Cost Trade-Offs and the Role of Compensation in Landfill Siting

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Abstract

An hypothesized trade-off between transportation and external costs in locating a landfill relative to a population center is investigated. The role of compensation in increasing economic efficiency in landfill siting is developed conceptually and the magnitude of compensation needed for a particular landfill site is estimated.

Disposal of domestic solid waste (better known as garbage or trash), though not usually considered to be of a "hazardous" nature, promises to become an even more serious and pervasive problem in the future than it is today. Increasing per capita generation rates together with a growing population implies that the problem will grow in terms of physical volume if nothing else. Due to economic constraints and other factors, the most commonly used method currently for solid waste disposal is landfilling. For municipalities other than major metropolitan areas, for which recycling and/or incineration may prove economically feasible in the future, landfilling will continue to be the only real alternative.

Though today solid waste is buried in "sanitary" landfills, many people continue to perceive them as "dumps" with significant external costs borne by nearby residents.[1] Thus, siting a new landfill is often a highly political and emotional issue.[2] Sheaffer, Tolley, et al., analyzed 20 landfill siting proposals, finding that 15 were actively protested with only seven of this group ultimately successful. In eight of the 20 cases, direct offers of remuneration were made. However, these offers were "impressively arbitrary" and had "not met with any great success" perhaps because they were not directed well enough to the specific group of nearby residents facing the external costs. An alternative strategy for reducing opposition to a landfill site is to isolate it further from centers of population. External costs are reduced in this way along with associated approval costs on the part of the operating entity and protest costs on the part of nearby residents. However, transportation costs in particular are increased, suggesting an

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1 These costs have been estimated in the form of property value impacts by Havlicek and Richardson and more recently by Baker with hedonic pricing models of residential property.

2 Bealer, Martin and Crider provide a comprehensive literature review regarding sociological aspects of siting landfills. Massey, in a survey of residents in four communities, documents the negative attitudes toward landfills and factors influencing those attitudes.

important trade-off to be considered. Even with enough compensation to virtually eliminate approval costs (above standard administrative procedure) and protest costs, the trade-off between transportation and external costs is relevant in consideration of the social cost-minimizing location or distance from a population center.[3]

The purpose of the study reported upon in this paper was to investigate for a case study landfill site: 1) this trade-off between external costs and transportation costs as it relates to the distance a landfill is located from a population center and 2) the magnitude of compensation that would be appropriate given estimates of external costs. The case study area is the Knoxville, Tennessee, metropolitan area with a population of approximately 400,000. In the late 1970's, Waste Management, Inc., received a contract to dispose of Knoxville's domestic solid waste and made plans to develop a landfill on Fleenor Mill Road in Anderson County, which adjoins Knox County where Knoxville is located. Nearby residents and elected representatives in Anderson County protested vehemently, and a lengthy and costly legal battle ensued. At one point, an offer to landfill Anderson County's solid waste at a reduced rate was made by Waste Management, Inc., but rejected. Ultimately the Fleenor Mill Road landfill began operation.

The remainder of the paper is structured as follows. First, a more formal treatment of compensation's role in increasing economic efficiency is provided. Then, transportation and external cost estimates are presented and used to identify the cost-minimizing distance and magnitude of compensation. Finally, conclusions and policy implications are outlined.

Compensation and Economic Efficiency

Though compensation from a landfill operator to nearby residents might be considered appropriate by some from the standpoint of equity, only the potential efficiency

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3 There are other significant costs associated with landfilling, such as land acquisition and operation. However, costs other than external (and related) costs and transportation costs can reasonably be assumed to be invariant with respect to location or distance from a population center.

impacts are considered here. In terms of the various methods for correcting the incentives of an entity generating an externality, such a flow of compensation could be viewed in one of two ways depending on the property rights perspective taken. First, it could be viewed as a tax on the operator to correct his location incentives, with the revenue then used to compensate nearby residents in order to reduce protest and approval costs. Or it could be viewed as a bribe on the part of the landfill operator to get nearby residents to willingly accept the landfill site. Given the author's assessment that residential property owners do not generally have the property rights implicit in the latter view, the former view is taken here.[4] The efficiency impacts of the tax-compensation scheme envisioned are outlined more rigorously in the graphical treatment below.

