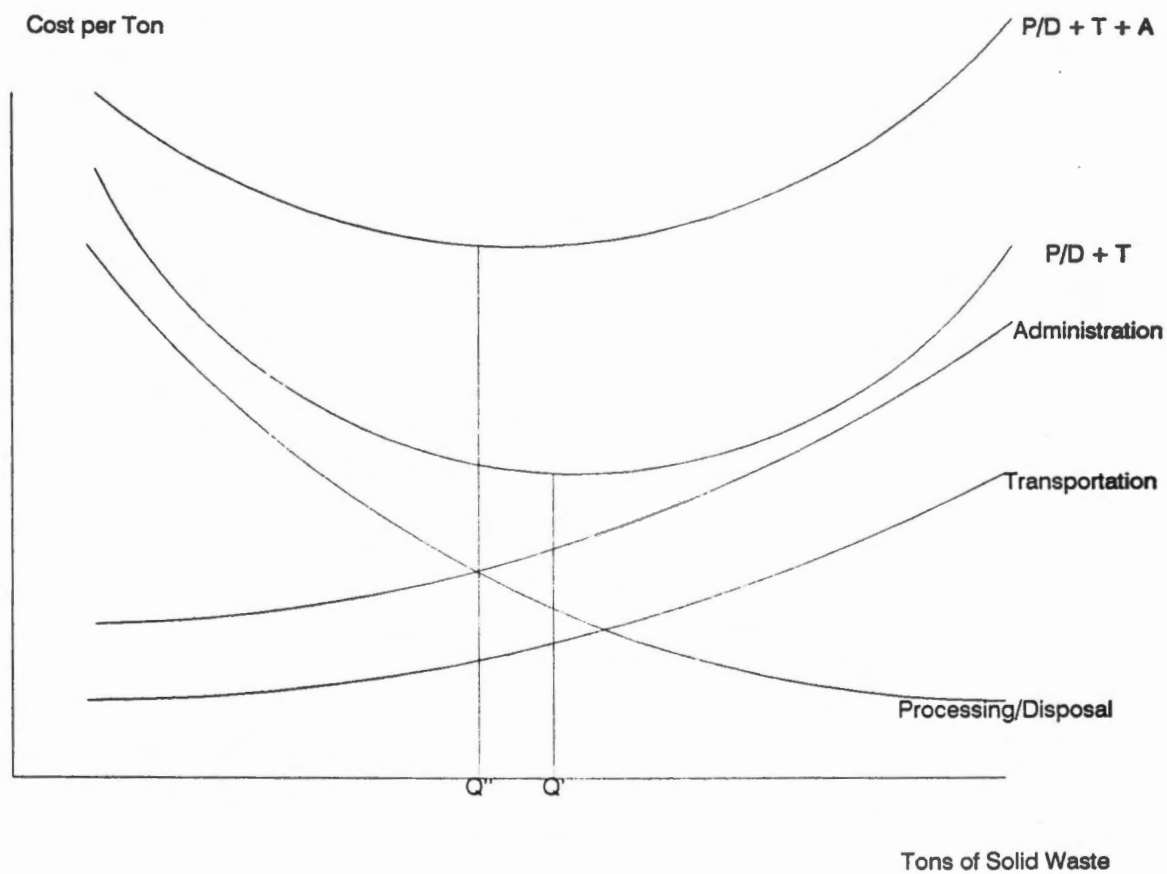


Figure 3.1 Cost Tradeoffs in Regionalization of Solid Waste Management

for an entire region. Costs such as these are subtle and tend to be nonmonetary in nature. Nevertheless, they constitute real economic costs that often preclude the achievement of cost savings possible from economies of size in the operation of solid waste facilities. These costs can generally be referred to as the "administrative" or "transactions" costs associated with establishing and maintaining new regional arrangements.

Having pointed out certain nonmonetary costs associated with multicommunity regions, Shaffer points out that there are also some nonmonetary benefits associated with regionalization. Larger regions provide "access to more resources, including financial resources and technical skills," and the political power associated with a larger constituency. Neighboring counties in a region are also among the first to help in times of crisis, and they help to devise new ideas for dealing with common problems.

While it would be difficult to predict or generalize, it is likely that the broader "administrative" costs of regionalization solid waste management could outweigh the broader benefits and be directly related to the number of communities in a region. The effect of these administrative costs on the "optimal" region size can be illustrated by Figure 3.2, where the administrative costs are added to the processing/disposal and transportation costs. Although the actual level of these additional costs may not be precisely



T = Transportation

A = Administration

P/D = Processing and Disposal

Figure 3.2 Effect of Administrative Costs on Optimal Region Size

measurable, it is clear that their presence reduces the optimal quantity of solid waste handled and thus the optimal region size or number of communities in the region.

Review of Previous Research

Several studies of the potential benefits of regionalization for solid waste management were identified for review. The first three focused on solid waste collection and disposal. The fourth study focused exclusively on the processing of recyclables. The last study addressed regionalization in both of these components. All of these studies concluded that the economies of size present justified serious consideration for some degree of regionalization.

Hardy and Grissom (1976) conducted one of the seminal pieces of research in the area of rural waste management. They studied a five county region of northwest Alabama to examine the possibility of cost savings through cooperative efforts in the collection and disposal of solid waste. They did this by formulating a programming model to find the least-cost system for collecting and disposing of the solid waste produced using data from Alabama Regional Planning District 1. Results of the study indicated that collection costs were dependent on population density and the size of the service area. Collection costs increased as the size of the region increased, but disposal costs decreased as the size of the region increased. The study concluded that total collection costs increased from \$237,206 for the five county region with

six landfills to \$249,319 with only one landfill. Conversely, total cost for landfill disposal decreased from \$356,985 with six landfills to \$236,661 for one landfill. Thus, the economies of size present in the disposal component outweighed the increased cost of transportation for the larger region. The sizeable cost savings were realized through less duplication of large equipment and increased operational efficiency.

Two separate case studies of rural Mississippi regions were conducted. One focused on the Three Rivers Region (Neel-Schaffer, 1990) and the other focused on the Pine Belt Region (Neel-Schaffer, 1991). Both studies examined possible cost savings resulting from three different degrees of landfill regionalization within each area. The first scenario in each study involved each city and county retaining responsibility for their own solid waste disposal requirements. The second involved two identical landfills for the entire region, while the third assumed one large landfill for the entire area. All landfills proposed in the study were assumed to meet Subtitle D regulations as proposed in the year of the study.

With each county and city operating a solid waste system autonomously, the average cost in the Three Rivers Region for landfill disposal was \$47.64/ton, while in the Pine Belt Region the cost averaged \$37.90/ton. For particular entities within the region disposal costs ranged from \$135.86/ton for Okalona to \$25.08/ton for the city of Tupelo in the Three

Rivers Region and from \$82.81/ton for Perry County to \$26.58/ton in Hattiesburg for the Pine Belt Region. For the scenario with two regional landfills, disposal costs averaged \$22.94/ton for the Three Rivers Region and \$23.14/ton for the Pine Belt Region. In the scenario with only one regional landfill the cost in the Three Rivers Region was \$18.51/ton and in the Pine Belt Region the cost was \$18.74/ton. Both cases showed that the increased transportation costs resulting from a larger region size would be more than offset by the lower disposal costs. Other possible advantages of one or two regional landfills noted were less trouble in the permitting process and avoidance of duplication of services.

In a case study of the First Tennessee Development District, Park, Holt, and Roberts (1991) explored the potential benefits of regionalization in the processing of recyclables collected in rural areas. The costs associated with transportation and processing were estimated and compared under two different scenarios. In the first case each county in the district was assumed to operate and maintain its own recyclables processing plant complete with the collection, processing, and marketing functions. In the second scenario a regional recycling system for the eight-county region was assumed in which processing and marketing of recyclables were done at a central site within the region.

The authors concluded that if all eight counties in the region joined together for the processing of recyclables, net

processing cost savings considering transportation costs, would range from 16.9% to 34.0% depending on the specific assumptions regarding processing and transportation costs (p. 15). They also examined the decision from the perspective of a single county in the region attempting to decide if it is practical for them to ship their residential recyclables to a pre-existing processing plant, assuming no payment to or from the county dropping off the materials. A break-even line for processing options facing a rural county in the region was constructed, which showed the combinations of distance to a pre-existing processing plant and volume of recyclables necessary before it became economically justifiable feasible for that county to construct a recyclables processing plant (p. 18). For all but one county, the lowest-cost option was to send recyclables to a regional processing facility.

The authors tempered their conclusions with two important qualifications. The analysis focused exclusively on residential recyclables. It was noted that if commercial recyclables were collected and processed along with residential materials, the results of the comparisons would differ, but the general conclusions would likely remain unchanged. Secondly, transactions costs associated with development of the institutional arrangements for regional cooperation were ignored but must be recognized as real costs offsetting the potential savings in operational costs.

The Tellus Institute, designers of the WastePlan software, used their solid waste planning tool to do a comprehensive analysis of waste management practices in the state of Vermont (1991). This research was mentioned briefly in an earlier chapter describing the WastePlan computer model. In the study WastePlan software and demographic information from the state were combined to perform an analysis which incorporated a full range of solid waste management options including leaf and yardwaste composting, waste to energy facilities, landfills, and recycling processing plants. WastePlan evaluated three scenarios involving different degrees of regionalization of the state's districts. Scenario I evaluated costs when each Vermont solid waste district developed a single facility for recycling and disposal. Scenario II split the state into four waste management regions while Scenario III split the state into two regions.

Not surprisingly, as the size of the region is increased, collection costs increase at a rate slower than facility costs decrease. An integrated system can therefore achieve a reduction in overall costs due to the increased efficiency in the operation of its facilities. Both Scenarios II and III were found to have significantly lower overall costs than the base scenario in which each county operated their own collection, processing, and disposal operations. Scenario II, with four districts, was the lowest cost option. Scenario III, with two districts, was 2% higher in overall costs. The

small difference in overall costs associated with the regional configurations was considered insignificant by the authors, given the nature of the assumptions made in the analysis.

Tellus noted that such a large and comprehensive analysis was inherently loaded with uncertainty. Broad assumptions regarding the costs of collection, costs of equipment, and cost of labor must be made if such an analysis is to be completed, but these assumptions compound the uncertainty of the research. For this reason, sensitivity analysis was performed to evaluate how changes in certain assumptions might affect the overall results. It was found that costs of garbage collection and disposal were similar for all three scenarios, but the recycling costs were the primary source of higher system costs in Scenario I. Sensitivity analysis also revealed that changes in assumptions regarding garbage collection and disposal had a larger effect on system costs than changes in assumptions regarding the cost of composting and recycling. This is due to the larger volume of garbage handled relative to recyclables or compost.

This review of the literature strongly indicates that there are substantial economies of size in the processing and disposal functions of a solid waste system. In each case study, the cost savings from taking advantage of these economies of size outweighed the additional transportation costs associated with larger solid waste planning regions, at least up to a certain point. However, one must recognize that

sweeping generalizations are not appropriate. The optimal degree of regionalization in any particular area will depend upon demographic and other characteristics in the region, as well as the broader benefits and costs discussed earlier in this chapter.

CHAPTER FOUR

Generation and Collection

In this chapter the development of information and inputs required for the generation and collection modules of WastePlan are discussed, along with the relevant assumptions concerning their use. In addition, a rough estimate of the tonnage of solid waste generated within each political jurisdiction, as well as projected costs for collection of garbage and recyclables, are reported.

Generation

The first step in this research was to determine the tonnage and composition of the solid waste that must be managed in the UCDD. Doing so required that certain assumptions be made to allow for simplification of a large and complex problem into a more manageable one. Throughout this discussion key assumptions are noted.

