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Institutional Analysis and Case Study
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Steven B. Duprey

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Lynn R. Harvey
Major professor

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Solid Waste Collection: Institutional Analysis and Case Study - Delhi Charter Township, MI

By

Steven B. Duprey

A Thesis

Submitted to
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ABSTRACT

Solid Waste Collection: Institutional Analysis and Case Study
–Delhi Charter Township, MI

By

Steven B. Duprey

Competitive market provision of traditionally publicly provided services is widely viewed as the preferred policy option for communities. However, the dichotomy of public versus private provision of solid waste collection is incomplete and value laden. This analysis focuses on the economic characteristics of solid waste collection and lays forth the full spectrum of policy alternatives and associated policy outcomes. The case study is of a community utilizing the competitive market for collection services. Forced to cope with pecuniary and aesthetic externalities as well as excessive road damage due to a multiple provider collection system with non-contiguous routing, Delhi Charter Township is faced with a choice between those preferring low unit cost and those desiring variety and choice.

To my wife, Zandra.

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My major professor and mentor, Dr. Lynn Harvey is the main reason I have reached this point. As teacher, employer, counselor and friend, I am deeply indebted to Dr. Harvey and hope to prove worthy of the investment made in me.

Finally, without the sacrifices of my wife, Zandra, my graduate education at Michigan State University would not have been possible. For putting your dreams on hold so that I might obtain mine, I am forever grateful.

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INTRODUCTION

Solid waste collection is not often viewed as a subject worthy of consideration until a crisis arises, such as contract negotiations with unionized sanitation workers or delayed collection due to national holidays. While many communities are satisfied when solid waste collection is within budget or service is consistent, others have opted for privatization hoping 'free-market' competition will provide more efficient and effective service. But the question of how trash is collected, who is collecting it, and at what price is not simply the question of public versus private provision. Public versus private is a false dichotomy that fails to recognize the institutional and community variables that affect the performance of any solid waste collection system.

Most of the debate concerning solid waste collection is centered on the question of privatization of public services. In fact, many simply assume that public service provision is less efficient than private provision due to the lack of competitive market forces. There is a wealth of information on the benefits of privatization. However, the lack of evidence pertaining to inefficiencies in the competitive market provision of refuse collection is startling. This analysis adds a layer of complexity to the solid waste collection privatization decision and should give pause to those policymakers pushing to privatize other publicly provided services as well.

Officials in Delhi Charter Township, MI, sought assistance from the Department of Agricultural Economics at Michigan State University to examine the costs associated with siting a rural residential recycling center in their community. The process quickly evolved to include an examination of the solid waste collection system because of clear linkages with household recycling.

The nature of the problem with solid waste collection is twofold. First, the economies of scale and contiguity present in the collection of solid waste are a source of both interdependence and conflict. A set of institutions that fail to account for scale and contiguity in collection routes will yield higher marginal and average costs than institutions designed to take advantage of these characteristics. Second, efficient solid waste collection requires unanimity, either voluntary, coerced or incidental, without regard to the institutional structure that brings it about. One service provider must serve each household within a given geographic area. This poses difficulties when tastes differ or are contemptuous of governmental regulation.

Chapter one will provide a brief history of solid waste collection and the components of a modern collection system. Chapter two provides a theoretical foundation to the analysis as well as a review of empirical work related to solid waste collection. Chapter three describes the objectives and methodology of the Delhi Charter Township study. The findings of the case study are detailed in Chapter four and an institutional perspective to the public policy alternatives available to local governments is offered in chapter five.

Chapter 1

BASICS OF SOLID WASTE COLLECTION

The usefulness of theory lies in its ability to abstract from specific problems, observations, and data to uncover fundamental forces often overlooked. Toward that end, chapter one provides us with a background of solid waste collection while chapter two builds the economic foundation utilized in the remainder of this analysis. The economic facts of interdependence that will be laid forth are the results of the development of human society. That is, people have evolved socially to live near one another allowing Increased specialization in economic activities and providing mutual gains from trade. Proximity of neighbors provides many benefits and opportunities for interaction, yet also imposes costs. Collection and disposal of solid waste is just one of these. So before asking how cities, townships and villages should collect solid waste, it is useful to ask why it is collected at all.

History

One problem with garbage is the space it occupies. As early human beings evolved from nomadic hunter-gathers to more stationary food growers, the choice of where to live became very important. Agricultural production became a more reliable food source and eventually specialization and trade made humans increasingly dependent on one another. Communities developed along trade routes and waterways and the development of cities began.

Population centers continued to grow, and the increased density meant less space for individuals and their trash. Excavations of domiciles in the ancient city of Troy found alternating layers of rubbish and clay indicated trash was not removed from the home, but simply dispersed across the floor and covered with fresh clay. Eventually, the roof would be raised to accommodate for the lost space (Savas, p. 11).

There is also ample evidence that early societies recognized the public health dangers of solid waste. Evidence exists of street cleaning laws in early Chinese writings as well as the sanitary influence of religious doctrine on Islamic cultures. Dogs and more often swine were herded through the streets of most European cities until the mid-nineteenth century. In fact, most collection activities were performed by scavengers, either human or animal, until organized management was forced upon city leadership. Modern management of solid waste is indebted to flies, rats, pigs, odor and smoke (Hickman and Eldredge, 1999). Flies, rats and other vermin were attracted to the open dumpsites, pigs eventually became ill or developed trichinosis and the open burning of garbage produce vast amounts of odor and smoke. In addition, the experiences of cities like New York during the nineteenth century show the devastating consequences of poor sanitation (Rosner, 1996). Epidemics of cholera and typhoid swept through the infamous tenement districts causing widespread despair. But public health conditions were greatly improved when solid waste was collected regularly. Thanks in part to the US Army's development of sanitary landfills

(Bjornson and Bogue, 1961) and the growing wealth of this country after WWII, management practices became cleaner and healthier.

This short historical summary shows solid waste is collected because human beings are interdependent. Trash left by A will effect B. Rubbish burned by C will effect A and B. These facts are inescapable when population density reaches a critical value.

Modern Management System

The modern solid waste system contains five main components: production of goods, consumption of goods, collection of waste, recycling and disposal. Many efforts are aimed at reducing the amount of solid waste being disposed. Some urge less consumption, others desire reduced packaging. Some think recycling should be mandatory. These attempts to alter one or more components of the solid waste management system have little or nothing to do with the collection system. The exception being dual collection, offered in a growing number of communities, that combines recycling and trash collection in one vehicle.

The generic details of a collection system[1] are described in Table 1. At some critical value, population densities begin to overwhelm self-disposal options such as burial or burning. Organization is required and must contain each of the components listed in Table 1. Who receives collection services is the only constant. Most human activities produce waste and its removal will always be needed. All other components are variable, a municipality can provide collection service and finance it through general tax revenues. Or, a township could auction a franchise to a private firm to haul waste and directly bill consumers. The myriad of policy options is discussed in detail in chapter 3.

Two aspects of the collection system not mentioned are the method of disposal and level of service. From the cost of collection perspective, whether the waste is sent to an incinerator or landfill, for example, is immaterial.

Table1: Components of a Solid Waste Collection System

System Component	Description
Consumer of Service	households, businesses, schools, etc.
Provider of Service	firms, local governments, self-haulers
Organizing Authority	consumer, local governments
Financing Authority	consumer, local government

That is to say, the physical act of transporting rubbish is uncorrelated with the manner of disposal, holding distances to the various disposal sites fixed. However, the price consumers face is affected by the method of disposal and the structure of the local disposal industry. If financed through user fees, the large capital investment in a municipal incinerator could substantialy increase the price of disposal. A private landfill can extract monopolistic rents in relation to the distance of the nearest competing landfill. These examples increase the price of *disposal* not the cost of collection. But because the cost of disposal is transmitted through the price charged for collection, consumers may interpret any

[1] Adapted from Savas (1977) Table 3-1 pg. 28.

price increase as solely an increase in collection costs. Analytically, at least, these two must be differentiated.

The level of service will have dramatic effects on the cost of collection. Number of collection days per week, amount of waste allowed per pickup, whether yard waste or bulk items are collected, and many other service variables influence the cost. However, this is not what is of interest to this analysis. Clearly comparing different levels and types of service is an apples and oranges comparison. The thrust of this analysis is, holding the level of service constant and regardless of institutional characteristics, the cost of collection will be lower with one provider servicing a contiguous geographic region, increasing it's customer base and/or service area to the physical constraints of the state of technology.

Chapter 2

ECONOMICS OF SOLID WASTE COLLECTION

The economic theory supporting this analysis is presented in chapter two. It is crucial to identify the inherent features of solid waste collection not only for the purpose of assisting Delhi Charter Township, but to allow broad application of our findings to other good or services with similar characteristics. Additionally, a theoretical understanding of solid waste collection permits the interpretation of related literature and empirical work. The lack of specific literature and analysis pertaining to non-contiguous routing in a multiple provider competitive market makes theoretical knowledge even more important.

Economies of Scale

In the production of many goods and services, the average cost of production declines as output increases. This means a proportionate increase in output is accompanied by a less than proportionate increase in inputs. Goods exhibit increasing returns due to indivisible inputs when a particular physical asset is needed to produce output. Or, experience can provide cost savings when the next unit is being produced. These economies are extracted with complicated or evolving production processes, like bringing a new automobile to market. And, as Schmid[2] notes certain physical properties can provide

[2] For example, the volume of fluids passing through a pipe more than doubles as the circumference of the pipe doubles (p.62)

increasing returns to scale. While there are several sources of economies of scale, two[3] are relevant to solid waste collection.

First, as the number of households serviced by a fixed capacity collection vehicle increases, the average cost per household falls. Fixed costs are being spread over larger output amounts, driving average cost down. The truck is, in a sense, indivisible because while other inputs (fuel, oil, and labor hours) can vary, the capacity of the vehicle remains fixed.

A slightly different aspect of indivisibility delivering economies of scale to solid waste collection occurs when additional vehicles are added to the organizational entity providing the service. A firm or department of public works needs a management and maintenance infrastructure to operate. The first truck purchased requires both of these structures in place, while the additional truck adds minimally to the overhead costs. This assumes there is some range of capacity that both the management and maintenance portions of the organization can handle. Over this range, average costs of delivering collection service declines as the size of the fleet increases. These two sources of economies of scale in waste collection are both related to the concept of indivisibility because additional units are being added to a fixed asset. In the first instance, more units are collected by a fixed capacity vehicle and in the second, more vehicles are added to a given organizational size.