If no internalization of the external costs is undertaken, the costs expected to impinge upon the landfill siting decision are graphically presented in Figure 1. The operator of the landfill will base his siting decision upon the minimization of the transportation (T) and approval (A) costs he has. Their summation is the operator's total cost curve and its minimum point (D_o) represents the optimal distance from the population center for the landfill site from his point of view. External (E) costs enter his decision-making process only inasmuch as they affect protest costs (P) and thus approval costs.[5] However, in addition to the costs considered by the operator, external and protest costs are relevant in determining the socially optimal distance. The summation of all these costs is the total social cost curve and its minimum point (D_s) represents the optimal distance for the landfill from society's standpoint. Total social costs decline from SC_o to SC_s in moving from D_o to D_s since the reduction in external, approval

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4 Practically speaking, the only difference in the two views is that the latter view would call for a "willingness to accept compensation" basis for external costs, the former a "willingness to pay" basis for external costs.

5 External, protest, and approval costs are expected to be positively related and downward sloping with respect to distance. Nothing beyond this is to be inferred from the way the curves are drawn in Figure 1.

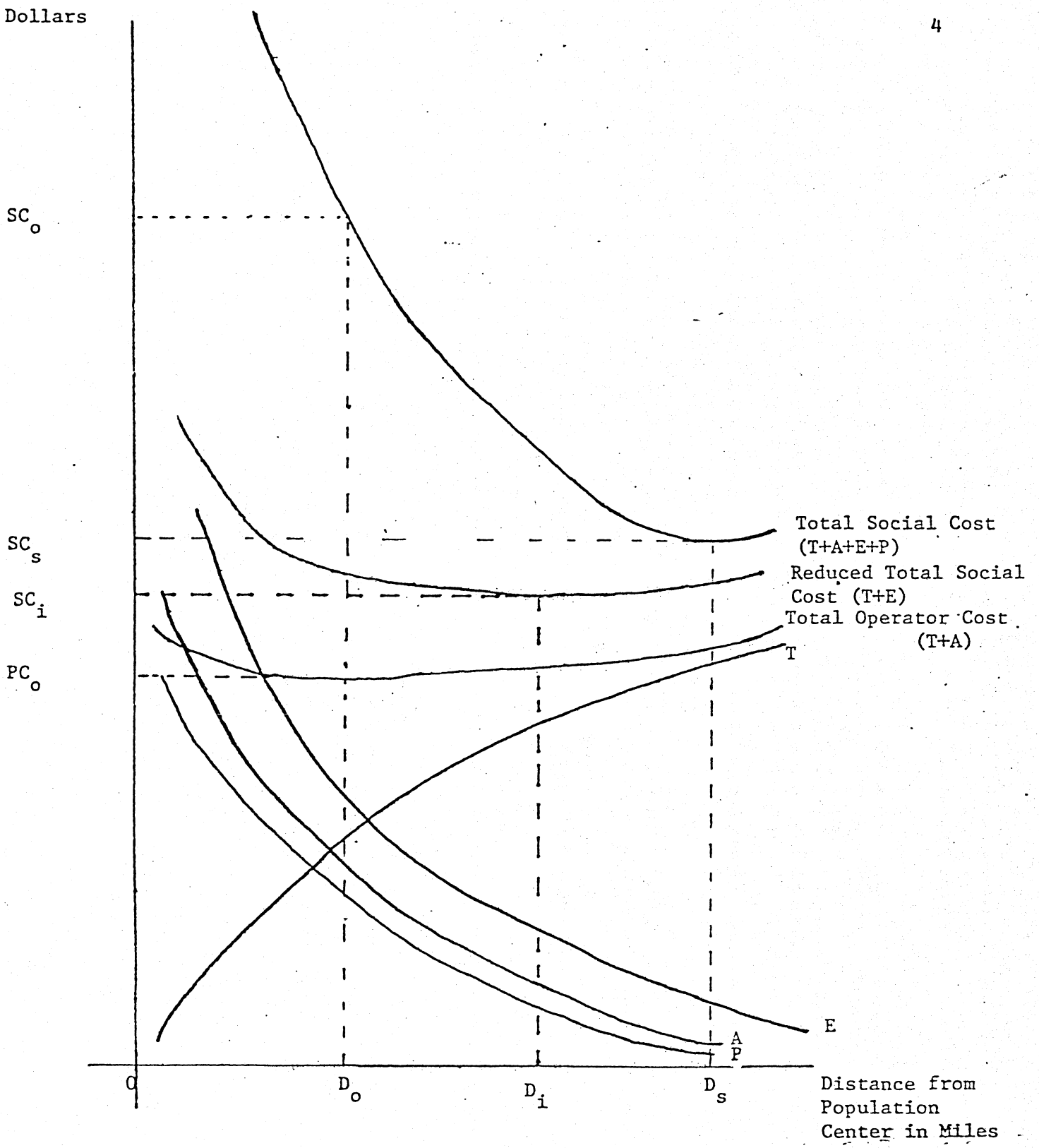

FIGURE 1. Costs of Siting the Landfill with No Internalization and with Full Internalization and Compensation Payments to Affected Residents.

and protest costs more than offsets the increased transportation costs incurred in shifting the site further from the population center.

On the other hand, suppose the external costs generated by the landfill were internalized by taxing the operator by the amount of the external costs and the nearby residents were then compensated with the revenues. The payment of the tax would correct the operator's location incentives, forcing him to take into account the external costs. The receipt of compensation by nearby residents is assumed to eliminate protest costs and thus approval costs.