For the purposes of this study, the waste stream was split into two broad sectors--the residential sector and the commercial sector. Each of these sectors have a waste stream composition that is unique. The residential waste stream would include traditional household garbage along with any wastes produced at home. The commercial sector would encompass garbage generated by businesses and institutions such as schools, prisons, and hospitals. Together these two

sectors are assumed to make up the entire amount of waste generated in the UCDD.

A simplifying assumption was made to handle commercial collection within WastePlan. Each of the fourteen counties was split into two areas. One of these waste producing areas was the largest city in the county, whatever city that may be, while the other area within the county encompasses everything else. The "city" area was assumed to produce all commercial waste in the county as well as a proportional share of the residential waste. The other area (hereafter called the "rural" area) produced only the amount of residential waste proportional to its share of the population. This assumption facilitates the routing of waste in the collection systems without affecting the results of the regionalization scenarios to be examined.

In order to project the volume and composition of solid waste produced in the UCDD, the starting point used was the estimate that solid waste generation in the UCDD averages about 0.8 tons per person per year (UCDD District Needs Assessment, p. III-7). This is highly consistent with the statewide estimate for rural areas of 4.54 pounds of solid waste per person per day in 1989 (WMREI, p. S-3).

The next step was to determine the allocation of the total waste stream between the residential and commercial sectors. In the UCDD, with a population of about 250,000 in 1990 (Cleland, 1992), total generation would thus be

approximately 200,000 tons per year (0.8 tons per year x 250,000 persons).

Rather than arbitrarily split this total between the residential and commercial sectors, default generation and composition figures for the commercial sector from the WastePlan model were used. By entering the appropriate information regarding characteristics of each commercial sector into the program, the tonnage and composition of the commercial waste in the UCDD was projected. The information called for by the WastePlan program is shown in Figure 4.1, for the district as a whole. These characteristics include such things as retail sales, food sales, number of students, manufacturing employees, etc.³ Once the district's total commercial generation was determined, the information was entered for each county individually to obtain volumes and composition figures for each of the fourteen counties as well as for the entire UCDD.

The residential waste stream generated for the entire UCDD was determined by subtracting the commercial generation from the total generation, which yielded the total tonnage of residential solid waste. Residential waste for each particular county was determined by allocating the total

³Commercial inputs were supplied by Henry Bowman of the UCDD staff from sources such as the Tennessee Department of Revenue, the Tennessee Department of Employment Security, and the Tennessee Statistical Abstract.

SECTOR	ACTIVITY UNIT	NUMBER OF UNITS
Retail and Merchandise	Annual Sales (\$)	777,800,000
Furniture	Annual Sales (\$)	44,300,000
Food Stores	Annual Sales (\$)	379,000,000
Restaurants	Annual Sales (\$)	118,000,000
Schools	Number of Students	45,000
Nursing Homes	Number of Occupants	2,000
Hospitals	Number of Occupied Beds	1,000
Office Buildings	Sq. Ft. of Space	4,300,000
Large Manufacturing ^a	Number of Employees	29,000
Small Manufacturing	Number of Employees	1,600

Source: Henry Bowman, UCDD Headquarters.

a. Manufacturers are considered large if they have twenty or more employees. All others are categorized as small manufacturers.

Figure 4.1 Commercial Sector Characteristics Used to Project the Commercial Waste Stream for the UCDD

tonnage of residential waste among counties based on their percentage of total population within the district. For example, Putnam County has roughly 20% of the population of the district, so Putnam County was assumed to produce roughly 20% of the residential solid waste in the district.

The composition of the residential waste stream is based on an average of residential waste stream percentages from four composition studies conducted in rural areas of Mississippi similar to the UCDD (Neel-Schaffer, 1991, Table 1-4). These percentages are presented and compared with the waste stream percentages for the commercial sector in Figure 4.2. Not surprisingly, the percentage of corrugated cardboard produced is much greater in the commercial sector while households produce relatively more yardwaste.

A summary of solid waste⁴ generation used in the analysis, along with the area in which it originated, is presented in Figure 4.3.

General Description of Collection Systems

The collection and transportation of garbage and recyclables is the most logistically complicated process in the entire area of solid waste management, and routing the correct material to the correct facility at an appropriate cost is crucial if the results of this study are to be applicable. For this reason it was assumed that the

⁴Solid waste is assumed to be made up of both garbage and recyclables.

WASTE NAME	RESIDENTIAL PERCENTAGE ^a	COMMERCIAL PERCENTAGE
Newspapers	7.48	1.53
Other Paper	23.33	23.83
Cardboard	3.40	40.55
Glass	8.70	2.45
Textiles	3.78	0.99
Plastic Film	4.05	2.18
Rigid Plastic	3.48	2.16
Recyclable Plastic	2.58	1.96
Foodwaste	10.80	8.94
Wood/Lumber	0.35	4.73
Yardwaste	19.00	1.60
Ferrous Metal	4.00	3.16
Aluminum	1.58	0.27
Bulky Waste ^b	0.88	0.00
Miscellaneous	6.59	5.65
TOTAL	100.00	100.00

a. Adapted from Three Rivers Region Solid Waste Master Plan. Neel-Schaffer Engineers and Planners. April, 1991.

b. Bulky Waste is defined as large items such as bicycles, lawnmowers, and appliances.

Figure 4.2 Commercial and Residential Waste Stream Percentages for UCDD

COUNTY	POPULATION	RESIDENTIAL GENERATION	COMMERCIAL GENERATION	TOTAL GENERATION
CANNON	10,467	3,268	3,573	6,841
Rural	8,180	2,553	---	
Woodbury	2,287	715	---	
CLAY	7,238	2,256	3,263	5,519
Rural	5,745	1,791	---	
Celina	1,493	465	---	
CUMBERLAND	34,736	10,839	18,682	29,521
Rural	27,806	8,676	---	
Crossville	6,930	2,163	---	
DEKALB	14,360	4,482	6,340	10,822
Rural	10,569	3,299	---	
Smithville	3,791	1,183	---	
FENTRESS	14,669	4,575	6,188	10,763
Rural	12,807	3,995	---	
Jamestown	1,862	580	---	
JACKSON	9,279	2,899	2,826	5,725
Rural	8,277	2,587	---	
Gainesboro	1,002	312	---	
MACON	15,906	4,962	6,355	11,317
Rural	12,265	3,826	---	
Lafayette	3,641	1,136	---	
OVERTON	17,636	5,502	5,965	11,467
Rural	13,827	4,316	---	
Livingston	3,809	1,186	---	
PICKETT	4,548	1,417	1,536	2,953
Rural	3,550	1,108	---	
Byrdstown	998	309	---	
PUTNAM	51,373	14,140	32,054	46,194
Rural	29,629	7,296	---	
Cookeville	21,744	6,844	---	
SMITH	14,143	4,416	6,201	10,617
Rural	11,757	3,670	---	
Carthage	2,386	746	---	
VAN BUREN	4,846	1,511	1,499	3,010
Rural	3,721	1,161	---	
Spencer	1,125	350	---	
WARREN	32,992	10,295	18,073	28,368
Rural	21,798	6,803	---	
McMinnville	11,194	3,492	---	
WHITE	20,090	6,267	9,407	15,674
Rural	15,409	4,806	---	
Sparta	4,681	1,460	---	
TOTAL	252,283	76,829	121,962	198,800

Note: Rounding Error is present.

Figure 4.3 Solid Waste Generation for Counties and Selected Cities in the UCDD in Tons/Year

collection systems discussed in this chapter employed standard technologies and operated at maximum efficiency.

The distance that solid waste is transported within the county either to a landfill or to a recycling facility was assumed to be one half the average distance from the center of the county to the border. Such an assumption is reasonable because it relieves the necessity of modelling the facilities at a different sites within the county but accounts for the likelihood that counties with larger land areas will face higher transportation costs.

There are two broad streams of materials to be dealt with (garbage and recyclables), and two different sectors from which they originate (commercial and residential). Residential and commercial garbage in the largest city of each county is assumed to be picked up where it is generated and is transported directly to the local landfill facility. Residential garbage in rural areas is gathered by means of a convenience center system with an appropriate number of locations scattered throughout the county. A well designed convenience center system is widely believed to be the most efficient system for collection of rural solid waste because it provides a relatively low cost system of garbage collection, discourages roadside dumping, and is consistent with a dropoff approach to recycling.

City collection of residential recyclables is assumed to occur by means of unattended dropoffs from which materials are

transported to the local processing plant as needed. Recycling collection systems of this type are familiar sights at shopping centers throughout Tennessee. Commercial cardboard, which is assumed to be the only commercial material recycled in this system, is gathered at the site where it originates and is also transported directly to the processing plant. Rural collection of residential recyclables takes place at attended convenience centers where residential garbage is also collected. This allows a greater measure of quality control for the materials collected than in the case of unattended dropoffs, provides a base for recycling education programs, and improves public relations.

City Collection of Garbage

Modelling municipal collection of garbage entails making many of the same assumptions and simplifications as in the city collection of recyclables. However, there are important differences between characteristics of recyclables collection and garbage collection. The most basic of these is volume. The proportion of the waste stream collected as garbage to be landfilled far outweighs the amount of the waste stream diverted by recycling. Even with optimistic assumptions regarding the amount of recyclable materials collection, the collection of garbage requires more money and more administrative effort than collection of recyclables.

Initially, an attempt was made to develop a detailed model of curbside collection of residential garbage that would

be representative of what is used in the larger cities in the UCDD. However, but because information from the UCDD District Needs Assessment was often inconsistent in this area, the WastePlan module that allows for the precise design of a curbside collection system for garbage was not used. Instead, curbside collection of garbage in the cities of the UCDD was modelled on a fixed cost per ton basis.

Information on costs of curbside collection was taken from the Tellus study Analysis of Solid Waste System Costs for the State of Vermont (p. 4-8). Cost per ton for curbside garbage collection was scaled up or down depending on distance to the landfill and population. Landfill distance, when not reported in the District Needs Assessment, was assumed to be one-half the average distance from the center of the county to the border in the manner mentioned earlier.

For the commercial sector, a similar method was used to model disposal of garbage, with certain notable exceptions. In the Vermont study, the commercial and residential waste streams were merged into one so that the cost per ton reported reflected the average of both residential and commercial collection costs. It is generally accepted that collection of commercial garbage is less expensive than collection of residential garbage, so the average cost per ton for collection of municipal garbage drawn from the Vermont study was split into a commercial cost per ton and a residential cost per ton, with the former assumed to be only 40% as

expensive (Scott, 1993). The weighted average cost per ton for collection from the two sectors is equal to the figure reported from the Vermont study.

The tonnages of residential and commercial garbage projected for each of the fourteen major cities in the UCDD are shown in Figure 4.4. The mileage to the disposal facility is shown along with the average cost per ton for collection and transportation at that distance. The cost per ton for collection after segregation into commercial and residential sectors is also reported.

Rural Collection of Garbage

Rural collection of garbage has traditionally been one of the most difficult aspects of a solid waste collection system. Because of the distances involved, door-to-door collection in rural areas isn't considered to be economically feasible, even though traditional methods of rural disposal are now falling into disfavor for various reasons. For example, open burning of garbage is illegal in most cases because of the resulting air pollution, transporting garbage directly to the landfill is inconvenient for most residents, and "green box" systems are beset by problems such as scavenging, littering, vandalism, and burning.