Second, as the capacity of the collection vehicle increases, more households can be serviced along a fixed collection route. This reduces the

[3] One might argue that economies of scale can also be extracted through experience and repetition of activity, but these would most likely be negligible in solid waste collection and are thus ignored.

variable inputs such as fuel and labor required because less time need be spent traveling to the disposal site. The average cost curve of collection declines as the capacity of the truck increases. For example, the number of axles on a truck increase the load it can physically and legally transport (Sterns, p53). This is akin to when increasing the size of a plant reduces the unit cost and a lower point on the average cost curve is obtained. The following, taken from a recent industry publication *Public Works*, refers to the capture of scale economies in Cincinnati, Ohio:

"Over the planned six-hour route-days, each older packer (500-lb/yard compaction) and its two-person crew collect two 10,000-lb loads per day to service 700 to 800 stops. Each newer packer (1,000 lb/yard compaction) and the same two-person crew services the same 700 to 800 stops in one 20,000-lb load daily."

The older packers (vehicles that can compact trash hydraulically) and the new packers were both rated at a 20-yard capacity, a measure of volume. But the new vehicles could physically shrink the size of the trash collected allowing the weight of each disposal trip to double. This lowers average cost of collection by reducing unproductive drive time.

What issues are brought about by the economies of scale identified in solid waste collection? The overriding issue is interdependencies. When consumers are free to choose which firm they buy from, the price each pays is affected by the choices of everyone else. Imagine a neighborhood with ten homes that has the option of connecting to the nearby sewer lines. Some want desperately to connect to the municipal sewer system, while others are resisting the change. Further, suppose sewers will not be extended unless a simple majority of homeowners agree. Whatever the outcome, the 'price' each pays, either through being denied the benefits of the sewer connection when you want them or having to pay for the connection when you don't want it, is determined by the preferences of others. The same is true for solid waste collection. If in that same neighborhood, eight homes choose firm A and two choose firm B, the difference in preferences causes everyone to pay higher collection prices. Similar tastes would yield unanimity in firm choice, and each would pay a lower price because the increase in firm output (collection units) is accomplished with less than proportionate rise in costs. The possibility exists for the firm to lower the unit price and still maintain profit levels. But with variety in preferences, two trucks, two crews and additional fuel is needed to haul trash for this neighborhood. Schmid (pg. 64) summarizes the issue well with "The fulfillment of tastes is affected by who shares your tastes."

When local governments restrict individual choice through contracts, franchises or self-production, citizen interdependence is not removed, but simply altered. In such cases, preferences and tastes still need to conform to affect policy change and reach economies of scale. However, it is assumed a much lower hurdle need be overcome than under a free market choice scenario. The difference is that ensuring and enforcing unanimity of firm selection is cheaper when government is responsible than when it is left to neighbors.

Economies of Contiguity

Stevens and Edwards have defined the increasing returns related to contiguity as those economies derived from the alignment of customers along a service route. (Savas, p 150.) If truck A passes by a home along an existing collection route, it is less costly to society for that house to be serviced by truck A than by another truck. While this is clearly true, it becomes more relevant to solid waste collection when combined with Schmid's concept of superordinary economies of scale (Schmid pg.69). In truth, superordinary economies of scale is just a re-labeling of the more prevalent term natural monopoly. Both imply a market whose output is produced at the lowest cost when it is controlled by only one firm (or public entity). Natural gas and electricity are most often identified as natural monopolies.

But even these examples are limited by the size of the market under consideration. One company does not control the entire electricity industry in the U.S., even though many localized natural monopolies exist. They are limited (and in some cases created) by technology, topography, organizational inefficiencies and government regulation. Because of the properties associated with contiguity and increasing returns, solid waste collection exhibits superordinary economies of scale in localized markets. That is, the localized market for solid waste collection reaches the lowest point on the industry cost curve when one firm/entity captures the whole market. A localized market for collection is defined as the combination of geography, population density, and average waste production associated with the physical constraints on technology and organizational constraints on efficient management.

It is now offered, with evidence provided in the section on empirical studies and in chapter 2, that the increasing returns to the proximal arrangement of solid waste collection is unambiguously less costly than multiple provider systems. This outcome must be tempered by the facts associated with monopolistic power. The usual neoclassical analysis of monopolies predicts an outcome with output too low and price too high. This is because monopolists maximize profit when producing the output at which marginal revenue equals marginal cost. Since they face downward sloping demand, price exceeds marginal revenue and marginal cost. This difference over the quantity produced yields monopoly rents.

It is a safe assumption that most natural monopolies face downward sloping demand curves in the long run. Changes in consumption behavior and development of viable alternatives would likely cause the demand for a monopolist's goods to fall as long-run prices increase. For example, the development of more fuel-efficient vehicles was in part due to dramatic increases in gasoline prices here in the U.S. by the OPEC cartel's supply control measures. Exerting their considerable market power, OPEC brought about an eventual change in consumer demand for fuel.

Usually, goods exhibiting superordinary economies of scale are capital and infrastructure intensive. That presents substantial barriers to entry. (Nicholson, pg. 547) However, solid waste collection does not require the massive investments in infrastructure and the physical capital needed is small relative to other natural monopolies. For these reasons, a firm could not extract huge monopoly rents over an extended period in a localized collection market. Barriers to entry are relatively low and if predatory pricing is disallowed new firms could compete not for individual customers, but for the entire localized market. The entire market must be organized for firms to compete and for communities to accept bids. Thus, some form of collective action is needed to bring about unanimity.

A word needs to be said regarding the apparent conflict of actual conditions in Delhi Charter Township and the suggestion of localized superordinary economies of scale. If in fact the market reaches it's lowest average cost with only one firm, why do we currently find three operating? While avoiding the unique characteristics of this case, we can identify three possible explanations.

One, the market is in disequilibrium but moving toward a stable equilibrium. What we now see is just a snapshot of the market, but perhaps the whole picture will be revealed in the long run to find one firm prevailing. This fails to explain the persistence of multiple provider non-exclusive collection arrangements, like the one found in Delhi.

Two, the firms and their customers have relationships that are not easily swayed by price. Loyalty to the firm or fear of disrupted service could prevent the selection of new service providers. Another aspect to this reluctance to switch providers is the required purchase of the trash receptacle. The price of the trash bin represents a hurdle to weed out those who would change providers often. After all, new customers may mean altering the route structure, which can be costly to the firm if done frequently. The purchase of the bin is also a psychological barrier to prevent switching from your current provider. Even the rational economist can find sunk costs hard to ignore.

Or three, there is no institution to bring about such coordination. With most other goods displaying increasing returns to scale purchases need not be location specific. Firms have a variety of locations at which marketing can be targeted and purchases can rise to capture the scale economies present. Solid waste collection firms must increase their output along specific collection routes to have returns increase. This is compounded by the firm's pricing problem. Do firm's first lower price to attract more customers or build a larger customer base and then lower price? If firms lower price first, revenue falls, but advertising expenses aimed at potential customers will lower profits as well. Through it all, the level of service must be maintained to keep current clients satisfied.

To summarize, economies of contiguity suggest localized solid waste collection markets exhibit superordinary economies of scale whereas reaching the lowest point on the market cost curve requires one collection entity. The localized collection market is defined as the unique combination of service area, customer density, and transportation technology that permits full exploitation of scale and contiguity economies. Monopoly power within localized markets is combated with competition for the entire market through auctioning franchise rights or bidding out contracts. If a community wishes to achieve these economies, it will undoubtedly be forced to chose the preferences of one group over another.

Additional Conceptual Issues

If a community fails to reach economies of scale, the outcome has mainly pecuniary impact. That is, unit costs are higher for everyone. But if collection is such that economies of contiguity are ignored, additional costs are imposed. In a multiple provider solid waste collection system, the excess miles driven by the second or third garbage truck (when only one truck is necessary) can cause substantial road damage. And if trash is collected on several different days, a neighborhood is subject to a less aesthetically pleasing environment than that produced under a one provider collection structure. The aesthetic loss is a result of being subject to multiple days of collection vehicle traffic and visually encountering trash receptacles more frequently. This loss clearly can not be quantified, but communities with blight laws, for example, attach some value to having visually appealing surroundings. More generally, people labor to beautify their home with fresh coats of paint and landscaping for similar reasons.

Incompatible Use Goods

Four other theoretical concerns must be addressed with a multiple provider collection system. While there are varying degrees of road quality and aesthetic quality, only one type can exist at a given point in time. Goods that have multiple uses or classes, which are each incongruent with the others, are said to be incompatible use goods (Schmid, 1987). Roads and aesthetics are such goods. We must define who has property rights over roads and aesthetics in order to determine the quality that will be provided. An interstate highway is wholly incompatible with a gravel road or a cornfield. The land upon which the road is built can not be put to more than one use and the competing interests must be ranked. Which use wins is determined by who has ownership rights. For a city or township faced with a multiple provider collection system, a determination must be made as to the ownership of roads. If those preferring high quality roads have property rights, a single provider system will be implemented. On the other hand, if property rights are dispersed in another fashion the multiple provider system may be the outcome.

The crucial fact to remember with incompatible use goods is that whoever has the property rights will determine the resource use. With solid waste collection specifically, if excessive road damage and aesthetic loss occur we can say those preferring variety and choice in solid waste collection own these resources. It should also be noted that aesthetic loss, unlike measurable road damage, is closely linked to personal values and attempts to quantify it should reflect this fact.

High Exclusion Cost Goods

The second issue arising from multiple provider collection systems is a theoretical reason for the lack of consensus in group decisions. High exclusion cost goods are those goods where the costs of precluding unauthorized use is high. This should be distinguished from public goods (or Schmid's joint-impact goods) that are nonrival in use. This means if the good or service is produced, it is available to all and the marginal cost of another use is zero. High exclusion cost goods differ from public or joint-impact goods in that the marginal cost of another user is not zero. Consider rush hour traffic. It would be very costly to exclude any individual from using the streets who does not contribute to their production. The problem lies in the marginal cost additional vehicles impose during rush hour. Additional users occupy the roads and prevent other's use or at least increase the cost of use for others. Thus, use of the road is rival in use and not a public good.

The free rider problem is always present with high exclusion cost goods. Free-riders use a resource and do not contribute to it's production or bear costs associated with the resource. Here, individuals utilizing a resource without paying are either hard to detect or hard to deter. Often left out of traditional treatments of public goods is the counter piece to the free rider, the unwilling rider (Schmid, pg. 49). If a gasoline tax is used to fund traffic easing measures in congested urbanized areas, all gasoline buyers must pay the tax whether they add to the traffic congestion or not.