[6] The operator then would base his decision regarding location of the landfill upon minimization of the summation of external and transportation costs, the only social costs remaining. This is referred to as the reduced total social cost curve in Figure 1. With the operator's and society's interest thus aligned, the optimal distance for the landfill site is now D_i with total social costs reduced to SC_i. It is this method of tax plus compensation which provides the theoretical context to be empirically illustrated in the following section.

Cost Analyses

The Fleenor Mill Road landfill is located 11 (driving) miles from the transfer station in Knoxville where collection trucks deliver their loads to be transferred into hauling trucks for transport to the landfill. This site provided one point each on the transportation and external cost curves in relation to distance from the population center. To estimate how transportation and external costs varied with distance, it was necessary to establish other potential sites at various distances from the transfer station. The

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6 It is recognized that compensation based on property value reduction estimates of external costs may not result in total elimination of protest and approval costs. Only compensation on the basis of a "voluntary willingness to accept payment" could be expected to do so. The point is that protest and approval costs would be significantly reduced.

decision was made to draw a ray from the transfer station through the landfill site and designate potential sites at two-mile intervals from 3 to 15 miles.[7]

Transportation Costs

The cost of hauling solid waste from the transfer station to the landfill is made up of two basic components: vehicle expense and driver expense. Based on information from the Knoxville Department of Public Services for the fiscal year from July 1, 1982, to June 30, 1983, charges from the city's Fleet Management totaled $159,743, or $1.88 per mile, for the 84,970 miles driven. Since the Department of Public Services is charged for vehicle use almost exclusively on a mileage basis, this $1.88 per mile was employed as the variable cost per mile facing the Department of Public Services.[8] That is, if the landfill were located 10 miles from the transfer station rather than 11, vehicle expense would be lower by $3.76 per trip, reflecting the reduction in round-trip mileage of two miles.