From these circumstances, the convenience center system has emerged as the likely collection approach for rural areas of Tennessee. In fact, regulations promulgated by the state in The Solid Waste Management Act of 1991 require at least one

CITY	MILEAGE TO LANDFILL	RES. GARBAGE (TONS/YEAR)	COMM. GARBAGE (TONS/YEAR)	RES. COST/TON (\$)	COMM. COST/TON (\$)	AVG. COST/TON* (\$)
Woodbury	4.6	672	3,261	49.29	19.72	24.77
Celina	4.3	437	2,993	81.52	32.61	38.84
Crossville	15.0*	2,031	16,604	61.95	24.78	28.83
Smithville	16.0*	1,111	5,755	58.78	23.51	29.22
Jamestown	6.3	545	5,598	87.20	34.88	39.52
Gainesboro	5.0	293	2,588	84.77	33.91	39.08
Lafayette	13.0*	1,067	5,715	56.74	22.69	28.05
Livingston	3.0*	1,114	5,356	47.98	19.19	24.15
Byrdstown	3.6	290	1,413	76.87	30.75	38.60
Cookeville	10.0*	6,428	28,638	49.37	19.75	25.18
Carthage	1.0*	701	5,560	50.02	20.01	23.37
Spencer	4.7	329	1,399	75.80	30.32	38.98
McMinnville	5.9	3,280	16,218	46.33	18.53	23.21
Sparta	14.5*	1,372	8,518	59.27	23.71	28.64
TOTAL/AVG.	7.6	19,670	109,616	56.18	22.47	27.60

a. Adapted from Analysis of Solid Waste System Costs for the State of Vermont. Tellus Institute. July, 1990.

*These distances to the county landfill are taken directly from the UCDD District Needs Assessment. Others are computed as half the average distance from the center of the county to the border.

Figure 4.4 Estimated Cost of Curbside Garbage Collection for Selected Cities in the UCDD

convenience center in each county if house-to-house collection services are not provided publicly or readily available from private haulers. The Tennessee Valley Authority describes convenience centers as "...public garbage collection facilities that are fenced, manned, landscaped, and usually operated in rural areas." (TVA, p. 3) These systems collect only residential waste and have important advantages over traditional methods of rural garbage collection. Each convenience center has an attendant on duty during operating hours who is free to help patrons, keep the area clean, and call for a disposal truck when containers are full. Centers are open during regular hours and located along major roadways where there is easy access. Gates around the area provide security when the center is closed, and the overall public health is improved because of less illegal garbage disposal. Most importantly, convenience centers are more cost-effective than "green-box" systems. After an initial capital investment, a convenience center saves money by reducing routing problems, site cleaning labor, and transportation costs (TVA, p.9).

For the reasons cited above, rural garbage was assumed to be collected by means of a system of convenience centers located throughout the county. Unfortunately, WastePlan has no module to explicitly model the costs associated with convenience centers, so a decision was made to designate a convenience center as a single transfer station at an average

distance from the landfill. This would allow WastePlan to produce accurate cost estimates for the operation of a convenience center system by means of its transfer station module.

Data relating to the capital and operating costs involved with implementation of such a system were taken from research conducted by Lewis D. Bumpus for the County Technical Assistance Service (1992, p.47). This information is summarized and reported in Figure 4.5. One convenience center utilizing roll-off containers and built to these specifications can handle 1,300 tons of garbage per year at a cost of \$24.35/ton. Transportation cost, including time spent loading the container onto the truck, was \$.37/ton/mile, based on a 15 mile (one-way) trip. This transportation cost also accounted for labor, insurance, fringe benefits, and a truck purchase of \$60,000 financed at 5% over five years (Bumpus, p.33).

ITEM	COST/YEAR (\$)
Land	1,200
Construction @ 5% over 5 Years	8,174
Equipment	4,435
Operations	17,180
Total	31,619

Source: Bumpus, Lewis D. "Solid Waste: Transportation and Other Costs." County Technical Assistance Service, The University of Tennessee. December, 1992.

Figure 4.5 Annual Cost for a Convenience Center Collecting 1,300 Tons of Garbage per Year

Handling rural collection of garbage through WastePlan's transfer station module did not require explicitly stating the number of convenience centers modelled. However, since the most efficient number of convenience centers for a county is generally such a common concern, Figure 4.6 reports the optimal number of centers for provision of adequate rural collection under two different criteria. The first criterion based the optimal number of convenience centers on the tonnage of garbage produced in the rural area (i.e. its population). It was reasoned that since each convenience center could collect 1,300 tons of garbage per year, the tonnage generated in the rural area divided by 1,300 tons (rounded up) would yield the number of convenience centers required to handle the amount of rural garbage generated. An alternate criterion would be to assure that no county resident lived more than five miles from a convenience center. In this case the optimal number of convenience centers was based on the area of the county. The amount of garbage generated by the rural sector of each county, the total area of the county, and the optimal number of convenience centers under each criteria are reported in Figure 4.6. These two criteria thus suggest a range of convenience centers that would appear appropriate for each county.

COUNTY	RURAL GARBAGE (TONS/YEAR)	NUMBER OF CONVENIENCE CENTERS (VOL. BASED)	AREA (SQ.MI.)	NUMBER OF CONVENIENCE CENTERS ^a (AREA BASED)
Cannon	2,397	2	265.7	4
Clay	1,682	2	236.1	3
Cumberland	8,148	7	681.6	9
Dekalb	3,098	3	304.6	4
Fentress	3,751	3	498.7	7
Jackson	2,430	2	308.9	4
Macon	3,593	3	307.1	4
Overton	4,053	4	433.4	6
Pickett	1,040	1	162.9	2
Putnam	6,852	6	401.0	5
Smith	3,447	3	314.4	4
Van Buren	1,090	1	273.5	4
Warren	6,389	5	432.7	6
White	4,514	4	376.7	5
TOTAL/AVG.	52,484	3.3	357.0	4.8

a. Based on an algorithm developed by Dr. William Park.

Figure 4.6 Optimal Number of Convenience Centers Under Different Criteria

City Collection of Recyclables

As was noted earlier, the collection of residential recyclables in cities is accomplished with unattended satellite dropoffs which collect newspaper, glass, recyclable plastic, aluminum, and ferrous containers. Unattended dropoffs sites represent an inexpensive way to collect residential recyclables but can face problems of contamination. The merits and shortcomings of unattended sites depend on many factors and are not examined further here.

WastePlan has a module which can model particular satellite dropoff systems very accurately. Unfortunately, at this time there is very little recycling taking place in the UCDD, so any attempt to use this module would require making specific assumptions about future residential recyclable collection. Decisions regarding the optimal number of satellite dropoffs, the number of containers to be used, the size of containers to be used, the cost of the containers to be used, how often the containers are collected, and the distance from the dropoff to the facility, were considered to be details beyond the scope of this research. Instead of using WastePlan's module for satellite collection of recyclables, the cost of collection was handled on a cost per ton basis. This allowed an accurate representation of collection costs based on previous experience and avoided the

necessity of making specific assumption regarding future recycling systems.

Cost per ton figures for collection of uncompacted recyclables was based on research conducted by Lewis Bumpus from CTAS combined with two years of information associated with operation of the Williamson County recycling program. These sources, along with information that suggested the density of compacted garbage at convenience centers was approximately three times the density of uncompacted recyclables, led to a formula for determination of the cost per ton for collection of recyclable material. The base cost per ton for collection was assumed to be the same as for garbage, \$24.35; while transportation costs per mile were assumed to be \$1.11 per ton-mile.

Participation and capture rates for the newspaper, glass, recyclable plastic, ferrous containers, and aluminum collected from households were both set at 50%, yielding an overall diversion rate of 25%. These percentages are understood to be widely variable and site specific but are within the range of experience in Tennessee and elsewhere.

Corrugated cardboard is the only recyclable material assumed to be collected from the commercial sector. Corrugated cardboard has long been recycled and continues to command a price sufficient to justify private efforts in the market for recycled materials. Its processing consists of simply compacting and baling before it is shipped, so many

private companies process their own cardboard. These facts make it very difficult to arrive at an accurate diversion rate or project how much cardboard would flow through a public recycling system. Given this, a diversion rate of 25% was used with the recognition that a wide variation is possible. The rental cost of containers and the distance transported were assumed to be the same as for dropoff recycling in the cities.

Tonnages of residential recyclables and corrugated cardboard projected to be collected are reported in Figure 4.7. The mileage to the processing plant and the cost per ton for collection are also reported for each of fourteen cities in the UCDD.

Rural Collection of Recyclables

Since the commercial sector is assumed to be in the city, rural recyclable materials consist of those items collected from the residential waste stream. These include newspaper, glass, recyclable plastic, aluminum, and ferrous containers. A 50% participation and capture rate was applied to these materials, which again produced a 25% diversion rate overall.

Residents were assumed to drop their recyclables off in containers at the convenience center where they bring their household garbage for disposal. The distance the materials were transported to be processed was assumed to be one-half the average distance from the center of the county to the border. Since the materials were moved the same distance as

CITY	SHIPPING DISTANCE ^a (MI.)	RESIDENTIAL VOLUME (TONS/YEAR)	COMMERCIAL VOLUME (TONS/YEAR)	COST/TON (\$)
Woodbury	4.6	43	313	29.46
Celina	4.3	28	271	29.12
Crossville	7.4	132	2,078	32.56
Smithville	4.9	72	585	29.79
Jamestown	6.3	35	591	31.34
Gainesboro	5.0	19	239	29.90
Lafayette	4.9	69	641	29.79
Livingston	5.9	72	610	30.90
Byrdstown	3.6	19	124	28.35
Cookeville	5.7	416	3,417	30.68
Carthage	5.0	45	642	29.90
Spencer	4.7	21	100	29.57
McMinnville	5.9	212	1,856	30.90
Sparta	5.5	89	890	30.46
TOTAL/AVG.	5.3	1,272	12,357	30.75

a. In all cases shipping distances are computed as one half the average distance from the center of the county to the border.

Figure 4.7 Estimated Cost for City Collection of Recyclables in the UCDD

in city collection, the collection cost per ton was exactly the same. The volume collected, distance transported, and cost per ton for collection of uncompacted recyclables for rural areas in each of the fourteen counties of the UCDD are reported in Figure 4.8.

The previous discussion of collection systems modelled in the UCDD demonstrates the complicated nature of decisions that must be made in solid waste planning. WastePlan helps to do this by pointing out just what collection options are available and promoting efficient analysis by creating reports that let the manager compare different collection scenarios. These systems are essentially hypothetical, but they serve as adequate models of solid waste collection in the UCDD. Once material is collected and transported; however, it then must still go to a facility where it is processed or disposed.

COUNTY	SHIPPING DISTANCE ^a (MI)	VOLUME (TONS/YEAR)	COST/TON (\$)
Cannon	4.6	155	29.46
Clay	4.3	109	29.12
Cumberland	7.4	528	32.56
Dekalb	4.9	201	29.79
Fentress	6.3	243	31.34
Jackson	5.0	157	29.90
Macon	4.9	233	29.79
Overton	5.9	263	30.90
Pickett	3.6	67	28.35
Putnam	5.7	444	30.68
Smith	5.0	223	29.90
Van Buren	4.7	71	29.57
Warren	5.9	414	30.90
White	5.5	292	30.46
TOTAL/AVG.	5.3	3,400	30.75

a. In all cases shipping distances are computed as one half the average distance from the center of the county to the border.

Figure 4.8 Estimated Cost for Rural Collection of Recyclables in the UCDD

CHAPTER FIVE

Processing and Disposal Facilities

In this chapter the facilities used to process and dispose of materials in the waste stream are discussed. The functioning of these facilities constitutes the final, most expensive phase of solid waste management, and it is this phase in the waste management process where substantial cost reductions occur due to economies of size. The cost estimates reported in this chapter show that even in the Base Scenario where each county has one landfill and one processing facility, the counties with greater volumes of solid waste have a substantially lower cost per ton for the operation of their facilities than do the smaller counties.

Design and Operation of Recycling Facilities

Because large scale collection, processing, and marketing of recyclable materials is a fairly new phenomenon, the design and operation of a processing facility is subject to substantial uncertainty. This is especially true in rural Tennessee where county governments have had little or no experience in managing recyclables processing plants. Local officials may have trouble sizing the facility because they can't be sure of the volume of material that will be processed, or they may hesitate because of uncertainty regarding the cost of construction and operation of the

facility. The decisions to be made are important for the welfare of the ordinary citizen, because an over-sized facility can be a substantial financial burden, while an under-sized facility may be costly in the long run due to the need for expansion or replacement.