Unlike incompatible use goods, simply defining property rights will not resolve this conflict. For instance, the existence of a national defense system provides protection for everyone within that nation whether they contribute with taxes or not. Similarly, ensuring roads are of high quality or aesthetic value is difficult because people can enjoy the benefits without contributing to their production. In the free-market scenario with a single provider, one can choose an outside firm, and still enjoy the majority of benefits her neighbors choices, i.e. high aesthetic values and good roads. It is impossible, or at least prohibitively costly to prevent the dissenter from benefiting or to force contribution..

This is more generally a problem of collective action. As Mancur Olson (1965) asserted, as the size of group increases, the difficulty in achieving the common interest increases. Two main reasons explain this phenomenon. First, with larger groups the share of benefits is small for each member and second, organizational and transaction costs increase. So it is costly to initiate and maintain consensus in larger groups unless each member can receive selective benefits while non-members receive none. This result is suggestive of some form of coercive power to achieve the economies derived from a single collection agency in localized markets. That said, if economies are not reached, some in the community are 'coerced' into paying higher unit costs than necessary.

When utilizing the concepts of high exclusion cost and incompatible use good it is important to identify the good under analysis. Both are irrelevant if we are speaking of solid waste collection itself. However, they become extremely useful when the object of examination is the road damage from excessive truck traffic or loss of aesthetic quality from more frequent sightings of trash bins.

Financing Road Repair

How communities choose to finance road repair is the third theoretical consideration. Because collection vehicles can cause deterioration of local streets, excessive collection traffic can impose additional costs beyond those paid by customers. These added costs are imposed upon society and are not reflected in market prices. Entities (individuals, firms, governments) engaging in transactions with externalities create an artificial equilibrium. With negative externalities, like road damage in this case, too much of the good creating the external effect is produced. A tax set at a rate equal to the marginal social cost of collection is one solution set forth by Pigou (Rosen, pg.94). Referred to as 'internalizing an externality', this tax would shift the supply curve to the left causing demand to fall and price to rise. If communities had a formula to charge each resident the cost of repairing road damage resulting from their choice of waste hauler, then the full cost of their decision could be known. There is no such formula so the question of who should pay for what road damage is an interesting one.

Governments generally have two ways to finance activities, through general tax dollars or special assessments. Funding repair projects with general tax dollars is how most roads are improved. This is due to the high exclusion cost aspect of streets. It is administratively impossible to use assessments, tolls or other mechanisms to pay for road work. The exception being when the beneficiaries of a project are identifiable and represent a sub-group of the community. A dead-end residential street is a good candidate for special assessment when road repairs are needed. Users are identifiable and should be willing to contribute because they are the sole beneficiaries of the improvements.

If the entire community benefits, each member should contribute and therefore general tax dollars should be used.

The relevance to solid waste collection is that general tax dollars do not induce citizens to alter their choice of collection agency. Those who chose to dissent from the majority's selection by employing an 'outside' firm can not be made to pay for the additional costs their actions impose, either pecuniary or with regard to road repairs. Yet even a pricing institution that can discriminate between dissenters and those subscribing to the majority selection might not reduce the aesthetic damage. If the dissenter's preferences are strong enough, he will pay the added costs he imposes but unless property rights are assigned to aesthetic views, garbage bins will be more prevalent than a one-provider collection system. If the owners of pleasing views are determined to be the dissenters, the majority can either gather a bid and buy out the dissenters or the majority can petition government and affect change democratically. However, the majority faces the same pitfalls of collective action mentioned previously.

Variety versus Cost

The last concept important to this discussion could fit with the earlier topics of economies of scale and contiguity. It is the tradeoff between variety and cost and it warrants it's own treatment because it acknowledges human values. It also gets to the heart of all economic activity. Humans enjoy variety and uniqueness in almost every marketable item. Having hundreds of choices in automobiles and thousands of choices in food imposes costs on society. But the sea of products on the market provides people with a means to satisfy their individual tastes. Science could develop some bland pelletized kibble to meet our physiological requirement of vitamin and minerals, but most people wouldn't be happy. Economists and policy makers should not forget this. Even with something as undifferentiable as picking up trash and hauling it away, people may desire choice. One of the duties of policy makers is to order these desires and preferences when they are in conflict. With some goods and services, variety is too costly whereas with others people are willing to pay more for it. Part of the reason for this analysis is to determine just how costly it is to have variety in solid waste collection so that, with this information, Delhi Charter Township and other communities can be begin to think deeply of the consequences that flow from individual choice.

Empirical Review

The earliest study of solid waste collection was conducted by Hirsh (1962). The motivation for this work was determining the cost functions of the public provision of solid waste collection. The findings are not generally applicable since the focus was on service level, not market structure. However, two interesting conclusions were put forth. Economies of scale were not found, but part of this was due to the misalignment of municipal and collection boundaries. That is, firms operated collection routes in more than one city. So from the company perspective, they may well have achieve economies of scale, but the study could not make this determination. Secondly, the point is made that these types of studies are simplified by the "relatively few external effects" of waste collection. Yet pickup density is found to have significant effect on the cost of collection. This is a contradiction that becomes apparent when two or more collection agencies operating in non-exclusive areas. With non-exclusive routing, pickup density is decreased, unproductive driving time is increased and per unit costs rise. This price increase is a pecuniary externality and is ignored by Hirsh. This either shows a lack of understanding of the institutional impacts on cost or collection is assumed to occur with contiguous routing. However, no mention is made of returns to contiguity. This entire chapter aims to show 'external effects' do exist and to illuminate their underlying economic causes.

Edwards and Stevens (1976) present data showing the cost savings to economies of scale and contiguity. Market structure is found to have significant price implications. Specifically, they attribute a 10 to 41% cost reduction to government intervention that creates a one-provider collection system. The 25 year old study included 77 cites and compared cities with contracts to cities with either franchises or 'unregulated' private markets. Contiguity is found to be more significant than scale, offering cost savings to cities regardless of their size. Achieving these cost reductions is possible with a competitive bidding process or through some price regulation mechanism. An interesting finding is that billing costs can represent between 15% and 24% of total collection costs per household for franchises and only 3% for municipal providers. Local governments can issue one bill, collect fees and charges for several services while lowering average billing cost.

Two years later, Stevens authored another study that is as close to this analysis that the literature provides. In "Scale, Market Structure and the Cost of Refuse Collection" (1978), she argues that a competitive market is considerable more costly per unit than a monopoly arrangement. The majority of the difference in cost is attributed to economies of contiguity. Less important for our purposes, but significant for policy makers, is the finding that private single provider systems are less costly than public assuming there are limitations to the monopolist's power. Institutional structure and rules are shown to have implications on price. Stevens identifies and, along with her previous study, quantifies the pecuniary externalities. However, any additional external effects are ignored.

A more recent examination of solid waste collection in the U.K. by Bello and Szymanski compared average collection costs before and after the 1988 Local Government Act that forced competition into the provision of most public services, including refuse collection. This act called for the mandatory bidding of refuse collection to both public and private providers. Two findings are of note. One, that infusion of competition through compulsory contract offerings lowered costs an average of 22% from the year prior to the Act to the year after. This suggests that some inefficiencies were eliminated as a result of competition. And two, when the contract was awarded to the public provider as opposed to the private contractor, the cost reduction was only 10%. This could be do to a lack of competition in some local markets. Of the localities involved in the study, only 10% had bid out collection services. This means that entrepreneurs had little experience with the refuse collection business and perhaps this precluded a truly competitive process. The significance of this British study is that monopolies are not a solution even though a one-provider system is obtained. Periodic contract appraisal and requests for bids can provide the competitive incentive to operate more efficiently.

In addition to those listed above, nearly a dozen studies focused solely on the organizational distribution of solid waste collection. Useful for describing the general trends in the choice of collection structure, lacking cost data and leaving service levels variable, all are decidedly less useful to our purposes. (See Savas, Chp. 4 for a summary of these studies)

In summary, the literature points toward the existence of scale economies and the importance of exclusive routing arrangements for low cost provision. Yet communities must not simply surrender market power in order to obtain a one-provider collection system without the ability to restrain a public or private monopolist.

Chapter 3

SOLID WASTE COLLECTION IN DELHI CHARTER TOWNSHIP

The Charter Township of Delhi, MI is home to approximately 21,000 residents. Roughly eighty percent of the population is classified as urban and the remaining twenty percent as rural according to the 1990 census. The township maintains 118 miles of roads within its 29 square mile community. Solid waste collection is currently and always has been organized via the 'free' or competitive market. The market structure has resulted in three private collection companies simultaneously operating throughout the township. While each firm optimizes its own collection routes by minimizing the number of miles needed to service their customers, the overall structure fails to capture economies of contiguity and economies of scale. The majority of residential streets have two or three times the minimum refuse collection vehicle traffic necessary for collection.

The Igham County Solid Waste Management Plan is a collaborative effort intended to meet the needs of county residents and promote wise resource use. One of its goals is to devise 'best management' practices for the county and all local units of government to follow including the collection, transportation and disposal of solid waste. This suggests duplicative private collection services that create externalities affecting prices, roads, and the environment is sure to be divergent with county goals.

According to the Ingham County Solid Waste Management Plan, Delhi Charter Township will experience strong population growth over the next several years. By 2008, the population is projected to increase by nearly 4,000 residents. Given the current development patterns of large subdivision with large plot sizes, the problems of non-contiguous routing will likely be exacerbated due to increased service demands and greater distances between units.

Objectives

When presented with the assignment of examining solid waste collection in Delhi Charter Township, the first step was to determine the specific objectives. Working with township officials, it was ascertained that two issues were of most concern. It was assumed the current collection arrangement was more costly than a single-provider system and that the added collection vehicle traffic increases township road repair costs. Providing empirical research to guide policy makers on these two points was the generalized objective. More specifically, the research questions to be addressed were: (a) what is the pecuniary impact of the multiple provider solid waste collection system on market price; and (b) what is the cost of excess road damage resulting from the multiple provider system. Only residential curbside refuse collection is included in the analysis as multiple-unit dwelling, commercial and industrial collection impose additional complications due to different collection techniques. However, the analytic approach is valid for these types of collection as well.