Driver expense in terms of variable cost per mile was estimated by computing the time required per mile driven. Based on communication with personnel in the Department of Public Services, regarding actual time for the 22-mile round-trip, an additional mile would take 2.64 minutes. With a wage rate of $9.07 per hour, this implies a variable cost of $.40 per mile for driver expense.[9] Combining this with vehicle expense gives a variable transportation cost of $2.28 per mile.

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7 An alternative approach would have been to use other sites which were actually considered or potential sites based on geological feasibility, regardless of direction from the transfer station. It was rejected due to the greater data requirements involved.

8 It is recognized that the true vehicle cost per mile may well decrease as the distance traveled per trip increases.

9 An alternative assumption would have been that "slack time" for drivers, in waiting for a full load for their trucks, increases by the same proportion as actual driving time, which would increase the estimate from $.40 to approximately $.60.

External Costs

At least two studies have employed hedonic pricing models to estimate the influence on residential property values of proximity to a landfill (Havlicek and Richardson, Baker). The estimates of external costs for purposes of this study were made by applying the distance coefficient in Baker's natural logarithm model of residential property values within two miles of a landfill near the town of Dryden, New York. Baker's distance coefficient was translated into percentage terms since the general level of residential property values along the ray from the transfer station through the landfill was greater than those in Baker's sample. Percentage reduction in property values ranged from 21.04% at 0.25 mile to 0.55% at 2.0 miles (which was the approximate range in Baker's sample). Percentage reductions at 0.25, 0.75, 1.25 and 1.75 miles were applied to residential property identified by 1980 Census tract information as being within four concentric rings of 0.5 mile radius (0-0.5, 0.5-1.0, 1.0-1,5, 1.5-2.0 miles) around the Fleenor Mill Road site and other points along the ray.[10]

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10 Baker's study converted the distance (measured in terms of hundreds of feet) between a house and the Dryden landfill to its natural logarithm. He found that for each unit increase in the natural logarithm of distance, the property value increases by $3651.43. Due to limitations in transferring Baker's Dryden, New York study to Knoxville, Tennessee, this coefficient was converted from absolute dollar terms into percentage terms. The percentage effect was expected to be zero beyond a distance of two miles, corresponding to the maximum distance in Baker's data set, 11,000 feet. The natural logarithm for 110 is 4.7 (Baker's distances were measured in terms of hundreds of feet, thus, 11,000 feet is 110 units in Baker's model.). This was chosen as the zero point. With each unit change in the natural logarithm from this value, the value of the housing unit was expected to change by $3651. For example, the natural logarithm of 13.2 (1320 feet) is 2.58. The difference between 4.7 and 2.58 is 2.12, which was then multiplied with $3651. This results in a dollar discounted effect of $7,741 for each house 1320 feet from the landfill. This number was then used as the numerator in the fraction used to determine the percentage reduction in property values. The denominator was composed of the dollar discounted effect computed above ($7,741) plus the median nominal house value in Baker's Dryden model, which was $29,043. This resulted in the following fraction 7,741/(7,741+29,043), or 7,741/36,784 which reduces to .2104, of a 21.04 percent reduction in the value of a housing unit 1320 feet (.25 miles) from the Dryden landfill. This process was used to compute dollar discounted effects and percentage reductions for the remaining distances listed above.

Identification of the Cost-Minimizing Distance

The findings from the cost analyses described above are presented in Figure 2. As indicated, the sum of transportation and external costs is minimized for a landfill site at a distance of 11 miles from the transfer station, which is approximately where the Fleenor Mill Road landfill is located. As one moves out the ray from the transfer station, external costs fall more quickly than transportation costs rise up to this distance. beyond this distance transportation costs rise more quickly than external costs fall.

Sensitivity analysis was undertaken given the uncertainty inherent in the external cost estimates relating to sample variation in Baker's study and transferability to the Knoxville area and the difficulty in identifying the variable cost component of the transportation costs. Both costs were varied 25% in either direction alone and 25% in opposite directions together. In three of these six cases, the cost-minimizing distance was shifted to 13 miles.