Most communities within the UCDD are only beginning to promote recycling, and there is a wide variation in the types of recycling systems in place. As such, a representative design for processing plants with four different scales was employed, based on information from the Analysis of Solid Waste System Costs for the State of Vermont (Tellus 1991, p. 5-23). The design of these facilities has been previously researched, and the costs documented. Also, the expenditures associated with construction and operation of a processing plant are translated into units which are easily input into the WastePlan program.

Discussions with recycling coordinators in the UCDD indicated that the costs of a processing facility in rural Tennessee would be less than was assumed in the Vermont study. Costs associated with the design of these facilities were thus adjusted as follows: operating costs were reduced by 10%, construction cost for the building required was cut in half, conveyors were removed from the list of equipment, and labor costs were reduced by 10% and made variable depending on the volume of material processed. Figure 5.1 shows the final capital and operating costs of processing facilities with

scales of 520 tons per year, 2,600 tons per year, 6,500 tons per year, and 13,000 tons per year. Depending on the volume of recyclables collected by each county, an appropriate sized processing facility was chosen. Since the stream of recyclables entering the processing plant contains 75% corrugated cardboard which is easily baled and marketed, it was assumed that each facility could handle material volumes somewhat larger than the tonnage indicated. That is, the tonnage figures were not considered to be absolutely constraining but rather design volumes. For all but the three largest counties, the 520 ton per year scale was adequate for the base scenario.

TYPE OF COST (\$)	FACILITY SCALE			
	520 TONS/YEAR	2,600 TONS/YEAR	6,500 TONS/YEAR	13,000 TONS/YEAR
Building	80,000	325,500	400,000	500,000
Land	12,500	15,000	17,500	20,000
Equipment	78,600	176,100	216,000	280,400
Total Capital	171,600	516,100	633,500	800,400
Total Operational	74,250	168,300	314,100	420,300
TOTAL	245,850	684,400	947,600	1,220,700

Source: Adapted from Analysis of Solid Waste System Costs for the State of Vermont. Tellus Institute, 1990.

Note: Facility is assumed to operate 260 days/year.

Figure 5.1 Cost in Dollars of Recycling Facilities Handling Different Volumes of Material

Once a stream of recyclable material has been routed to a facility and processed, the materials must be marketed. It was assumed that there would be no residue resulting from the processing function, i.e. that the material routed to the facility is actually marketed and diverted from the waste stream even though small percentage losses are normal and could be incorporated. Market prices for processed recyclable materials were obtained from Deanna Moore Fry in the Tennessee Department of Environment and Conservation and Andy Mitchell, the Recycling Coordinator for Overton County. The prices, net of shipping cost, were assumed to be as follows: \$25/ton for newspaper, \$35/ton for corrugated cardboard, \$30/ton for glass, \$65/ton for plastic, \$30/ton for ferrous containers, and \$280/ton for aluminum. It is extremely important to note that these are only recent market figures, and that prices will change due to increased volumes and other market pressures over time. For example, the aluminum price is low relative to average prices over the last few years. However, it is important to note that while modest variations in these prices can have a significant effect on the net cost for operation of a recyclables processing plant, they have very little effect on the overall cost of operation for a solid waste system, because they relate to a very small portion of the waste stream. The volume of recyclables processed, the annual cost, the annual revenues from the resale of materials, and net cost per ton are presented in Figure 5.2. A summary

COUNTY OR REGION	TONS/YEAR PROCESSED	COST/YEAR (\$)	REVENUE/YEAR (\$)	NET COST/TON (\$)
BASE SCENARIO				
Cannon	511	94,075	20,563	143.75
Clay	408	90,075	16,114	181.35
Cumberland	2,737	235,158	104,647	47.68
Dekalb	858	107,408	33,681	85.94
Fentress	869	107,819	34,148	84.77
Jackson	415	90,364	16,884	177.12
Macon	943	110,700	37,039	78.14
Overton	945	110,726	37,545	77.48
Pickett	210	82,457	8,502	352.33
Putnam	4,277	277,632	161,219	27.22
Smith	910	109,417	35,459	81.25
Van Buren	192	81,757	7,944	384.86
Warren	2,482	277,837	95,264	53.41
White	1,271	123,327	49,853	58.04
TOTAL	17,027	1,898,752	658,862	72.82
REGIONAL SCENARIO I				
North ^a	8,976	413,708	346,910	7.44
South ^b	8,051	404,191	311,683	11.49
TOTAL	17,027	817,899	658,593	9.36
REGIONAL SCENARIO II				
UCDD ^c	17,027	544,878	658,953	(6.68)

Note: Rounding error is present.

- North region consists of Macon, Smith, Clay, Jackson, Putnam, Overton, Pickett, and Fentress Counties.
- South region consists of Cannon, Dekalb, Warren, White, Van Buren, and Cumberland Counties.
- UCDD consists of the entire district as one region.

Figure 5.2 Estimated Costs and Revenues for Processing of Recyclables Under the Base and Regional Scenarios

of the volumes of each material recovered by county and region is shown in Figure 5.3.

Average processing costs net of revenues received are much lower under the regional scenarios. This phenomenon is noted by Tellus in the Vermont study, "One clear conclusion is that a 2 TPD (ton per day) recycling facility that does any processing is simply not cost effective. Even the 10 TPD facility is overly burdened by the fixed equipment and building costs." (p. 5-21). However, the question must still be addressed as to whether the lower processing costs outweigh the higher transportation costs required with one or two regional processing facilities. The answer to this question is shown in Figure 5.4, where the costs associated with operation of a recycling processing plant and the collection/transportation costs are presented and summed. Results show that the total costs are still 50% lower than in the base scenario with two regional processing facilities (Regional Scenario I) and 61% lower when there is one regional processing facility (Regional Scenario II). Even in the event that transportation costs were 50% higher than originally assumed, the same basic results hold. For this "high cost" case, Regional Scenario I has total costs 44% lower than the Base Scenario, and Regional Scenario II has costs 51% lower. These findings demonstrate that there are economies of size in the processing of recyclables that outweigh the increased transportation costs associated with regionalization.

COUNTY	NEWSPAPER	CARDBOARD	GLASS	PLASTIC	FERROUS	ALUMINUM	TOTAL
Cannon	61	313	71	21	33	13	511
Clay	42	271	49	15	23	9	408
Cumberland	203	2,078	236	70	108	43	2,737
Dekalb	84	585	97	29	45	18	585
Fentress	86	591	100	30	46	18	869
Jackson	54	238	63	19	29	11	415
Macon	93	641	108	32	50	20	943
Overton	103	610	120	35	55	22	945
Pickett	26	124	31	9	14	6	210
Putnam	264	3,416	308	91	141	56	4,277
Smith	83	342	96	28	44	17	910
Van Buren	28	100	33	10	15	6	192
Warren	193	1,855	224	66	103	41	2,482
White	117	889	136	40	63	25	1,271
TOTAL	1,437	12,352	1,671	496	768	303	17,027

Figure 5.3 Volume of Recyclable Materials Collected in Each County of the UCDD in Tons/Year

	PROCESSING COST/TON (\$)	COLLECTION AND TRANSPORTATION COST/TON (\$)		TOTAL COST/TON (\$)
		ORIGINAL ^a	HIGH ^b	
BASE	72.82	30.75	34.01	106.83
SCENARIO I	9.36	42.06	50.99	60.35
SCENARIO II	(6.68)	47.16	58.66	51.98

a. Using original transportation costs

b. Using 50% greater transportation costs

Figure 5.4 Total Cost/Ton for Collection and Processing of Recyclables Under the Base and Regional Scenarios

Landfill Disposal

Landfilling remains the most common method of disposal for residential and commercial solid waste. Despite current controversies regarding the siting, safety, and sustainability of landfilling solid waste, it remains the most cost-effective method of solid waste disposal in areas like the UCDD where land is generally more abundant and volumes are substantially lower than in urban areas.

New regulations promulgated by the federal government (Subtitle D) and state government (Solid Waste Management Act of 1991) will substantially increase the cost of landfill disposal in the UCDD over the next few years. It is expected that these tighter regulations will better protect public health and environmental quality. Subtitle D does this by restricting location to ecologically safe areas, strictly enforcing operating standards for protection of the public health, requiring proper design to ensure safe drinking water, requiring adequate provision of closure/post closure care, and requiring financial assurance of that the facility is stable (CTAS. Appx. B). Similarly, state regulation of landfilling practices takes into account Subtitle D requirements and adds further refinements for the state of Tennessee. Regulations specifically related to landfill facilities include new criteria for permitting facilities, requirement of financial assurance, regulation of existing facilities, and run-off and erosion control (CTAS, Appx. C). In addition to the higher

costs in general, the economies of size in landfilling are accentuated because many of the new requirements involve costs that do not increase proportionally with volume.

For the Base Scenario in this study, each county was assumed to have a landfill built to fully comply with federal and state regulations. Two landfills, one serving the northern eight counties and one serving the southern six counties, were assumed in Regional Scenario I, and one regional landfill for the entire UCDD was assumed in Regional Scenario II (See Appendix A). In this way it was possible to examine the possible savings in disposal costs from economies of size that may occur as volumes of garbage are increased by moving from a single county level to regional levels.

Consideration was initially given to fully utilizing the landfill module built into the WastePlan program in order to generate costs for various sizes of landfills, but this task proved to be quite difficult. The information required was often difficult to locate and reported in units not amenable for input into the WastePlan model. This yielded consistently high cost estimates which were not considered accurate for the purposes of this research, given the landfill cost estimates developed by knowledgeable people in the state. Instead, overall cost per ton estimates were input directly in order to avoid the problems inherent in the use of the landfill module. These estimates were derived from model landfills developed by CTAS, ranging in size from 9,125 tons per year (25 tons per

day) to 182,500 tons per year (500 tons per day). These model landfills were developed to be in full compliance with all relevant regulations and are assumed to have a composite liner and public debt financing (CTAS, Appx. D). Linear extrapolation was used to arrive at cost estimates for sizes in between the CTAS model sizes.

The volume of garbage landfilled each year, the cost per ton associated with that volume, and the annual disposal cost is presented in Figure 5.5 for each of the fourteen counties, the two regions in Regional Scenario I, and the one region in Regional Scenario II. As can be seen, the cost per ton falls from an average of \$49.26 under the Base Scenario (with a range across counties of \$25.80 to \$85.58) to an average of \$21.48 with two regional landfills, and to an average of \$16.13 with one regional landfill.

To further explore the economies of size in the landfilling function alone, the cost per ton for landfilling garbage is summed with the cost of collection in the Base Scenario, Regional Scenario I, and Regional Scenario II. Results are reported in Figure 5.6. Under Regional Scenario I, the cost of collecting and disposing of garbage in a landfill is 22% less than under the Base Scenario, and under Regional Scenario II, collecting and disposing of garbage in a landfill is 26% less than under the Base Scenario. Even in the case where transportation costs are 50% higher, total costs are substantially less than under the Base Scenario.

COUNTY OR REGION	TONS/YEAR LANDFILLED	ANNUAL COST (\$)	COST PER TON (\$)
BASE SCENARIO			
Cannon	6,331	486,173	76.82
Clay	5,112	407,549	79.74
Cumberland	26,783	972,226	36.30
Dekalb	9,964	668,352	67.08
Fentress	9,895	663,701	67.08
Jackson	5,311	418,202	78.76
Macon	10,375	685,815	66.11
Overton	10,523	685,400	65.14
Pickett	2,744	234,705	85.58
Putnam	41,918	1,083,990	25.86
Smith	9,708	651,135	67.08
Van Buren	2,818	241,118	85.58
Warren	25,887	958,577	37.03
White	14,014	797,911	55.40
TOTAL	181,773	8,954,854	49.26
REGIONAL SCENARIO I			
North ^a	95,586	2,028,160	21.22
South ^b	86,187	1,877,044	21.78
TOTAL	181,773	3,905,204	21.48
REGIONAL SCENARIO II			
UCDD ^c	181,773	2,931,785	16.13

Note: Rounding error is present.