Framework of Analysis

With clearly defined objectives, a framework of analysis was developed. Both goals set forth require some measure of the differential impact of single and multiple provider collection systems. Therefore, the cost of collection under the current three firm structure is compared to a hypothetical one firm structure. Under both structures, a collection vehicle spending identical time and using identical labor and resources visits each customer. Workers perform the same function at each stop and under both scenarios. Vehicle capacities are the same so the aggregate number of trips to the disposal site are equal. In fact, the only assumed difference between the three provider system and the one provider system is the number of total miles driven. The reason for this is simple. One centralized route planner would want vehicles to be efficient, that is, not pass by any customers while on route and reduce backtracking miles. Imagine this planner connecting the dots on a map of the township, connecting house to house in the shortest possible manner. Routing design is often done manually with the input of the driver, but there exists computer programs that build routes automatically. However, the current structure in Delhi has three different planners with three different maps (See Appendix F). Each map contains only the individual firm's customer base. Assuming each is equally efficient at minimizing individual route mileage, the ratio of the miles driven under the three provider and single provider system is hypothesized to be greater than one and less than or equal to three.

The imaginary single provider drives the minimum number of route miles needed to collect solid waste at each home within the township. Excess route mileage is defined as the current number of miles driven by the three firms minus the minimum number of route miles. Once excess route mileage is obtained, a value figure must be placed on each mile of excess. This figure must include labor, resources and road damage estimates. The cost of excess mileage minus the new costs incurred by the imaginary sole provider from its added market share is assumed to represent the cost differential between the two structures. This cost differential represents the added household expenditures on solid waste collection resulting from the three firm system. Unrealized returns to scale and contiguity are theorized as the sources of these added expenditures.

Methodology

The efforts to collaborate with the local firms proved fruitless. Each firm was extremely protective of information they deemed proprietary, such as number of customers and actual route structure. Ironically, this information is in no way private, as simple observation could provide the research with identical information. After experiencing this setback, it was decided three separate samples representing high, medium and low density neighborhoods would provide a sufficient data set. Each neighborhood was selected based on the criteria of available, accurate GIS maps and apparent housing density. Using both road and GIS maps as well as visual observation, high, medium and low density sample were selected. Considering the costs of collecting relevant data for the entire township and the lack of firm cooperation, the sampling methodology was appropriate.

Data points were collected by observing the type of waste receptacle each home in the sample set out to the curb and on which day. Each firm currently collects on different days. These points were entered into a geographic information system (GIS) map provided by the Tri-County Regional Economic Development and Planning Agency. Twelve different maps were created with this data, with each of the three sample neighborhoods having four maps associated with it. One map represents the single provider system while each firm required a separate map with only their customer base and route information.

These maps were used to calculate the additional miles of collection vehicle traffic from maintaining a three firm collection structure as opposed to a one provider system. The marginal cost per excess mile is developed to find the direct firm expenditures on this excess mileage. Then a scenario is proposed to find the pecuniary costs associated with failing to capture economies of scale and contiguity. This scenario shifts all customers to one firm to simulate a one-provider structure. Under said scenario, the monetary impact can be interpreted from the firm perspective as increased profit or the community perspective through lower prices. Finally, the cost of road damage is estimated by combining excess route mileage values with an U.S. Department of Transportation study on pavement deterioration.

Chapter 4

DATA AND OUTCOMES

The sample data displayed in table 2 shows both the relative market share for Firms X, Y, and Z and the size of the neighborhoods comprising the sample. Extrapolating the sample market share to the entire amount of single unit residential customers yields the estimated customer base for each firm in the township as a whole.

Table 2: Market Share from Three Neighborhood Sample

Sample Neighborhood	Firm X	Firm Y	Firm Z	Total
Holt/Wilcox/Aurelius	255	137	31	423
Bishop/ Grovenburg/ Holt	76	15	7	98
Sandhill/ Dell/Pine Tree	153	17	22	192
Total Sample Market Share	484	169	60	713
Total Township Market Share	4684	1635	581	6900

Excess Route Mileage

The assumption of firm efficiency in route planning was difficult to maintain because of the route measurement technique. The shortest route calculated from the GIS maps might not produce the actual route driven due to certain traffic laws, traffic patterns etc. In its place, the average of three routes through each sample neighborhood was used. Repeating this process for each of the three firms and the hypothesized single provider for each sample neighborhood yielded weekly route miles driven. Table 3 should be interpreted in the following manner.

The row named 'Three Firm Structure' is the current *combined* number of miles needed to collect solid waste per week. See Appendix A for specific assumptions.

Table 3: Weekly Route Mileage in Sample Neighborhoods

	Sample Neighborhoods			
	Bishop/ Grovenburg/ Holt	Holt/ Wilcox/ Aurelius	Sandhill/ Dell/ Pine Tree	Total
Three Firm Structure	6.95	20.98	13.38	41.31
Single Provider Stucture	4.48	10.17	8.37	23.02
Difference	2.47	10.81	5.01	18.29
Road Miles	3.74	9.29	11.30	24.33
Households	98	423	192	713
Density	26.20	45.53	16.99	29.31

'Single Provider Structure' is the *minimum* required mileage necessary for collection. The excessive road traffic is found in the row entitled 'Difference.' The actual length of streets involved in the sample as well as the number of households in the sample is also provided.

It should be noted that the sample neighborhoods were by a purposive sampling technique constrained by the availability of up-to-date GIS maps, time necessary for observation and the desire to obtain different housing densities in the sample. A few weeks of direct observation produced a sample size of over 10 percent of the single unit residences and over 20 percent of the total road miles in Delhi Charter Township. Additionally, table 3 contains the density of the three sample neighborhoods measured as houses per road mile. For example, in traveling one mile in the Holt/ Wilcox/ Aurelius neighborhood, 45 single unit homes will be encountered. From a firm perspective, this is the most profitable neighborhood to be operating.

Having obtained the number of excess route miles for the sample, it is necessary to translate these into the relevant township values. This is accomplished by using the ratio of road miles in the sample (Table 3, 24.33 miles) to actual miles in the township, 118.28 miles. Sample data points were then multiplied by this ratio. Table 4 displays the estimates of the miles necessary to collect solid waste every week from the sample homes, from all Delhi single unit homes, and every year under the single and multiple provider structures. See Appendix A for specific information regarding these assumptions.

Table 4: Route Miles in Excess in Delhi Charter Township

	Weekly Sample Totals	Weekly Delhi Totals*	Yearly Delhi Totals
Three Provider Structure	41.31	200.83	10,443.06
Single Provider Structure	23.02	111.91	5,819.40
Difference	18.29	88.92	4,623.66
Total Road Miles	24.33	118.28	N/A

*Multiplying sample road miles by the ratio of actual road miles over sample road miles yields estimated Delhi totals.

With Table 4, we have quantified the average yearly excess mileage from non-exclusive routing. This figure is 4,623.7 miles, or difference between the most efficient routing and the current three firm routing structure.

Marginal Cost Per Mile

The next step is to derive a marginal cost per mile to be multiplied by the excess route mileage to provide us an estimate of the cost differential. As was stated previously, excess route miles are those driven between collection points, not inclusive of any time spent collecting and as such are seen as an unproductive use of resources. The framework views the entire amount of excess miles as a fixed component of the three firm structure. The concepts of marginal and average costs are equivalent in this context because excess mileage is unchanged. Marginal is the term used here since total cost is derived from a breakdown of each cost component (Sugden and Williams, p. 33). Marginal is also used to emphasize the fact that unproductive miles do have cost associated with them. Including depreciation is controversial but justifiable as marginal costs equal average costs for the remaining components labor, maintenance and fuel. See Appendix B for a detail explanation of depreciation.

Table 5 displays the assumptions needed for a marginal cost per mile estimate. See Appendix B for specific information on these assumptions. Left out of the assumptions are overhead cost, which might include insurance and other fringes as well as rental or electricity costs. Besides not having the financial data on overhead, it should be excluded from marginal analysis because these costs need not be incurred to drive the four thousand or so excess miles. These would be included for an average cost per mile value, but these are fixed not variable costs. Since they do not vary with firm output or excess route miles driven, they must be excluded from marginal analysis.

Multiplying the marginal per mile cost of $1.54 (from Table 5) by the excess route mileage from Table 4 yields $7,120/year, which is the combined three firm total cost of overlapping, non-contiguous routes. This is a seemingly insignificant amount, but it represents only the firm's direct expenditures on excess route mileage. What remains unaccounted is the lost opportunity each time a collection vehicle passes a household serviced by another firm. Each firm must charge customers a higher per unit price when the customer base is geographically dispersed. If each firm faced a geographically homogenous population to service, there would be no unproductive miles. But if variety is desired, routes are intermingled and excess route miles occur to satisfy demand. The next section will provide an estimate of the magnitude of resources spent on maintaining variety by way of increased prices.

Table 5: Cost Per Mile of Excess Route Mileage

	Cost per Mile	Comment
Fuel	$ 0.18	Average of 5.5 mpg @ $1/gal
Maintenance	$ 0.13	$5,000/year @ 150miles/day
Labor	$ 0.90	$12/hr @ 13.3 mph in Delhi
Depreciation	$ 0.33	$170,000, 12 yr. useful life, 10% salvage
Total	$ 1.54	

Pecuniary Externalities of Non-Contiguous Routing

When communities permit more than one firm to operate in a non-contiguous fashion, residents will be paying more for solid waste collection. The basic approach is shifting the current three firm market to a single firm structure. The market share of one firm is determined from the sample data, then revenue and cost information is derived. Then the entire market share is shifted to that one firm and again revenue and cost figures are determined. What does this accomplish? First, revenue and cost data for a single provider collection system is generated. Secondly, revenue and cost data can be compared before and after this imaginary shift in market share, the difference is a good proxy for the total pecuniary cost of non-exclusive service boundaries (assuming the cost differential is returned to customers via competitive bidding). Quantifying this additional cost of variety requires some specific information that if not available must be supplied with suitable assumptions.

The distribution of the sample market share among the three private firms was used to project the actual market share for the entire township and establish a figure for the customer base for 'Firm X'. Firm X has the largest actual market share and was chosen at random to be the representative firm receiving this hypothesized shift in market share. Calculating the added gross revenues from the new market share is a simple task. It is the number of new customers multiplied by $144, which is the average monthly cost mulitipled over the course of one year.

Table 6: Firm X Gain From a Shift to the Single Provider Collection System

			Gross Revenue	
Firm X	# of Customers	Price/ month($)	Monthly ($)	Yearly ($)
New Share	6,900	12	82,800	993,600
Old Share	4,684	12	56,206	674,477
Gain from Shift	2,216	12	26,594	319,123

Table 6 present two scenarios for the township and Firm X. The single provider system is seen in the row 'New Share' where the entire customer base of 6,900 single unit households is serviced by Firm X. The assumed price of twelve dollars is an approximate average of current prices charged in Delhi. Actual prices range from nine dollars a month to over sixteen dollars (see Appendix , depending on the quantity of trash that will be removed each week. The most costly plan provides customers with a 106 gallon bin, while the least costly service will collect only two bags of waste per week although it is restricted to senior citizens. Other plans offer pre-paid bags, encouraging conservation. This study assumes household production of solid waste to be 60 lbs. per week, a figure commonly assumed in the field. (Cite Igham Co Study) Plans that would accommodate this 60 lbs. requirement were priced at $11.75, $12.00 and $13.75 per month. Gross revenue increases by $319,123 under this twelve dollars per month price assumption.