This finding has little bearing on the question of whether the Fleenor Mill Road site was the optimal site among all alternatives (whatever direction from the transfer station) which were feasible in terms of geology and current land use. Such an ex post analysis could be conducted by estimating transportation and external costs for all such alternative sites. Similarly, a priori analyses could be conducted for the set of feasible sites identified in the planning stage, as demonstrated by the economic model and empirical procedure illustrated above.

The Role of Compensation

Compensation could conceivably play an important role in promoting social efficiency through reducing the acceptance costs associated with the landfill site for which

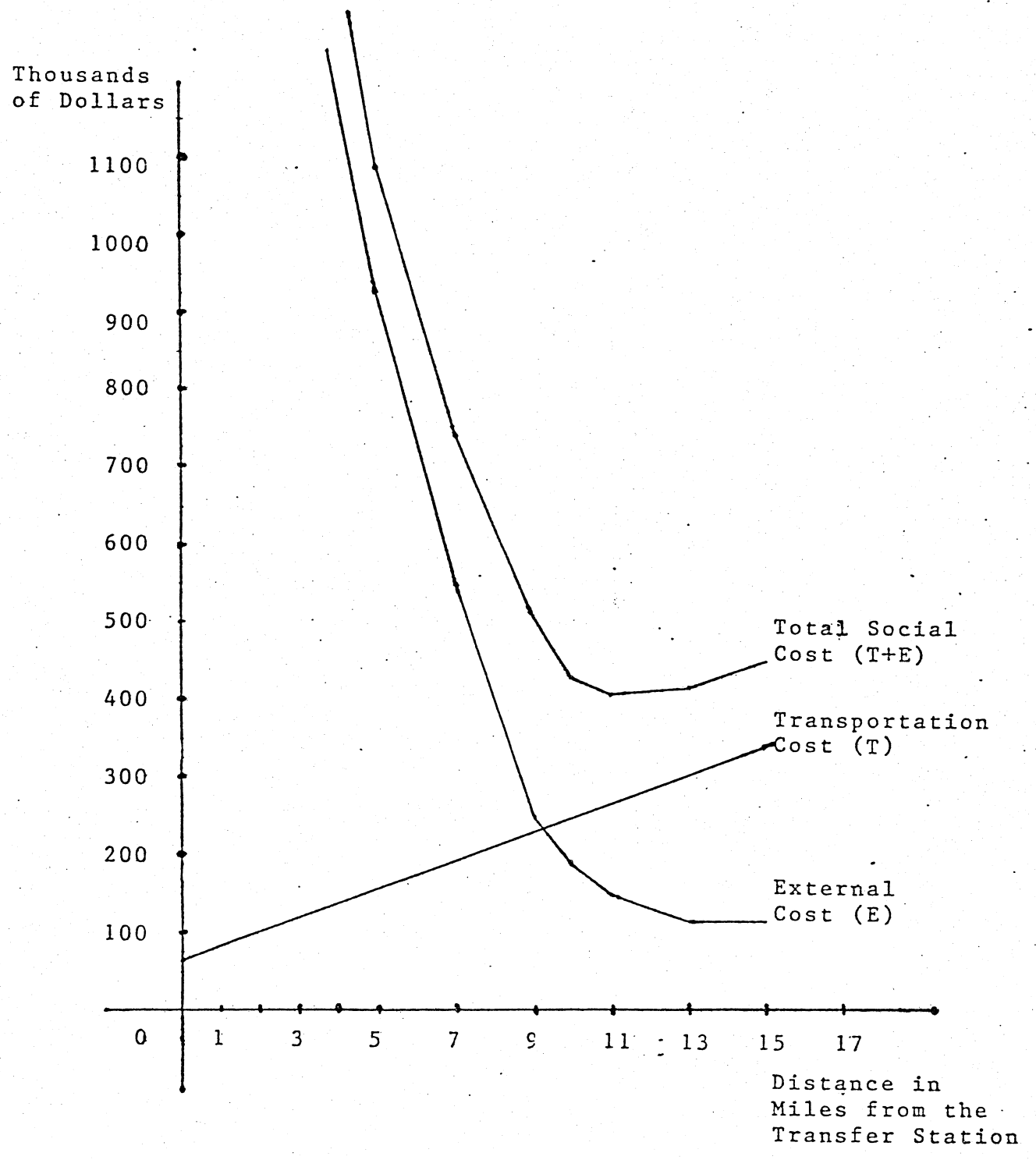

FIGURE 2. Total Social, Transportation, and External Costs at Selected Distances from the Baxter Avenue Transfer Station.

transportation plus external costs are minimized. As is evident from Figure 2 external costs of $142,000 exist at the cost-minimizing distance along this particular ray, the approximate location of the actual Fleenor Road Mill landfill. Thus, it is not surprising that the conflict over its siting was costly and time-consuming to resolve. The average property value reduction in the four concentric rings around the landfill ranged from $878.00 to $106.00 per residence, high enough to invest a significant amount of time and expense in protest. These estimates provide an appropriate nonarbitrary order of magnitude for compensation payments for this particular landfill site.

The problem of directing compensation to the specific group of nearby residents facing external costs could be addressed by the employment of the following methods:

1. Direct payment to affected residents.
2. Reduced rates for solid waste services for affected residents.
3. Reduced property taxes for affected residents.
4. Development of the retired landfill site into a facility whose value to the affected residents would equal or exceed their external costs.

These alternative methods may differ, of course, in terms of legality, public acceptability, administrative cost and other factors, analysis of which would involve another study in itself.

It is of interest to note what magnitude of added tax burden or added costs for solid waste disposal would be required for residents of Knoxville in order to generate the revenue needed for full compensation of affected residents. Given a population of 175,045 for Knoxville based on the 1980 Census, the cost would be $.81 per capita per year. Based on the 1980 Census figure of 2.39 persons per household, the cost would be $1.95 per household per year. City residents pay for their solid waste pickup and disposal through their property taxes. However, Knox County residents are charged $7.20 per month for solid waste pickup and disposal; a figure which can be used as