- a. North region consists of Macon, Smith, Clay, Jackson, Putnam, Overton, Pickett, and Fentress Counties.
- b. South region consists of Cannon, Dekalb, Warren, White, Van Buren, and Cumberland Counties.
- c. UCDD consists of the entire district as one region.

Figure 5.5 Estimated Landfill Volumes and Costs Under the Base and Regional Scenarios

	LANDFILLING COST/TON (\$)	COLLECTION AND TRANSPORTATION COST/TON (\$)		TOTAL COST/TON (\$)
		ORIGINAL ^a	HIGH ^b	
BASE	49.26	27.84	29.77	77.10
SCENARIO I	21.48	39.04	41.69	60.52
SCENARIO II	16.13	40.54	44.03	56.67
				60.16

a. Using original transportation costs

b. Using 50% greater transportation costs

Figure 5.6 Total Cost/Ton for Collection and Landfilling of Garbage Under the Base and Regional Scenarios

For Regional Scenario I at 50% higher transportation cost, total costs are 20% less than the Base Scenario, and Regional Scenario II averages 24% less than the Base Scenario given 50% higher transportation costs. This shows that economies of size are present exclusively in the landfilling function as well as in the processing of recyclables, and that the cost reductions from taking advantage of economies of size in landfilling outweigh the increased transportation costs associated with larger regions.

CHAPTER SIX

Base and Regional Scenario System Summaries

Summaries of total system costs for the base, two region, and one region scenarios are presented in this chapter. Relevant assumptions regarding the distance to regional recycling facilities and landfills are noted along with the costs associated with transportation of solid waste to these facilities. Finally, because transportation costs are a key factor in considering regional strategies, the effect of a 50% increase in transportation costs on total system cost is displayed for each scenario.

Base Scenario Summaries

The total system costs for each county in the UCDD under the base scenario are reported in Figure 6.1 and range from \$52.19 to \$139.11 per ton. System costs are a weighted average over every phase of the solid waste management system from collection through the facilities. As such, the cost of recycling has a smaller effect on total system cost than does the cost of disposal. In fact, only 8.6% of the total waste stream is assumed to be diverted through recycling.

COUNTY OR REGION	TONS/YEAR GENERATED	TONS/YEAR RECYCLED	TONS/YEAR LANDFILLED	SYSTEM COST/TON (\$)
BASE SCENARIO				
Cannon	6,841	511	6,331	108.12
Clay	5,519	408	5,112	121.99
Cumberland	29,521	2,737	26,783	66.56
Dekalb	10,822	858	9,964	97.53
Fentress	10,763	869	9,895	103.55
Jackson	5,725	415	5,311	119.66
Macon	11,317	943	10,375	95.35
Overton	11,467	945	10,523	92.42
Pickett	2,953	210	2,744	138.66
Putnam	46,194	4,277	41,918	52.19
Smith	10,617	910	9,708	93.77
Van Buren	3,010	192	2,818	139.11
Warren	28,638	2,482	25,887	63.53
White	15,674	1,271	14,014	84.37
TOTAL	198,800	17,027	181,773	79.13
REGIONAL SCENARIO I				
North ^a	104,553	8,976	95,586	59.51
South ^b	94,238	8,051	86,187	60.03
TOTAL	198,800	17,027	181,773	59.75
REGIONAL SCENARIO II				
UCDD ^c	198,800	17,027	181,773	55.34

Note: Rounding error is present.

a. North region consists of Macon, Smith, Clay, Jackson, Putnam, Overton, Pickett, and Fentress Counties.

b. South region consists of Cannon, Dekalb, Warren, White, Van Buren, and Cumberland Counties.

c. UCDD consists of the entire district as one region.

Figure 6.1 Estimated System Cost Under the Base and Regional Scenarios

Regional Scenario Summaries

The costs of collection were assumed to be the same under the regional scenarios as under the base scenario. Only the cost of additional transportation to a more distant facility was incorporated into the regional scenarios. In each county's largest city, garbage was assumed to be collected at the curbside and transported to a transfer facility three miles away. From there, it was compacted and transported to a regional landfill. The cost and design of the transfer facility was taken from the Vermont study by Tellus (p. 8-10), and the cost of transportation for moving compacted solid waste from the transfer facility to the regional landfill by means of a tractor trailer was assumed to be \$.29/ton/mile (Bumpus, p. 41). Rural garbage is transported to a regional landfill from the convenience center where it is originally collected and compacted. This garbage is shipped the appropriate distance by roll-off truck to a regional landfill at \$.37/ton/mile, the same cost per ton for transportation as in the Base Scenario (Bumpus, p. 33).

In Regional Scenario I, two landfills were modelled to accommodate the entire district. One regional landfill was located in the northern part of the UCDD near the borders of Jackson, Putnam, and Overton counties. A second regional landfill was assumed to service the southern part of the district and was located in White County. In the case of Scenario II, it was assumed that the one regional landfill

which would serve the entire district was located in the south-central part of Putnam County (Maps are shown in Appendix A). The mileage from each individual county to any of these regional landfills was estimated by map using straight line distance, rounded up to the nearest five mile increment (Figure 6.2). It should be made clear that simply because these locations were found to be the most central does not mean that there are any plans to locate landfills there.

Collection of recyclables was assumed to be handled the same way as in the base scenario. The regional recyclables processing plant was assumed to be at the same location as the regional landfill, so the distance recyclable materials were shipped was the same as the distance the garbage was shipped in the regional scenarios. Higher transportation costs were incurred based on the distance they were transported. The extra cost for transporting one ton of recyclables one additional mile was assumed to be \$1.11, which is consistent with the transportation cost used in the base scenario.

System cost summaries for the two regional scenarios are shown in Figure 6.1 for comparison with the base scenario. Compared to the Base Scenario cost of \$79.13, the costs under Regional Scenario I averaged 25% less (\$59.51/ton) for the North region and 24% less (\$60.03/ton) for the South region. This cost differential is even greater in the case of Regional Scenario II, under which the total system cost of \$55.34/ton is 30% lower than under the Base Scenario.

COUNTY	REGIONAL SCENARIO I	REGIONAL SCENARIO II
Cannon	30	40
Clay	20	35
Cumberland	20	20
Dekalb	20	20
Fentress	30	40
Jackson	10	20
Macon	30	40
Overton	10	20
Pickett	25	40
Putnam	5	5
Smith	25	25
Van Buren	15	20
Warren	20	30
White	5	10
Average	19	26

Figure 6.2 Average Distance in Miles to Regional Solid Waste Facilities Under Two Different Scenarios

Potential cost savings from regionalization appear quite substantial for all except the three largest counties; in fact, it would appear that Putnam County would "lose" from regionalization. However, this comparison is misleading. Under the Base Scenario, each county was assumed to handle its own collection, transportation, and facilities; but under the regional scenarios, each county was assumed to be responsible for its own collection and transportation while sharing proportionally in the cost of the regional facilities. Thus, each county will have a different total system cost depending upon its collection and transportation costs. The total system cost per ton reported under the regional scenarios is the weighted average of costs accruing to all counties.

For this reason, the total system costs for two individual counties under Regional Scenario II were estimated in order to provide a range for the costs accruing to a single county under the highest degree of regionalization. To illustrate this, the total system costs for Putnam County (the largest county and the closest to regional facilities) and Pickett County (the smallest county and the farthest from regional facilities) were estimated under Regional Scenario II. In this case, Putnam County would have a total system cost of \$44.34/ton while Pickett County would have a total system cost of \$62.97/ton. Since these two counties represent the extremes of generation and transportation distance, it is reasonable to assume that the total system costs of all other

counties in the district would fall between these two. This means that even Putnam County would gain from regionalization, and that smaller, more distant counties would not save as much as the weighted average cost figures under the regional scenarios might suggest, when compared to the weighted average total system cost of \$55.34/ton reported earlier.

Effect of Higher Transportation Costs on Total System Costs

Because transportation costs are a key factor in considering regionalization, and the possibility that average distances to regional facilities or transportation costs per mile may have been understated, sensitivity analysis was performed to determine the effect of a 50% increase in transportation costs on overall system costs. The cost of operation of a regional solid waste management system under 50% higher transportation costs is reported in Figure 6.3 and contrasted with the system costs under the original assumptions.

For the Base Scenario, a 50% increase in transportation costs leads to a \$1.86/ton, or 2%, increase in total system costs. In Regional Scenario I the average system cost per ton increases \$3.18/ton to \$62.93/ton, representing a 5% increase. In Regional Scenario II, total system cost increased by \$4.12/ton to \$59.46/ton, representing a 7% increase. This shows that as transportation costs increase, total system costs under the regional scenarios grow at a faster rate than do the costs under the Base Scenario, due to the fact that

COUNTY OR REGION	VOLUME OF SOLID WASTE IN TONS/YEAR	SYSTEM COST/TON WITH ORIGINAL TRANSPORTATION COSTS (\$)	SYSTEM COST/TON WITH 50% GREATER TRANSPORTATION COSTS (\$)
BASE SCENARIO			
Cannon	6,841	108.12	109.19
Clay	5,519	121.99	122.88
Cumberland	29,521	66.56	69.18
Dekalb	10,822	97.53	100.05
Fentress	10,763	103.55	104.84
Jackson	5,725	119.66	120.68
Macon	11,317	95.35	97.40
Overton	11,467	92.42	93.40
Pickett	2,953	138.66	139.39
Putnam	46,194	52.19	54.47
Smith	10,617	93.77	94.46
Van Buren	3,010	139.11	140.11
Warren	28,368	63.53	65.05
White	15,674	84.37	86.75
TOTAL	198,800	79.13	80.99
REGIONAL SCENARIO I			
North	104,553	59.51	62.35
South	94,238	60.03	63.58
TOTAL	198,800	59.75	62.93
REGIONAL SCENARIO II			
UCDD	198,800	55.34	59.46

Figure 6.3 Estimated System Costs with Original and 50% Higher Transportation Costs

regions are larger. However, even with substantially higher transportation costs, a comparison of total system costs suggests that the potential savings from regionalization of solid waste facilities remain quite substantial for most counties.

CHAPTER SEVEN

Results and Conclusions

The main objectives of this research were two-fold:

(1) to evaluate the WastePlan computer software package and assess its usefulness for solid waste planning in rural areas of Tennessee, and (2) to estimate the potential cost savings from regionalization of solid waste facilities for the Upper Cumberland Development District. Findings relative to these two objectives are presented in this chapter.

Conclusions Regarding WastePlan

It must be noted that WastePlan was designed to be a planning tool. As with any computer model, the accuracy of the output depends upon the accuracy of the inputs. Since reality can only be approximated, WastePlan can never be completely accurate, and any cost estimates derived from its use, however precise, must be understood to be somewhat variable.

In Chapter Two, a list of questions concerning the use of WastePlan was presented. In this section answers to these questions and the explanations behind those answers are presented. Although this discussion is not intended as a comprehensive and definitive guide to WastePlan, it is hoped that it will provide some guidance for solid waste planners who might be considering its use.

What kind of equipment is needed to run this program?

WastePlan can be installed on any IBM compatible personal computer with an MS-DOS operating system. The computer should have 640 KB of RAM, and the program requires 1.3 MB of free storage space. Installation is as simple as typing "A:INSTALL" and answering a few simple questions. Use may begin immediately after the program is installed on the hard drive.

Is this program "user friendly?"