The change in costs resulting from the additional units being served is a more complicated derivation. The details are best left for Appendix C, but a summary of the major assumptions is found in Table 7.

Table 7: Added Costs to Firm X Under Single Provider Collection System

Cost Category	Change	Rational
Fuel	(+)	Increased route mileage consumes more fuel
Maintenance	(+)	Increased route mileage increases maintenance requirement
Disposal	(+)	More customers increase the number of trip to the disposal site
Labor	(+)	More customers requires more labor hours to service
Labor	(-)	Excess route mileage declines, shortens the time between stops, fewer labor hours required to service an equivalent population

Fuel, maintenance and disposal costs are all variable costs that increase as output increases. The cost of disposing waste at a landfill can only increase because the volume of trash being transferred has increased. Fewer excess miles are traveled as Firm X obtains more market share. But the reduction of excess mileage is offset by the additional miles on route and to the landfill. These offsetting miles can only be assumed to consume an amount of fuel greater than the excess miles. This is because a vehicle traveling to the disposal site is hauling its capacity, while the unproductive miles occur still on route. If a truck is on route, it is not at capacity, otherwise no additional waste could be carried. Simple physics reminds us the energy required to move a heavier object (a full garbage truck) is greater than a lighter object (a truck that is not full). So, the offsetting miles driven to the disposal site require more fuel at the margin. Miles traveled on route are assumed to require a similar amount of fuel as the excess miles traveled under the three provider structure. For ease of calculation, this analysis will only account for the additional fuel consumed resulting from the increased number of trips to the disposal site. This is a rough approximation, but the miles driven to collect solid waste from the new customers is assumed to be equivalent to the savings in excess miles driven by Firm X.

Labor has both a positive and negative component. First, more households, 2,216 to be precise, must be served. This obviously requires more labor hours. But there is also a reduction in work hours from the removal of excess route mileage. As a single provider, Firm X does not pass by any household with one vehicle only to have another a second vehicle service it.

Therefore the time between collecting waste at unit A and unit B decline as all economies of contiguity are extracted. The underlying assumption is a savings of five seconds between stops under a one provider structure (See Appendix D). Calculated over the number of original customers provides a savings of nearly 350 hours per year in labor hours.

Table 8 displays the results of various formulas used to derive the added cost of the over 2,000 new customers Firm X provides service after the hypothesized shift in market shares. For the specific calculation, see Appendix C.

Table 8: Estimates of Cost Increase Accruing to Firm X Under Single Provider Collection System

Cost Category	Cost ($)	Detail
Fuel	1,341	7,375 miles at $1/gal and 5.5 mpg
Maintenance	959	$0.13/mile on average
Disposal	120,994	11,523 yds at $10.50/yd
Labor	15,360	1280 hours at $12/hr
Labor	(4,056)	338 hours saved at $12/hr
Total Cost Increase	134,597	

Having calculated the increases in gross revenues and total costs for Firm X under a one provider system, estimating the cost differential with the current structure is a simple matter of subtraction. The justification for this technique is the following. One, the additional firm expenditures on new collection customers are more efficient than the previous expenditures of firms 'Y' and 'Z' combined because Firm X captures economies of contiguity (and scale to a lesser extent). Whatever those previous expenditures on the 2,216 units were, they must exceed the cost of a single provider. So, Firm X reaches a lower point on the average cost curve and can theoretically provide collection services to the additional units at lower cost relative to the other firm's ability. Two, if the price remains at $12/month, total household expenditures on solid waste collection are unchanged. Three, the difference between the additional revenue generated (from Firm X's perspective) and the cost of that additional service is firm profit. This can be returned to customers via lower prices, distributed to labor through increased wages or used to increase the owners return on investment. Finally, lacking cooperation from the three firms and with no actual cost and route information forthcoming, deriving revenue and cost in this manner was the next best alternative. Table 9 displays the specific revenue and cost figures if this profit is used to lower price, as is the theorized result with competitively bided contracts and franchises arrangements.

Table 9: Unit Price and Estimated Profits Under a One Provider System

Firm X	$12/month	$11/month	$10/month
Revenue increases	319,104	236,304	153,504
Cost increases	134,597	134,597	134,597
Profit	184,507	101,707	18,907
Consumer Benefit	na	82,800	165,600

At $12/month, consumers do not experience a price decrease, and therefore the firm maintains all additional revenues as profit. If the price is lowered to $11/month, all 6,900 single unit residential homes receive a saving of $12 year. If the price collection service falls to $10/month, households receive $24/year in the form of reduced prices. But in aggregate, total consumer benefit can be as large as $165,600 every year. In the case of Delhi Charter Township, this makes up nearly the entire 1997 road improvement and maintenance budget of $178,490. The benefit looks even great if we consider the Township policy of funding 75% of local access road improvements and maintenance with special assessment dollars. These assessments come directly from the taxpayers that benefit most from the repairs. In 1997, $98,000 was raised with special assessments, while the remainder came from state, county and township sources. Solid waste collection price reductions could substantially offset road repair and improvement costs. These can only be obtained through a single provider system, or exclusive routing areas. The latter of these will be more costly unless the firm can somehow create contiguous routing in neighboring communities. Three exclusive routing areas would not permit firms to fully capture economies of scale, as the Delhi population is small and under 2,500 units per company would yield high average costs.

Road Deterioration

The ability of a road to withstand traffic loads depends critically on construction techniques and usage. Holding fixed the quality of local roads and streets in Delhi Township, as usage declines, the life span of the transportation infrastructure increases. Yet when calculating the value of a road through some measurement of usage, as in construction costs per mile traveled per year, the cost of a road increases as traffic volume decrease. Think of an expensive bridge built in a rural area. The bridge will last longer because it is sees traffic rarely, but the cost per trip over the bridge is higher than it would be in a more populous area.

So to achieve the greatest value and lowest cost per use, roads should be constructed well and the most destructive traffic should be discouraged. Herein lies the problem with excessive route miles in solid waste collection. It causes considerably more damage than normal automotive traffic and it is unnecessary. The same weight and volume of trash can be collected, transported, and disposed of with nearly half the mileage (See Table 4).

The road damage actually comes in two forms, pavement deterioration and damage to the road 'shoulder'. The deterioration of concrete or asphalt is the gradual wear and stress placed upon a road from the dynamics of traffic load, number of axles, climate, traffic density etc. Damage to the road shoulder occurs when vehicles drive on the road edge where it meets a dirt or gravel substrate. Unfortunately, there is no literature available on this particular type of road damage. Attempting to quantify the damage caused solely by collection traffic is hampered by an inability to distinguish between sources of the damage. While garbage trucks do spend a majority of time on the road shoulder, so do mail delivery vehicles as well as individuals homeowners entering and exiting their driveway. An additional complication is having a combination of curbed and un-curbed roadways. Only those roads with out curbs will sustain this second type of damage.

It is possible to quantify damage done to pavement. An U.S. Department of Transportation study (1997 USDOT Comprehensive TS&W) estimated the deterioration of pavement resulting from various vehicle dynamics, such as number of axles and gross vehicle weight. Because road construction quality is the major determinant of damage from different vehicles, Table 10 shows the proportion of roads by type for Delhi Charter Township. Primary roads are those maintained by the Ingham County Road Commission, while local major and local access roads are the responsibility of the township.

Table 10: Cost of Pavement Deterioration from Excess Collection Vehicle Traffic

Road Type	Total Road Miles by Type	Pavement Damage Per 1,000 Miles ($)	Miles in Excess of Minimum in Sample	Pavement Damage Per Year in Sample ($)	Pavement Damage Per Year in Delhi Township($)
Primary Roads	43.33	0.13	6.70	0.05	0.22
Local Major Roads	24.48	2.34	3.79	0.46	2.24
Local Access Roads	50.47	2.34	7.80	0.95	4.62
Total	118.28		18.29	1.46	7.08

Table 10 presents the entire pavement deterioration costs as slightly exceeding $7 per year. Considering the damage caused by a single unit, three axle, 54,000 gross vehicle weight truck is only fraction of a penny per mile and the sum total of excess mileage is around 4500, the amount seems more plausible. This argument regarding increased road damage is fatally flawed until some methodology can estimate the damage occurring on the shoulder of roads. Attempting to decompose the township expenditures on road repairs into the various deleterious effects would involve a tremendous effort at great cost. Even then, as was presented in the previous section on pecuniary effects, budgetary expenditures on road improvements in 1997 were less than $200,000. This budgetary cost at least provides some upper bound on a possible cost allocation of road damage to excess mileage, although the actual figure is expected to be considerably less.

Summary of Results

Due to lack of cooperation from the three firms operating in Delhi Charter Township, sampling techniques were implemented and particular assumptions were forced upon the analysis. The general finding support what theory predicts, that a single provider system will have lower costs than the three provider system. We hypothetically shift all of the market to one firm, and examine how this firm's revenues and costs respond. The added customer base increases firm revenue by $319,104 at a price of twelve dollars a month, while the cost of delivering service rises by $134,597. This difference is a measure of the pecuniary impact of variety. That is, the lack of consensus in firm selection imposes a cost of $184,507 on the township. This represents a price that is $2.15 higher per month that a single provider system. Future analysis might seek out more cooperative firms. As economists, our analysis is only as strong as the data we uncover. Public providers should be more open and could be source of valuable insights into the industry.

The other objective of this study was to determine the cost of a three firm structure in terms of road damage. Findings suggest that virtually no pavement deterioration can be attributed to excessive collection vehicle traffic. Unfortunately, the major theoretical component of road damage, shoulder deterioration, could not be measured. Similarly, aesthetic damage is an unquantifiable loss to residents. It's relative value can be viewed as being either less than the cost of collective action or less than the value of 'free' choice in the solid waste collection market.

Chapter 5

PUBLIC POLICY ALTERNATIVES

Having explored the theoretical aspects of solid waste collection and presented the findings of the empirical study in Delhi Charter Township, chapter 3 attempts to synthesis our understanding of theory and real-world observation into applicable knowledge. It is hoped policy makers will find this chapter a way of framing their individual community's solid waste collection issues, and not prescriptive advice. Let it be known in advance, the institutional framework laid forth is the work of A. Allan Schmid and not of the author.

Institutional Framework

The bacis process of institutional analysis will be described, but the focus is to illuminate the distributional and substantive consequences of a given institution. Institutions are the laws, rules, habits, traditions, mores, etc. that govern our social and economic/political lives (Samuels, 1989). Specifically, institutional impact analysis will be employed which holds fixed the good under analysis and the ways in which rules are made. For example, impact analysis ignores voting rules that could affect the outcome of an election. Rather, it examines the consequences of alternative 'mechanisms' that will produce governmental leaders.

The institutional paradigm has four elements: (a) the good; (b) the situation; (c) the structure; and (d) the performance. This analytic tool with be refered to as the Situation-Structure-Performance paradigm, or SSP paradigm. The **good** is the object under examination. Here, the goods are solid waste collection, roads and aesthetics. **Situation** refers to the inherent physical properties that the goods exhibit. With solid waste collection, the inescapable fact is that scale and contiguity economies exist. How communities choose to handle goods with these characteristics will have distributional and pecuniary impacts. **Structure** is the set of rights granted to individuals. It is a policy choice to be made, as in deciding between a competitive market solid waste collection system and a franchise arrangement. **Performance** is the predicted outcome of a given set of property rights for a good or service that has specified properties. One such performance prediction could be that under a market structure, goods exhibiting economies of scale would be priced higher than the lowest point on their cost curve unless collective action bring about unanimity.

Three more considerations must be mentioned. First, a model of behavior is needed to link structure with performance. For instance, what are the dynamics of group behavior that may facilitate or present obstacle to collective action. Second, transactions are the basic unit of analysis. Individuals engage in economic transactions that are structured by behavior, rules, laws, etc. that have aggregate impacts. Third, constancy must be maintained in measuring performance. If the direct cost of solid waste collection is the object of concern, then some attempts must be made at quantifying these costs as the structural variable is altered. The remainder of this chapter will proceed with an institutional analysis under three policy alternatives: Market, Hierarchy, and Administrative Rule.

Situation

Situation, as defined by Schmid, refers to the inherent physical characteristics of goods or services that create human interdependence. The inescapable feature of solid waste collection is that of economies of contiguity and scale. It is useful to note the distinction between economies of scale and economies of contiguity. The former refers to a declining average cost as the customer base increases (several other sources are described in chapter 1), while the former points to the diseconomies of non-exclusive service boundaries which result in two or three firms operating similar routes.

Roads are considered an incompatible use good (IUG), suggesting the inability to provide (or at least extreme cost of providing) differing levels of quality. Additionally, roads are a high exclusion cost good (HEC) due to the prohibitive costs of denying use of the roads to any particular user. The aesthetic environment of a community has the same inherent characteristics as roads. One level of environment precludes any other and prevention anyone from enjoying the benefits of a given aesthetic quality is nearly impossible.

The SSP paradigm is useful in identifying conflicting parties. Because economies of scale, economies of contiguity, IUG and HEC are presented as the relevant variables, theory will lead to us the source of interdependence and conflict. Economies of scale in solid waste collection produce a tradeoff between low average cost and variety in service delivery. Residents desiring low cost service are pitted against those who would opt for choice in the selection of a solid waste collection firm or differing quality levels. Incompatible use implies only one quality of the good is available or only one use of the good in question is viable at any given time. Road quality and a pleasing aesthetics are thus incompatible use goods. If someone deviates from the collective choice of aesthetics or road quality, all members are forced to accept the altered level of road and aesthetic quality. Similarly, roads and aesthetic quality are both high exclusion cost goods. The free-rider problem (and associated unwilling-rider problem) is present because an individual who deviates from community preferences enjoys all benefits from defection but shares the costs of defection with the entire community, therefore only paying for a fraction of the costs imposed. A one provider system that coerces cooperation (prevents defection from community preferred option) produces unwilling-riders.

The breadth of conflict and interdependence is summarized. Increasing returns to contiguity and scale create a tradeoff between low-cost service demanders and those desiring variety and choice. IUGs force a declaration of property rights because the resource may only be used in one manner. Thus if the problem is to be settled, one party must be granted ownership or use rights. A conflict between free-riders and unwilling-riders emerges when the community desires a HEC be produced and tastes differ, such as roads and the aesthetic quality. Left for further research are the conflicts among solid waste collection firms resulting from returns to scale and the conflicts between neighboring jurisdictions over the costs imposed by collection vehicle traffic and pollution that crosses political boundaries. A related issue is the input of county, state and federal jurisdictions when intergovernmental transfers are used to finance local road repairs and improvements.

Structure and Performance

The institutional impact of public (governmental) provision, competitive market provision, and regulated market provision will be analyzed. Following the SSP paradigm directly, structure is defined as the designation of rights (a policy choice to be made) and performance is meant to predict distributional and substantive consequences of a given institution. An underlying behavioral model links structure to performance via institutional knowledge of the complexities of humans and human interaction. Bounded rationality[4] and difficulty in mobilizing large groups for collective action[5] are the foundation upon which the behavioral model rests. Further elaboration will be added where needed as the alternative structures are specified.

Public Provision

Governments provide all types of services. Over the past few decades, there has been a push to 'shrink the size of government' and privatize many traditionally publicly produced services. It makes little economic sense for townships to produce solid waste collection publicly due to their low population

[4] When information is costly to obtain and cognitive processing is limited, it is irrational to seek full information when making decisions. (Frank, pg. 247)

densities. There would simply be too few customers to justify the large capital investment collection requires. This is often called the make or buy decision (Kelly, pg 97) This requires specific information on the cost to self-produce, the cost to contract out as well as monitoring costs if the community is to make an educated choice.

However, higher density cities can benefit from a single provider or geographic segmentation of the market (Stevens, 1978). Self-provision is one means by which this can occur. The institutional questions that must be addressed are who determines the level of service (frequency of pick-up, type of trash collected, etc.) and how is the public collection financed. If general tax dollars fund the service, calculating the amount of the service to demand based on cost is impossible for individuals. This would most likely lead to an undervaluing of the price and overuse of the service. Monthly billing would simplify the cost information for customers, but no incentive to economize on the production of household use is present. Unit-based pricing allows citizens to adjust household production of solid waste according to the cost charged per weight/volume unit. Note that this could be accomplished simply with a per bag fee, or more sophisticated means such as weighing the trash with an onboard scale. The cost of these methods will clearly vary.

Providing solid waste collection publicly can introduce adverse incentives in the delivery of service. Public managers, facing no competitors, may allow

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[5] Olson posits large groups are prevented from further their own interest because 1)only a small fraction of benefits accrue to individual members, 2) only a small fraction of benefits accrue to any subset of group and 3)transactions costs are a function of group size. (summarized pg. 48)

costs to increase and quality to deteriorate. Unionized labor can also exert influence over wage rates causing costs to rise. Proper incentive contracts for mangers, or bidding out to private collectors a few geographic segments of a community will act to curb some inefficiency thought to be present in the public sector (Bello and Szymanski, 1996).

Public provision, an act of coercion, provides lower unit cost by capturing economies of scale, minimizes road damage with efficient routing and maximizes aesthetic value by reducing the number of collection day per neighborhood. Those preferring variety experience a loss in utility under public provision. Thus, this segment of the community will not choose this provision option. For policy makers who seek the public provision alternative, it becomes a choice of compensating the variety lovers for their loss of utility or realigning their preferences to better fit with the rest of the community. Compensation is not viable because individuals would misstate their losses and we have no way of measuring such a loss even if people were honest.

There, policy makers are left to change their constituent's minds. To alter preferences of variety lovers, Schmid (1999) and Margolis (1987) suggest providing patterns and cues to allow the brain to fit the current situation with past situations. A salient example of the resource waste associated with multiple providers of a good with economies of scale, like municipal water, telephone, or cable television service, could cause the mind to jump (Margolis, p. 39) to an appropriate conclusion without full information regarding the issue's complexity. For a policy maker faced with questions regarding the public provision of solid waste collection or pressure from those wary of government could point to the municipal water or sewer system as an analogy without having to explain issues of declining marginal costs or returns to contiguity.

Competitive Market Provision

By competitive market provision the author refers to the collection of solid waste via multiple "unregulated" firms. Collection is unregulated in the sense that price and location of operation are left to market forces, but even the market has rules. All drivers have to be licensed and vehicles must meet not exceed load restrictions, for example. But more to the point, market rules establish a set of opportunities under which firms, consumers and governments operate. If neighbors were allowed to sue one another and recover damages for the higher prices incurred under the multiple provider collection system, the likely result is a one provider system. However, market rules do not set forth these property rights. Those preferring low unit cost collection have no legal standing from which to collect compensation from those preferring variety and choice.

Therefore, economies of scale and contiguity are not fully exploited and low cost service, high quality roads and aesthetic quality are underproduced. There are two ways to extricate a community from this outcome and still maintain a largely unregulated market. One, a firm can attempt to alter preferences. A firm might try to engage in differential pricing or change preferences to lure customers from the competition and build customer base along their existing collection routes. However, given that all firms would follow these or similar tactics, the gain for those preferring low cost service is likely to be zero. And differential pricing is currently an unavailable firm strategy under any foreseeable rights structure. Altering service levels is another way to change consumer behavior. For example, a firm might offer recycling at a reduced rate to current refuse collection customers. This would induce those wishing to recycle to switch from a competitor. Yard waste and bulk item pickup offer similar opportunities for firms to segment the collection market. Yet, unless community preferences are similar, multiple providers will most likely prevail.

The second option to capture contiguity and scale economies under a competitive market system is collective action. Community based or government led educational campaigns could act to increase demand for one firm and induce cost savings to that one firm and cause average cost to rise in the others. As Schmid (1987) suggests, this will act to select one firm with this circular and cumulative effect thereby producing the desired outcome. Buchanan and Tullock (1965) observed that mutual gains from trade exist when a group is faced with externalities (like aesthetic deterioration from inefficient solid waste collection) and the cost of working together voluntarily are sufficiently low. What must be present for collective action to be successful in providing the incompatible use and high exclusion cost goods low-cost service, quality roads and quality aesthetics? Group identity is an important factor in building cooperation within a community (Dawes, p. 109). Communities with a point of convergence, such as religion or even high school athletics could provide individuals with a sense of the 'good of the whole'. Olson identifies group size and transaction costs as the limiting factors in collective or cooperative behavior. The evidence points to the difficulty in generating consensus and unanimity in large, heterogeneous groups. Friction is wonderful imagery for the transaction costs of organizations. Williamson (1989) posits these frictions to be value neutral, but one must acknowledge the role of transactions costs in protecting the rights of some while discouraging movements from the status quo. With Delhi Charter Township, those who favor the current three firm market structure are protected by the 'friction' obstacle.