Users of such common menu-driven software packages as Lotus 123 or Dbase should find the use of WastePlan easy to understand. The installation process as described above is simple enough to accommodate both advanced users and computer novices, so getting started is no problem.

Before describing its ease of use, it must be recognized that WastePlan is a comprehensive planning tool, and as such, it incorporates a wide array of modelling options (See Appendix B). Initially, an attempt was made to fully utilize all of WastePlan's potential, but it was soon apparent that for the purposes of this study, such complete use would not be possible. In many instances the necessary inputs called for were too precise, and any attempt to approximate these inputs would harm the accuracy of the overall system modelled. This problem was addressed by simply incorporating a fixed cost per ton derived from other sources or studies. In this way the

accuracy of the results was maintained without the need for precise inputs that weren't readily available.

No one response is sufficient to answer such a broad question regarding whether this program is "user friendly." WastePlan is easy to use in some respects and quite difficult to use in others. From the standpoint of moving through the modules and individual screens, as well as knowing what needs to be input, WastePlan is very easy to use. However, the inputs required for its use aren't always easily available, and often they must be converted into different units before the model will be accurate (See Appendix C). For instance, in the module to design a recyclables processing plant, various operating cost inputs must be entered in such units as percent of equipment cost, cost per ton of annual throughput, percent of total capital cost, and percent of total operations and maintenance cost. Often it is difficult to get an annual cost for some aspects of a solid waste system, and putting one cost in terms of another cost is even more difficult. This precision is helpful when accurate inputs can be used, but it makes analysis especially difficult when attempting to model systems that don't already exist.

It must be understood that objections such as those stated above are inherent in a computer model. It is impossible to completely model reality, but WastePlan allows solid waste planners to approach reality. Part of the difficulty in using WastePlan lies in the fact that it is such

a multi-purpose planning tool. Because there are so many options to choose from, it is tougher to understand them all, and that makes efficient use of any particular aspect more difficult.

How much technical knowledge of solid waste management is required to run this program?

An important concern regarding use of WastePlan is the amount of technical knowledge required to conduct an accurate analysis. In general, the greater the level of technical knowledge possessed by the user, the better. Naturally, the best results can be obtained when the user is knowledgeable and specific information can be obtained for the area under study. The need for this kind of technical knowledge may be alleviated somewhat if the inputs are in the appropriate units and are easily available.

For instance, in the use of the module to design a new landfill (shown in Appendix C), a strong technical knowledge of the engineering requirements for construction of a new landfill, and a good understanding of the statutory requirements for approval of a new landfill (e.g. Subtitle D) are very helpful. On page 106 in Appendix C the input screen for determination of landfill operating costs is shown along with the default inputs. The seven figures that are entered in this screen must be put into six different units. Examples of these are labor required which is figured in workers/tons/day, maintenance and supplies which are entered

in dollars/ton/day, pollution control operating costs are entered in dollars/acre/year, and methane revenues are figured in dollars/1000 cu. ft. Simply obtaining these inputs in the appropriate units is very difficult, and once they are gathered, it is nearly impossible to check their accuracy against other documented research.

What kind of local data is needed as inputs into the program and how difficult is it to obtain?

Local inputs required by WastePlan are diverse. Once again, the more accurate the local data input into the program, the more accurate the output. The User Guide (p. i) discusses three broad categories of data required by the WastePlan program. Some data entries must be entered to make the model specific to a certain location. These primary inputs would include economic and demographic variables such as population of the area under study, solid waste generation per person per day, composition of the waste stream, population per household, and the costs of various components of the solid waste management system (see Appendix C).

From these practical and easily documented inputs, the program begins to require more precise and difficult inputs such as diversion rates for recyclables, solid waste program administration costs, and stops per hour made by collection crews. Many times these inputs aren't available in the form needed for input into the program, and the process of conversion into useful units only adds to the uncertainty.

These inputs are such that the analysis will be improved if they can be obtained, but they are not absolutely necessary for WastePlan to produce useful results.

The final type of data is that which should not be changed unless the user has reliable information to the contrary. This final category of data would include cost per ton of daily throughput of different resource recovery technologies or methane generation in the landfill sizing module. A prime difficulty with this third type of input is the fact that there is no accepted guideline to determine which inputs would fall into this particular category. That determination would always depend on the objectives of the analysis. Therefore, it is never completely clear when it is appropriate to replace a confusing input.

Certain omissions from the WastePlan program may also limit its use. One example mentioned earlier was the fact that dropoff garbage collection (e.g. with convenience centers) cannot be explicitly modelled but must be approximated by transfer stations. Another example is the handling of commercial solid waste. Options for collection of commercial garbage and recyclables are limited to fixed fee systems, and many of the options for operation of residential collection systems are missing in the commercial sector. In this case, the problem lies not in the collection of local data needed for input into the WastePlan program, but in the

fact that the WastePlan program cannot readily accommodate some common local features.

How reliable is the Default Data?

This leads directly into the issue of default data built into WastePlan. This issue is always a prime concern because it is obvious that no one data set can be accurate for all areas. However, experience with WastePlan has shown that the default data, when used properly, is a benefit and not a detriment. This data provides a starting point for further analysis and serves as a check for the accuracy of any new inputs. For the more precise and difficult inputs that are required, default data can substitute until adequate information from the area under study can be gathered.

In this study, default composition data was used extensively to generate the commercial waste stream and to calculate the amount of compaction that would occur for the various components of the waste stream. To sum up, default data built into the program eases the need for technical expertise, provides a starting point for the gathering of inputs, and fills in when accurate information cannot be gathered.

Is WastePlan flexible enough to adapt to different types of analyses?

WastePlan is a very comprehensive and flexible program. It can model simple curbside garbage pickup or the operation of large-scale materials recovery facilities. This fact makes

the program broadly applicable but also rather complex. In this particular study, WastePlan was not used to its full capacity, yet the analysis was still very cumbersome. When problems were discovered, the corrections took a great deal of time. Because WastePlan routes the waste sequentially through generation, collection, and facilities modules, changing one aspect of the system requires changes in other areas too. For instance, to carry out a sensitivity analysis with a different diversion rate for recyclables would require not only changing the percentage diverted in each collection file, but also routing the recyclables through a whole new facilities file, and then creating a total system summary report. A small change in a collection file required making changes in three different modules. Sequentially moving through the program in this way also makes management of the files that are created in the process somewhat difficult. These difficulties suggest that the program may be somewhat better suited for analysis of various changes in a community's system than for an analysis of regionalization across a large number of communities, as done in this study.

The difficulty of doing sensitivity analysis efficiently is best illustrated by the proliferation of files that occurs in this study with just three scenarios and two transportation cost levels. In this study, there were fourteen counties and fourteen cities in which solid waste was generated. That means there were 28 generation files. The next module

modelled the collection of that solid waste for each one of those generators. There were 28 collection files in the simplest case, these 28 files in the Base Scenario were also collected at 50% greater transportation cost, which entailed running each of these 28 files at a higher cost. Modelling Regional Scenarios I and II meant having the solid waste collected from each of these generators transported a different distance at both the original and higher transportation cost. When the total number of collection files created were summed, there were 168 of them. WastePlan is limited to 128 collection files held in memory (User Guide, p. 3-4). By the final stages of the research, each collection file that was entered required removal of one collection file that was already in memory. Needless to say, management of all these files became very difficult. Added to this was the fact that all these collection files were routed to seventeen different facilities files. Finally a summary report could be created for the system under study. It is easy to see the tremendous logistical problems that can result from using WastePlan to perform a broad regional analysis requiring numerous individual files.

Do the reports provide the type of information that is really needed?

A final concern in the use of WastePlan deals with the use of the reports generated by the program, which include generation reports, collection reports, facilities reports,

and system summary reports. Examples of the facilities reports and system summary reports can be found in Appendices D and E. These reports present relevant information and are easily understood. If a cursory examination is preferred, there is a summary page with total costs, total tonnage, and cost per ton for collection systems and facilities. For a more in-depth analysis, specific information underlying the summary findings are contained within the body of the report. The structure of the reports is flexible enough to allow for a quick examination of the bottom line, or a more complete review of the system under study.

Based on the above discussion of WastePlan, it is easy to see that it is a powerful and potentially useful program. However, potential usefulness does not guarantee actual use by local decision-makers. The investment of time and effort required to "gear up" to use it and obtain the data inputs necessary for application to a particular situation may be substantial. After working with the program for months, aspects of it are still confusing to use. Local decision-makers would generally welcome the results of a WastePlan report but would not likely have the time or expertise to use the model themselves. Use of the model by personnel in technical assistance roles at the state or regional level is a more likely outcome.

Conclusions Regarding Regionalization

The results of the study with regard to regionalization of solid waste facilities are clear. Regional Scenario I, in which there were two regional processing and disposal facilities, one for the North section of the district and one for the South region of the district, had total system costs roughly 24% less than the Base Scenario. Regional Scenario II, with only one landfill and processing facility for the entire district, had total system costs 30% below the base. It is clear that under the assumptions made, the estimated cost reductions that occurs from taking advantage of economies of size in operation of facilities is substantially greater than the added transportation costs associated with larger regions.

The outcomes also show that single counties with large volumes have lower system costs than do counties with low volumes of solid waste. For instance, Putnam County, which produces 46,194 tons of solid waste per year, has a total system cost \$52.19/ton, but Pickett County, which produces only 2,953 tons of solid waste per year, has a system cost per ton of \$138.66/ton. Both are single counties, but the difference in volumes generated creates a wide disparity in system cost per ton.

These findings suggest that the monetary or fiscal costs for small counties to maintain control over their solid waste services by "going it alone" may be quite high. Whether the

potential cost savings available from operation of regional facilities are sufficient to justify participation in a regional organization is an individual county decision. This research has abstracted from the real problems of "administrative" and "transactions" costs which are unique for each county within the district. The decision-making environment encompasses not only monetary costs, but also a variety of nonmonetary costs and benefits, so no one decision criterion is appropriate in every case. In addition, it should be emphasized that the absolute cost estimates presented here must be considered imprecise and subject to variation. However, much greater confidence can be placed in the relative comparisons among scenarios, i.e. the percentage differences. As such, it is hoped that this research provides assistance in identifying and coping with issues that frame the decision of whether or not to pursue regional cooperation for solid waste management.

Further Research

The particular focus and limitations of this study suggest potentially fruitful areas for further research. One area would involve consideration of the nonmonetary costs and benefits that are inherent in regional cooperation. Comparing these to the potential cost savings from use of regional facilities would allow a more complete assessment of the optimal degree of regionalization.

Other limitations of this study relate to assumptions such as only the largest city in each county being assumed to have curbside garbage collection and commercial activity was limited to that city. This is obviously not the case because many smaller cities have curbside garbage collection, and many businesses and institutions are located outside the city limits. In this study, such an assumption was required to simplify what would otherwise be an even more complicated analysis. A more precise analysis could be undertaken in which more than one city had curbside collection and the commercial sector was located throughout the county. This would produce more accurate results, but at the cost of a more cumbersome analysis.

Another good suggestion for further research in this vein would be to use WastePlan to analyze system costs for a single community under various assumptions. This would allow a more precise model to be devised which would produce more accurate results. Assuming the area in question already had most aspects of a solid waste management system in place, the accuracy of the results of the WastePlan model could be checked against the actual costs of that particular system. For instance, if a solid waste management system was already using a landfill built to all legal specifications, a WastePlan analysis using actual costs of that landfill would produce more accurate results for that community than using costs gathered from other research. The same is true of a

recyclables processing plant, because the mix of capital and labor which might be used is even more variable. In a community where labor is more plentiful, it may be more efficient to use more labor and less equipment, but where labor is relatively more expensive, it would be cheaper to purchase more equipment. This would have a large effect on the efficiency of daily operation in a recyclables processing plant. It is important for WastePlan to incorporate this type of information. These are only two of the many examples in which local data regarding the operation and costs of a real solid waste management system would add to the accuracy of a WastePlan analysis.

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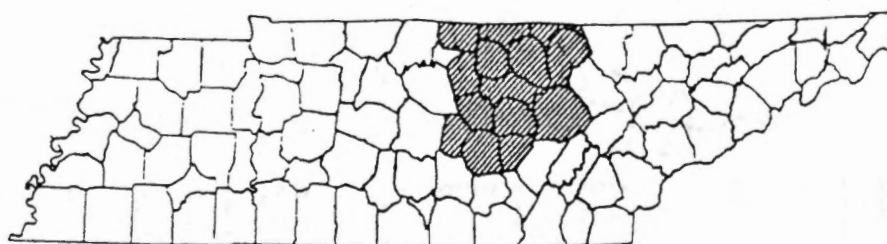
Three Rivers Region Solid Waste Master Plan. Neel-Schaffer Engineers and Planners. 1990.

WastePlan User Guide Version 92.0. Tellus Institute. 1990.

Appendices

Appendix A

Maps of Upper Cumberland Area

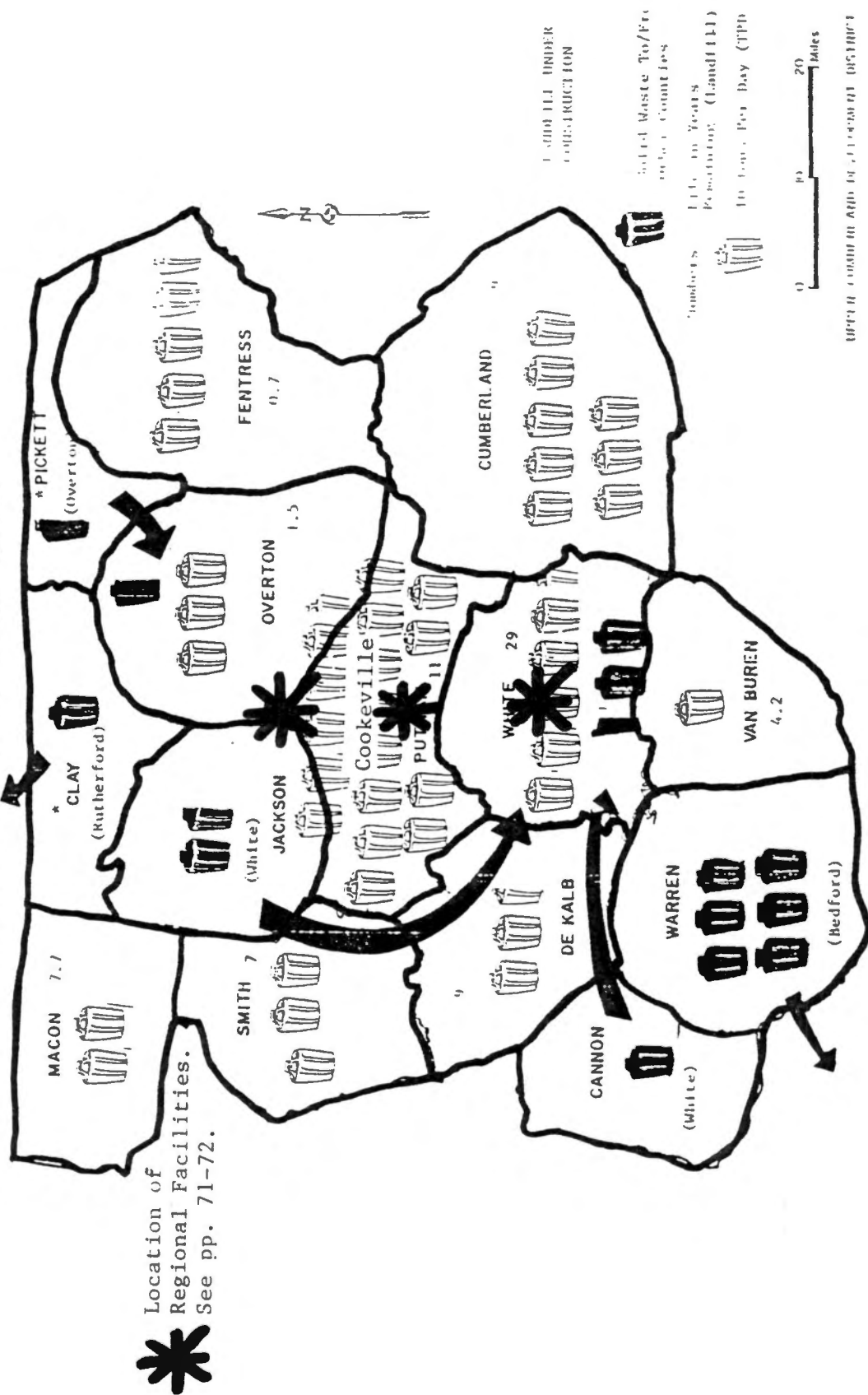
UPPER CUMBERLAND DEVELOPMENT DISTRICT

Cannon County
Clay County
Cumberland County
DeKalb County
Fentress County
Jackson County
Macon County

Overton County
Pickett County
Putnam County
Smith County
Van Buren County
Warren County
White County

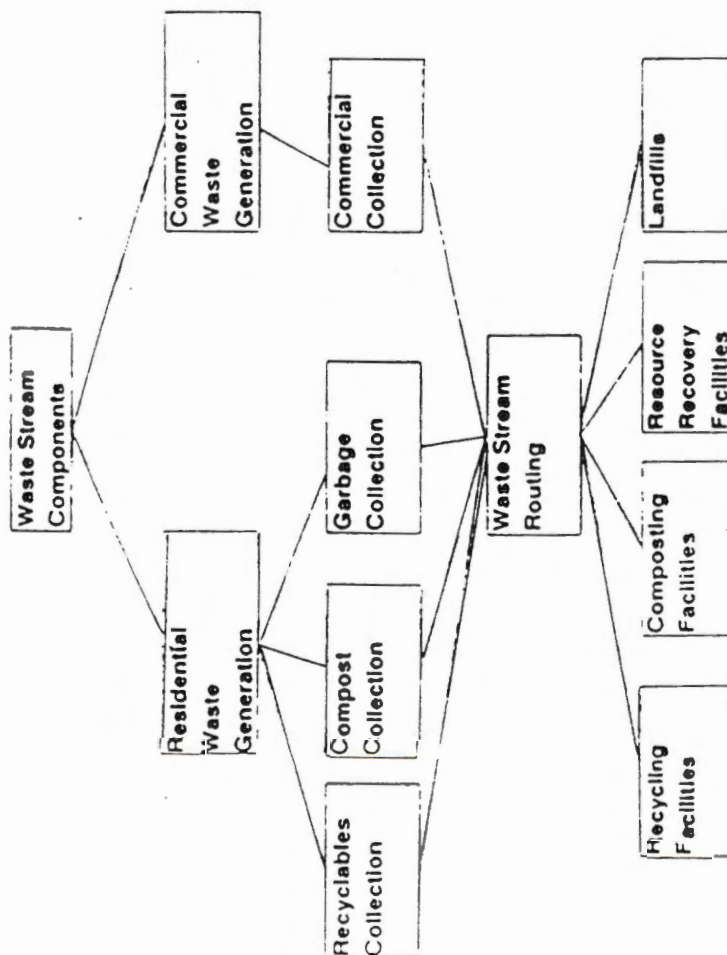
Source: Managing Our Waste: Solid Waste Planning for Tennessee, The University of Tennessee, Waste Management Research and Education Institute, February, 1991.

TONS OF SOLID WASTE PRODUCED PER DAY



Appendix B
WastePlan Schematic Diagram

WastePlan Software Structure



Source: WastePlan User Guide, Version 92.0, Tellus Institute, 1990.

Major Inputs

Density	Capital Costs
Ultimate Analysis (chemical and energy content)	Equipment Costs
Economic & Demographic Variables	Labor Costs
Trucks -- Capital and Operating Costs	Residue Percentage Materials
Containers	
Collection Efficiency	
Diversion Rates	

Appendix C
Sample WastePlan Input Screens

Residential Waste Generation and Demographics

GEN-R-D

	1993 -----	2001 -----
Waste generation (lbs/person/day)	1.71	1.71
Population (thousands)	10.47	10.47
People/Household	2.63	2.63
Percent Single-Family Households	100.0	100.0
Collection Route Miles in region	446	446
Percent Urban	.	.
Percent Suburban	.	.
Percent Rural	100.0	100.0

PgUp, F5: Prev Form
04-14-1993

PgDn, F6: Next Form
CANNON

F10: Menu

Residential Garbage Program Options

COL-R-G-G

Type of Collection Systems

	Urban	Suburban	Rural
Garbage Collection?	N	N	Y

Fixed Fee Collection Systems

	(Y/N)	(\$/ton)
Single-family Garbage Collection?		.
Multi-family Garbage Collection?		.

Transfer Station

Use a Transfer Station?	Y	
	(Y/N)	(\$/ton)
Fixed Fee?	N	.

PgUp, F5: Prev Form
04-14-1993

PgDn, F6: Next Form
CANNON

F10: Menu

Capital Costs

FAC-Y-2

Facility Name: Recycling Plant #1
 Land: . (1000 \$/Acre)
 Site Prep: . (1000 \$/Acre)
 Process Building: 6000 Size (sq. ft.)
 10 Cost (\$/sq.ft.)
 10 Lifetime (years)
 Capacity per site: 4 (TPD)
 Gross Area Multiplier: 4.0
 Equipment Life: 10

Equipment:	Cost (1000 \$)	Number		Cost (1000 \$)	Number
1 BALER	11.7	1	6 OIL IGLOO	2.2	1
2 TOWMOTOR	4.0	1	7 BINS AND SCOOP	2.3	1
3 CAN CRUSHER	3.0	1	8	.	0
4 GLASS CRUSHER	3.9	1	9	.	0
5 SCALES	1.2	1	10	.	0

Other Equipment: 10.0% of total equipment cost

PgUp, F5: Prev Form
 04-14-1993

PgDn, F6: Next Form
 CANNON

F10: Menu

Landfill Sizing Data

FAC-L-L

Compaction Rate	1.85
Refuse/cover volume ratio	3.50
Design life (years)	20
Post-closure costs period (years)	30
Average depth (feet)	45
Gross area multiplier (total site/fill area)	1.30
Methane generation (cu. ft./acre/year)	1000

PgUp, F5: Prev Form
07-20-1993

PgDn, F6: Next Form
DEFAULT

F10: Menu

Landfill Capital Costs

FAC-L-C

Land cost (\$/acre)	10000
Site preparation (\$/acre)	1000
Excavation and construction cost (\$/acre)	15000
Leachate collection system cost (\$/acre)	5000
Methane collection system cost (\$/acre)	5000
Other pollution control equipment (\$/acre)	2500

LINER:

Number of clay layers	2
Thickness per layer (feet)	4
Cost of clay (\$/CY)	7.00
Number of membrane layers	1
Cost of membrane (\$/sq. ft.)	1.00

Equipment costs (\$/ tons/day)	20.0
Cost of final cap and cover (\$/sq. ft.)	3.00

PgUp, F5: Prev Form
07-20-1993

PgDn, F6: Next Form
DEFAULT

F10: Menu

Landfill Operating Costs

FAC-L-0

Labor required (workers/tons/day)	0.0250
Salary and benefits (\$/worker/year)	30000
Maintenance, supplies (\$/ton/day)	2.00
Pollution control operating cost (\$/acre/year)	3500
Other operating costs (\$/ton/day)	3.00
Annual post-closure costs (\$/acre/year)	2000
Methane revenues (\$/1000 cu. ft.)	1