Increasing returns to scale provides a 'positive feedback mechanism' (Arthur) through which managers see improved firm profitability as output expands. This drive for output by managers is sometimes at the expense of contiguous routing and economies of scale and inefficiency results. Firm behavior combines with individual choice to produce a 'social trap', as described by Platt (1973). As additional firms enter a one-firm solid waste collection market, each new firm gains customers and behavior is reinforced. Citizens may be offered similar prices and select, as part of a generalized standard operating procedure, a firm of their personal choice. To cope with our increasingly complex consumption decisions, relevant information is often excluded from our decision making process. Thus, social costs are ignored for simplicity as often as they are for information deficiency. Simultaneously, road damage increases and aesthetic value declines. Individuals deciding from whom to buy services have little impact on the 'common interest' and little way of knowing which firm contributes the most to the 'common interest'. Thus, competitive markets fail to produce what is most desirable for some members of the community.

One competitive option does exist, but would most likely fail anti-trust tests. If firms coordinated market areas or developed standardized business practices about locating operations, the low unit cost could be reached. This is unforeseeable due to the entrenched notions of competition held by firm managers.

Regulated Market Provision

Under a regulated market structure, firms bid on geographically defined market segments. To ensure communities capture economies of contiguity and scale, the appropriate size must be established given the level of technology available, population density and geographical peculiarities. In large cites, geographic segmentation is required, while such segmentation seems inefficient in a township the size of Delhi, for reasons stated earlier. Two main alternatives exist for communities.

Competitive Contracts

First, a strict competitive contract could be negotiated. Here, the community defines the level of service and collects payments to distribute to the firm. Rules defining who chooses level of service and method of payment must be clearly established prior to contract issuance. The interests of low cost, standard quality users are served at the expense of unwilling riders. However, monitoring and enforcing contracts is costly because bounded rationality and information costs produce incomplete contracts. Thus, the true preferences of either party are not known during negations and planning for all contingencies is impossible. Cross subsidization among citizenry will occur if financed with general tax dollars in the sense that people utilize the service in differing levels but pay similar amounts. This is not the case if property tax mileage is used and we assumed household waste production is linked with housing values.

Franchise Arrangements

The second option of regulation is franchise arrangements. Franchises are exclusive rights to operate free from competition. Individual consumers negotiate level of service and price, which reduces the prevalence of unwilling-riders when compared with strict contracting. This administrative structure offers the highest level of service choice to residents while still capturing economies of contiguity and scale.

Before implementing a contract or franchise arrangement, policy makers should consider the availability of bids in the future. The question of asset specificity needs to be addressed. Williamson (1985) points out that future arrangements may not achieve initial levels of performance due to lack of competition if transaction specific assets are significant in the winning bid. For example, if a bid requests large investments in modern, expensive solid waste collection equipment, the winning contractor has advantages over the competition in future bids. However, the relative bargaining power is related to the communities willingness to accept different collection vehicles and the firms next best use for the vehicles. If the firm faces significantly lower returns to the assets in question, the community has a higher relative bargaining position.

Thus, competition may not prove that crucial if the firm has specific assets. However, this is unlikely given the nature of collection vehicles. Also unlikely is the lack of forthcoming bids in future contracts given the rise of large national collection firms.

Other administrative rules falling in this category are rules concerning hours/days of operation by location, licensing and vehicle weight laws enforced by the county or state weighmaster. These can combine to reduce the effects of multiple-firm markets, by lessening the aesthetic deterioration and better reflect the cost-variety tradeoff inherent in goods with increasing returns.

Regulated market provision, as well as public provision, create unwilling riders. Presumably the objection to regulation moves beyond variety for variety's sake to some qualitative service differences. Adapting Hirshman's (1970) concepts of exit and voice, unwilling riders do have the voice option available at both firm and governance level. Complaining or suggesting change directly to the firm could produce more optimal outcomes. Voting or legislative meetings provide citizens an opportunity to express their opinions. Exit is available to the community as a whole if collection performance is unsatisfactory, however voice is clearly the preferred option for the firm. The contract (or franchise) monitoring duties are an added cost, but can provide the firm with valuable information to maintaining the contractual (or franchise) arrangement. While voice does provide an option for unwilling riders, their lowest cost option, simple exit, is not available. This might suggest to policy makers to consider the viability of self-haulers, and specifically in more rural areas the possibility of illegal dumping.

Market Segmentation

If Delhi chose to divide its market into two or three sections and offer franchises or bided contracts, economies of contiguity would be reached and collection costs would decline. The amount of scale economies that would be extracted under such an arrangement would be minimal, and therefore costs would be higher than under a single provider system. Additionally, policy makers are faced with what would likely be different prices for different residents based on where they live. Perhaps offsetting this concern is the fact that monopolistic power can not be exploited.

Rules for Making Rules

This section is meant to highlight some of the positions where policy choice can impact the system of governance. Change analysis predicts the outcomes of rules for making rules. Stated differently, the various methods of decision making impact outcomes and performance as much as the choices available in the decision making process. An example might prove helpful. Several decades ago, South Carolina's legislature voted to wave a Confederate army battle flag atop its state capital building. Some find this offensive and a reminder of the South's racist and segregationist past, others a source of state pride. Supporters of the flag state point to the vote of years past by democratically elected officials as proof of the validity of its current status. But did the democratic process, as it existed before the civil rights movement, fairly represent the opinions of all South Carolinians? Did African Americans have the right to vote without discriminatory poll taxes? Were political boundaries drawn to prevent majority democratic or African American districts? This hopefully illustrates that the manner in which policy decisions are made is equally, if not more important than the policy options from which to choose.

If townships are prevented from regulating the solid waste collection industry operating in their jurisdiction, market provision will prevail. Townships populations are generally too small and too widely dispersed to realize economies of scale. Intergovernmental contracts may utilize some excess capacity, but customer density would likely decease not increase and may offset economies of scale with increase transportation costs.

At the local level, assuming townships may enact regulation, voting rules could affect the solid waste collection structure chosen. At-large elections of township board members, as compared with ward or precinct elections, increases group size and heterogeneity, reduce group identity and increase transaction costs. This will most likely result in market provision because collective action is more difficult and each board member is directly responsible to all citizens. Institutional analysis predicts ward elections will led to a single provider system because board members from high-density areas can be an effective issue advocate for the provision of the efficient solid waste collection. This assumes high-density areas are more acutely aware of the cost-variety tradeoff and are more homogeneous in preferences.

Future Research

Future analysis should be focused on refining the relationship between cost of service provision and density of service area. This was the essential issue under consideration in Delhi Charter Township. Three firms operating in the same service area decreases the density of collection units for all firms and increases the cost for all customers. Lack of access to firm information prevented establishing the cost structure associated with current density levels. Possible sources of similar information may be found in communities that are moving from a multiple provider to a single provider structure. A more intensive analysis might gather a panel data set of communities of differing service densities with single provider collection. This approach could shed light on the cost-density relationship. Further, it is necessary to obtain accurate, up to date GIS maps and detailed information on firm costs. Routing estimates are constrained by the tool used to measure them. And without firm cooperation with regard to financial and customer base data, economists are left to surmise and assume information making conclusive findings only as strong as those underlying assumptions.

Additionally, while not a component of this study, the location of disposal site can significantly alter the cost of collection. Examining the competitiveness of the disposal market could be a useful addition to collection analysis. If the local landfill can prevent use by one or more firms, a barrier to entry in the local collection market will exist relative to the location of the next closest disposal option.

Finally, researchers could ascertain the relative values placed on pleasing aesthetics and high road quality. This analysis assumes Delhi Charter Township to value these two goods. However, it is an empirical question whether a community in fact values these goods and is prevented from reaching them due to collective action problems or simply prefers having the choice of collection firm. Here it is left to township leaders to make this determination, but researchers could survey community opinion, or use road expenditures or blight laws and zoning rules to proxy the relative value of road quality or aesthetics.

Concluding Comments

The two outstanding features of efficient solid waste collection are: (1) economies of scale and contiguity; and (2) the requirement of unanimity. Policy makers must first begin with this basic understanding before manipulating the institutional structures to bring about the desired performance objectives. The fundamental fact of human interdependence helps focus institutional analysis on the physical characteristics of the good, the policy decision variables and behavioral norms that give this analysis predictive power. With solid waste collection, the interdependence comes in many forms. The individual selection of collection firm creates pecuniary externalities, found to be $2.15 per household per month in Delhi Charter Township. Damage to aesthetic quality and road deterioration results when individual choices do produce consensus. Additional interdependencies arise when collective action and cooperation are sought. Tastes and preferences should, in the end, inform policy makers on the proper community solid waste collection structure given the variety and cost tradeoff can be fully understood. This analysis attempts to provide a better understanding of this tradeoff.

APPENDICES

APPENDIX A

SAMPLE DATA

Table A-1: Sample Neighborhood 1

	Measurements (miles)			
Bishop/ Grovenburg/ Holt	1	2	3	Average
Firm X	3.82	3.49	3.77	3.69
Firm Y	1.17	1.26	1.38	1.27
Firm Z	1.67	2.50	1.80	1.99
Combined Route Miles				6.95
Shortest Route Miles	4.03	4.63	4.78	4.48
Excess Route Miles				2.47
Total Road Miles				3.74

TABLE A-2: SAMPLE NEIGHBORHOOD 2

	Measurements (miles)			
Holt/ Wilcox/ Aurelius	1	2	3	Average
Firm X	9.23	8.67	8.38	8.76
Firm Y	4.91	4.55	4.82	4.76
Firm Z	7.45	7.24	7.70	7.46
Combined Route Miles				20.98
Shortest Route Miles	10.39	9.95	10.18	10.17
Excess Route Miles				10.81
Total Road Miles				9.29

TABLE A-3: SAMPLE NEIGHBORHOOD 3

	Measurements (miles)			
Sandhill/ Dell/Pine Tree	1	2	3	Average
Firm X	7.51	7.40	7.25	7.39
Firm Y	3.54	4.10	3.56	3.73
Firm Z	2.18	2.39	2.23	2.27
Combined Route Miles				13.39
Shortest Route Miles	8.41	8.51	8.20	8.37
Excess Route Miles				5.01
Total Road Miles				11.30

ASSUMPTIONS USED TO DERIVE EXCESS ROUTE MILEAGE

The calculation of excess route miles is critical to this study. A straightforward formula was used. The ratio of sample miles to actual road miles (118.28/24.33) is the factor by which we multiply excess sample miles to yield total excess miles in the township. The underlying assumption is that the sample accurately represents the true routing structure throughout the township. That is, the same proportions of route miles and excess miles exist in both the three sample locations and the remaining township.

Table A-4: Route Miles in Excess in Delhi Charter Township

	Weekly Sample Totals	Weekly Delhi Totals	Yearly Delhi Totals
Three Provider Structure	41.31	200.83	10,443.06
Single Provider Structure	23.02	111.91	5,819.40
Difference	18.29	88.92	4,623.66
Total Road Miles	24.33	118.28	N/A

$$118.28/24.33 = 4.86 \times 41.31 = 200.83 \times 52 = 10{,}443.06$$

APPENDIX B

OBTAINING MARGINAL COST PER MILE OF EXCESS COLLECTION

These calculations require a number of assumptions. Kahn Manufacturing supplied estimates of fuel consumption per mile, ranging between 4 and 7 mpg. The average 5.5 mpg was included to better balance average consumption to account for the low speeds driven while collecting. Consumption tends to be less efficient as speeds decline.

TABLE B-1: FUEL USAGE ASSUMPTIONS

Per Mile Costs	Cost Per Unit ($)	Fuel Milage* (miles/gallon)	Per Mile Costs ($)
Fuel	1.00	4.0	0.250
	1.00	5.5	0.182
	1.00	7.0	0.143
Average Consumption	1.00		0.192

Maintenance expenditures per mile are based on interview data from the three firms. Mileage per year is the result of the following formula: Trucks average 18.75 mph over an 8-hour day, 6.25 hours with time spent off-route driving to the disposal site, time waiting at the disposal site and lunch. This yields 150 miles/day. Times 5 days/week and then times 52 weeks yields 39,000 miles/year. The 18.75 mph assumption is based on 1 / 4 day spent off-route at 35 mph. The remaining on-route time is spent traveling 13.3 mph.

TABLE B-2: MAINTENANCE ASSUMPTIONS

	Yearly	Miles/year	Maintenance/mile
Maintenance	$5,000	39,000	$0.13

Labor costs per mile are a function of time, speed at wages. Through interviews with the firms, a wage rate of $12/hr seems reasonable. Crew size was variable between the firms and within the firms depending on vehicle type. These are labor costs for only those miles traveled within Delhi, were all excess route miles are traveled. (12/13.3 = .90)

TABLE B-3: LABOR ASSUMPTIONS

	Wage ($/hr)	Crew size	Miles/hour	Cost/mile
Labor	12	1	13.3	$0.90

Data used to calculate depreciation were obtained through interviews with firm representatives. That depreciation is included in a marginal cost per mile figure should come as a surprise to all economists. Normally, cost-benefit and project analyses are only interested in marginal costs. This is because decisions are often incremental and marginal costs reflect the opportunity cost associated with incremental actions. (See Sugden and Williams, p.31-36) Depreciation is an arbitrary *average* cost value that is excluded from usual cost-benefit analysis. It is included here because the hypothesized decision is between a one-provider and three-provider collection structure, which is in the broad sense an incremental choice.

We have found the difference between these two policy choices to be 4,623.66 unproductive collection vehicle miles. What we are concerned with is the total cost of these excess miles. To obtain this cost difference we decompose it into labor, maintenance, fuel and some portion of the physical capital used. Labor, maintenance and fuel are assumed to have constant marginal costs, which are mathematically equivalent to their average cost. Constant marginal cost is a reasonable assumption because excess miles are identical, unproductive miles driven at a constant rate of speed. Some portion of the physical capital must be included because excess miles are not possible with vehicles. The portion chosen as appropriate is a simple straight line depreciation value. This average depreciation value, as well as labor, maintenance and fuel are unchanging because the choice of three firm structure dictates 4,623.66 miles must be driven.

More succinctly, choosing the three firm collection system is equivalent to choosing a one provider structure plus one truck driving 4,623.66 excess miles. Buying this amount of vehicle-miles requires labor, maintenance and fuel expenditures as well as a truck. Seen in this manner, there is no marginal decision per se. And the equivalence of average and marginal costs for labor, maintenance and fuel permits the inclusion of depreciation in the marginal per mile costs.

TABLE B-4: DEPRECIATION ASSUMPTIONS

Depreciation	
Price of New Vehicle	$170,000
Lifespan (yrs)	12
Salvage Value 10%	$17,000
Price-Salvage/ Expected Life	$12,750
Depreciation/Mile	$0.33

$12,750 = ($170,000 - $17,000)/12 years
$0.33 = $12,750/39,000 miles/year

APPENDIX C

COSTS AND BENEFITS OF SHIFT TO ONE PROVIDER SYSTEM

This is the most important set of assumptions to the validity of this study. Firm X is hypothesized to gain the entire market share of its two competitors. The revenue, at a price of $12/month, remains constant before and after the shift of market share. What is assumed to be different before and after the shift is the cost of service provision for the 2,216 new clients of Firm X. Lack of cooperation with this study from the three firms prevents calculation of cost under the three provider system. This is because the 2,216 units do not represent marginal units for Firms Y and Z. They represent the entire Delhi market of both firms. These units are marginal units, i.e. adding only variable costs and not requiring added capacity for Firm X. This may not be entirely accurate, but comparing Firm X's route mileage to the shortest route mileage shows only relatively small increases in route sizes will satisfy the townships routing needs. The ratio of Firm X route mileage to minimum required mileage is .82, .86, and .88 for sample neighborhoods 1, 2, and 3 respectively. The follow is the formula used to derive the costs of the 2,216 marginal units to Firm X:

$$C = K + D + F + M + Li - Ld$$

Where
C = Cost of new collection units
K = New capital requirements
D = Added disposal costs at landfill
F = Added fuel expenditures
M = Added maintenance expenditures
Li = Increased labor required
Ld = Decreased labor required on previous collection units

APPENDIX D

GAINS FROM ECONOMIES OF CONTIGUITY

Shifting to a one provider collection system is assumed to reduce the time between pickup points since all households are serviced by the same provider. No units are passed by and there are no excess route miles. Table D displays the assumptions used by the analysis. The five seconds saved (.75 minutes versus .67 minutes) will allow for the collection of 63 additional units per eight hour shift. The 480 minute shift is reduced to 375 minutes of collection time due to lunch breaks and off-route time traveling to the disposal site.

Table D: Savings from One-Firm Structure

	Three Firm Structure	One Firm Structure
Vehicle capacity (lbs)	30,000	30,000
Average lbs/stop	60	60
Collection minutes	375	375
Minutes/unit	0.75	0.67
# Units/day	500	563

APPENDIX E

LEVELS OF SERVICE IN DELHI CHARTER TOWNSHIP

Table E displays the current price structure and service options available to residents in Delhi Charter Township for solid waste collection. Service levels are measured weekly, except for yard waste, which is seasonal. Firm X has a one time fee of $85.00 for seasonal yard waste collection.

Table E: Price and Service Options

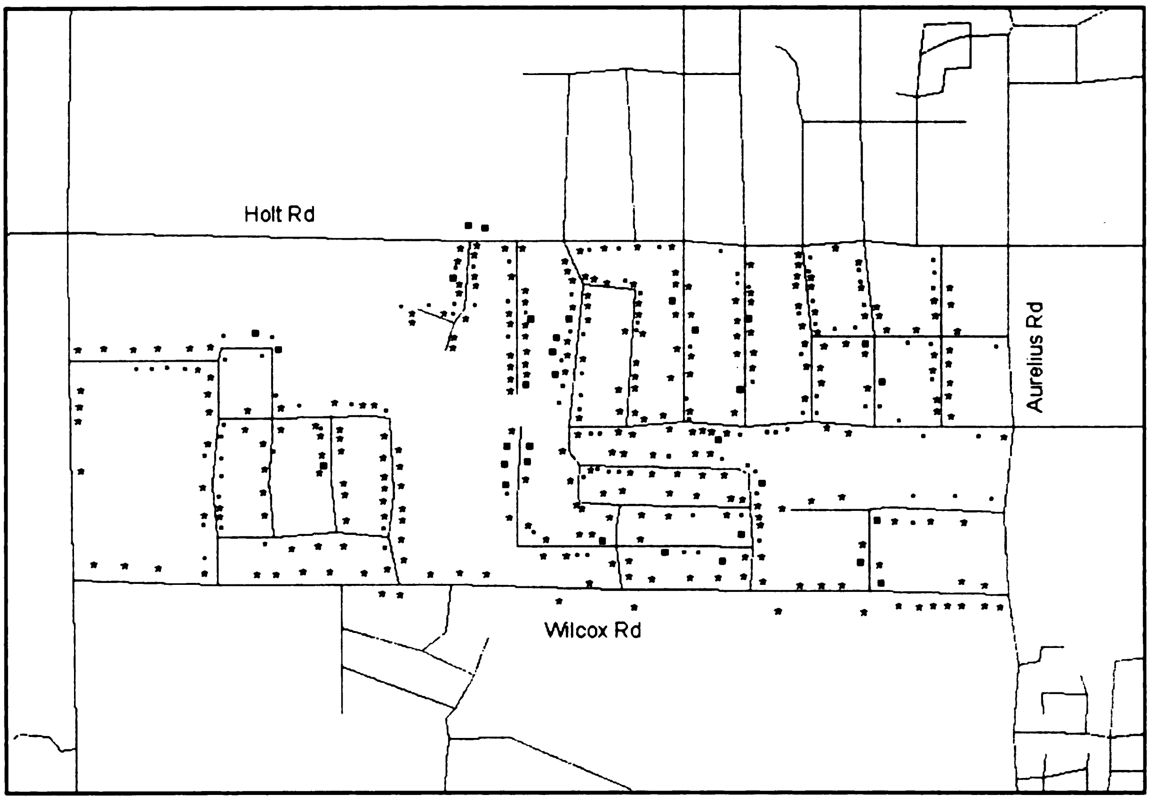
	Monthly cost		
Service Level	Firm X	Firm Y	Firm Z
60 gal bin + 1 bag	11.75		
90 gal bin + 3 bags	14.15		
63 gal bin		14.50	
104 gal bin		16.50	
65 gal bin			12.00
95 gal bin + 3 bags			14.00
6 bags only			12.00
Yard waste	85.00*	13.50	12.00

*One time seasonal fee

APPENDIX F

EXAMPLE OF GIS MAP:

SAMPLE DATA FROM HOLT RD/AURELIUS RD/ WILCOX RD.



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