PgUp, F5: Prev Form
07-20-1993

PgDn, F6: Next Form
DEFAULT

F10: Menu

Appendix D
Sample WastePlan Facilities Report

WASTE NAME	1993	1995	1997	1999	2001
Newspapers	264	264	264	264	264
Corrugated Cardboard	3,416	3,498	3,580	3,662	3,743
Glass	308	308	308	308	308
Plastic recyclable	91	91	91	91	91
Ferrous	141	141	141	141	141
Aluminum	56	56	56	56	56
TOTAL WEIGHT (TONS)	4,277	4,359	4,440	4,522	4,604
TOTAL VOLUME (CY)	77,817	79,452	81,087	82,722	84,357

PRODUCT SHIPPED FROM RECYCLING PLANT #1

WASTE NAME	1993	1995	1997	1999	2001
Newspapers	264	264	264	264	264
Corrugated Cardboard	3,416	3,498	3,580	3,662	3,743
Glass	308	308	308	308	308
Plastic recyclable	91	91	91	91	91
Ferrous	141	141	141	141	141
Aluminum	56	56	56	56	56
TOTAL TONS SHIPPED	4,277	4,359	4,440	4,522	4,604

— page 2 — PUTNAM — PUTNAM CO. BASE SCENARIO — 05-17-1993 — 2:25 PM —

GROSS LESS SHIPPING COSTS: RECYCLING PLANT #1 FACILITY

WASTE NAME	1993	1995	1997	1999	2001
Newspapers	6,611	6,611	6,611	6,611	6,611
Corrugated Cardboard	119,573	122,434	125,296	128,157	131,018
Glass	9,226	9,226	9,226	9,226	9,226
Plastic recyclable	5,928	5,928	5,928	5,928	5,928
Ferrous	2,242	2,242	2,242	2,242	2,242
Aluminum	15,639	15,639	15,639	15,639	15,639
TOTAL	161,219	164,080	166,942	169,803	172,664

TOTAL SHIPPING COST

0

0

0

0

0

0

0

0

0

FACILITY COSTS: RECYCLING PLANT #1

TPD CAPACITY PER FACILITY: 25

NUMBER OF FACILITIES

1993

1995

1997

1999

2001

1

1

1

1

TOTAL SITES AND BUILDINGS CAPITAL COS

342,906

342,906

342,906

342,906

342,906

193,710

193,710

193,710

193,710

ANNUALIZED CAPITAL COSTS:

44,408

44,408

44,408

44,408

44,408

25,086

25,086

25,086

25,086

TOTAL EQUIPMENT

69,494

69,494

69,494

69,494

69,494

69,494

69,494

69,494

69,494

TOTAL ANNUALIZED CAPITAL COSTS

130,928

130,928

130,928

130,928

130,928

15,497

15,497

15,497

15,497

OPERATING COSTS:

LABOR

MAINTENANCE

UTILITIES

RESIDUE DISPOSAL

SHIPPING

INSURANCE

OTHER

0

0

TOTAL OPERATING COSTS

208,138

208,138

208,138

208,138

208,138

277,632

277,632

277,632

277,632

TOTAL ANNUALIZED COSTS

161,219

161,219

161,219

161,219

161,219

116,413

116,413

116,413

116,413

TOTAL REVENUES

209,753

209,753

209,753

209,753

209,753

279,247

279,247

279,247

279,247

NET COST(+) OR REVENUE(-):

106,583

106,583

106,583

106,583

106,583

23.15

23.15

23.15

23.15

TOTAL TONS PROCESSED

4,604

4,604

4,604

4,604

4,604

4,604

4,604

4,604

4,604

QUANTITIES OF WASTE LANDFILLED

LANDFILL:

WEIGHTS RECEIVED (TONS PER YEAR):

WASTE NAME	1993	1995	1997	1999	2001
Newspapers	1,181	1,189	1,197	1,204	1,212
Other Paper	10,440	10,580	10,720	10,860	11,000
Corrugated Cardboard	10,730	10,975	11,220	11,466	11,711
Glass	1,708	1,725	1,741	1,758	1,775
Textiles	1,815	1,819	1,823	1,828	1,832
Plastic film	1,262	1,275	1,289	1,302	1,315
Plastic rigid	1,178	1,192	1,205	1,218	1,232
Plastic recyclable	928	942	955	969	982
Foodwaste	4,397	4,460	4,522	4,584	4,647
Wood/Lumber	1,555	1,583	1,612	1,641	1,669
Yard Waste	3,172	3,177	3,183	3,189	3,194
Ferrous	1,430	1,445	1,461	1,477	1,492
Aluminum	256	258	260	262	264
Bulky Waste	124	124	124	124	124
Miscellaneous	2,741	2,775	2,809	2,842	2,876
RESIDUES	0	0	0	0	0
TOTAL WEIGHT (TONS)	41,918	42,520	43,122	43,724	44,326
TOTAL VOLUME (CY)	519,641	528,687	537,733	546,779	555,824

LANDFILL COSTS:

	1993	1995	1997	1999	2001
-----	----	----	----	----	----
EXISTING LANDFILL					

WASTES LANDFILLED EACH YEAR:					
TOTAL WEIGHT (TONS)	41,918	42,520	43,122	43,724	44,326
TOTAL VOLUME (CY)	194,865	198,257	201,650	205,042	208,434
REMAINING CAPACITY (CY)	4,805,135	4,410,316	4,008,713	3,600,325	3,185,153
TIPPING FEE PER TON: \$ 25.86					
TOTAL TIPPING FEES	1,083,990	1,099,562	1,115,135	1,130,707	1,146,279
NO NEW LANDFILL CAPACITY NEEDED DURING THE STUDY PERIOD					

DEFAULT ROUTINGS

Collection Processes -----	Facility Processes -----	Fixed Fee -----
Dropoff Recyclables	Not handled in this Scenario	0
Commingled Recyclables	Recycling plant #1	0
Separated Recyclables	Not handled in this Scenario	0
Compost	Not handled in this Scenario	0
Household Garbage	Landfill	0
Commercial Recyclables	Recycling plant #1	0
Commercial Garbage	Landfill	0

ROUTINGS: DEFAULT/INDIVIDUAL, BY COLLECTION FILE

COOKEVILLE	Currently Using	Default	Routing
PUTNAM	Currently Using	Default	Routing

INDIVIDUAL ROUTINGS

COOKEVILLE - COOKEVILLE COLLECTION

Collection Processes -----	Facility Processes -----	Fixed Fee -----
Dropoff Recyclables	Not handled in this Scenario	0
Commingled Recyclables	Recycling Plant #1	0
Separated Recyclables	Not handled in this Scenario	0
Compost	Not handled in this Scenario	0
Household Garbage	Landfill	0
Commercial Recyclables	Recycling Plant #1	0
Commercial Garbage	Landfill	0

PUTNAM - PUTNAM CO. RURAL COLLECTION

Collection Processes -----	Facility Processes -----	Fixed Fee -----
Dropoff Recyclables	Not handled in this Scenario	0
Commingled Recyclables	Recycling Plant #1	0
Separated Recyclables	Not handled in this Scenario	0
Compost	Not handled in this Scenario	0
Household Garbage	Landfill	0
Commercial Recyclables	Recycling Plant #1	0
Commercial Garbage	Landfill	0

FACILITY SYSTEM SUMMARY

1. NET COSTS (dollars per year)	1993	1995	1997	1999	2001
RECYCLING					
Recycling Plant #1	116,413	113,956	111,498	109,040	106,583
Facility					
LANDFILL					
Existing Landfill Facility	1,083,990	1,099,562	1,115,135	1,130,707	1,146,279
Facility					
TOTAL SYSTEM COSTS	1,200,403	1,213,518	1,226,633	1,239,747	1,252,862

2. WEIGHTS (tons per year)

RECYCLING	1993	1995	1997	1999	2001
Recycling Plant #1	4,277	4,359	4,440	4,522	4,604
Facility					
LANDFILL					
Existing Landfill Facility	41,918	42,520	43,122	43,724	44,326
Facility					
TOTAL SYSTEM WEIGHTS	46,194	46,878	47,562	48,246	48,930

3. COST PER TON

RECYCLING	1993	1995	1997	1999	2001
Recycling Plant #1	27	26	25	24	23
Facility					
LANDFILL					
Existing Landfill Facility	26	26	26	26	26
Facility					
SYSTEM COST PER TON	26	26	26	26	26

Appendix E
Sample WastePlan Summary Report

page 1 PUTNAM PUTNAM CO. BASE SCENARIO 05-17-1993 2:44 PM						
TOTAL SYSTEM SUMMARY						
1. NET COSTS (dollars per year)						
RECYCLING	1993	1995	1997	1999	2001	
Recycling Plant #1 Facility	116,413	113,956	111,498	109,040	106,583	
COOKEVIL - Single-Family Commingled Co	19,860	19,860	19,860	19,860	19,860	
PUTNAM - Single-Family Commingled Coll	21,173	21,173	21,173	21,173	21,173	
COOKEVIL - Commercial Collection	162,961	166,860	170,760	174,659	178,559	
GARBAGE						
COOKEVIL - Single-Family Garbage Colle	317,319	317,319	317,319	317,319	317,319	
COOKEVIL - Commercial Garbage Disposal	567,031	578,954	590,877	602,800	614,723	
PUTNAM - Transfer Station Facility	195,487	195,487	195,487	195,487	195,487	
LANDFILL						
Existing Landfill Facility	1,083,990	1,099,562	1,115,135	1,130,707	1,146,279	
TOTAL SYSTEM COSTS	2,484,234	2,513,171	2,542,109	2,571,046	2,599,983	
2. WEIGHTS (tons per year)						
RECYCLING	1993	1995	1997	1999	2001	
Recycling Plant #1 Facility	4,277	4,359	4,440	4,522	4,604	
COOKEVIL - Single-Family Commingled Co	416	416	416	416	416	
PUTNAM - Single-Family Commingled Coll	444	444	444	444	444	
COOKEVIL - Commercial Collection	3,416	3,498	3,580	3,662	3,743	
GARBAGE						
COOKEVIL - Single-Family Garbage Colle	6,427	6,427	6,427	6,427	6,427	
PUTNAM - Single-Family Garbage Collect	6,852	6,852	6,852	6,852	6,852	
COOKEVIL - Commercial Garbage Disposal	28,638	29,240	29,842	30,444	31,047	
PUTNAM - Transfer Station Facility	6,852	6,852	6,852	6,852	6,852	
LANDFILL						
Existing Landfill Facility	41,918	42,520	43,122	43,724	44,326	
TOTAL SYSTEM WEIGHTS	46,194	46,878	47,562	48,246	48,930	
3. COST PER TON						
RECYCLING	1993	1995	1997	1999	2001	
Recycling Plant #1 Facility	27	26	25	24	23	
COOKEVIL - Single-Family Commingled Co	48	48	48	48	48	
PUTNAM - Single-Family Commingled Coll	48	48	48	48	48	
COOKEVIL - Commercial Collection	48	48	48	48	48	
GARBAGE						
COOKEVIL - Single-Family Garbage Colle	49	49	49	49	49	
COOKEVIL - Commercial Garbage Disposal	20	20	20	20	20	
PUTNAM - Transfer Station Facility	29	29	29	29	29	
LANDFILL						
Existing Landfill Facility	26	26	26	26	26	
SYSTEM COST PER TON	54	54	53	53	53	

VITA

Jeffrey E. Case was born on May 22, 1968, in Nashville Tennessee and resided twenty miles northwest of Nashville in Ashland City, Tennessee most of his life. He graduated from Cheatham County High School in 1986 and continued his education at Austin Peay State University. He graduated from Austin Peay in December of 1990 with a Bachelor of Business Administration Degree, majoring in Economics. After a short period of work, he enrolled at the University of Tennessee, Knoxville in August of 1991 and began work toward a Master of Science Degree in Agriculture. The Master's degree with a major in Agricultural Economics was awarded in August 1993.