representative of the actual cost to city residents. The $1.95 annual cost works out to a $.16 or a 2.28% increase relative to this $7.20 monthly fee.

Conclusions

The primary conclusion to be drawn from this study is that the economic framework developed provides a useful perspective from which to analyze the problem of sanitary landfill siting. The empirical findings for a case study area support the hypothesis that a trade-off exists between external and transportation costs with regard to the distance at which a landfill is located from a population center. This trade-off must be explicitly addresed in the interest of economic efficiency in landfill siting policy. Requiring compensation from the operator to nearby residents would serve to correct the operator's location incentives and reduce protest and approval costs, reducing total social costs of landfilling in two ways.

The limitation on the study imposed by use of the "ray" method for estimating costs requires some discussion. Not all of the points along this ray for which costs were computed were necessarily potential sites based on geological feasibility and current land use. The external cost curve had a shape which was peculiar to that particular ray. Use of ray in some other direction from the transfer station would have resulted in an external cost curve shaped somewhat differently. Thus, in regard to the Fleenor Mill Road landfill, nothing can really be said about whether it is the site in the Knoxville area for which the sum of transportation and external costs are minimized. Moreover, the economic framework developed can be applied most profitably to landfill siting in an "a priori" sense, providing estimates of external and transportation costs for a set of sites determined to be feasible given geological constraints and current land use.

Additional research in a number of areas relating to this study may prove valuable. One area would be an estimation of external costs of sanitary landfills. Using a linear model covering the 1962-1970 period, Havlicek et al., estimated an external cost of $.61 per foot of distance from a landfill. Baker's estimate for the latter 1970's using a logarithmic model, was $.96 per foot for the one-half mile to one-mile range and smaller effects for ranges further away. With reasonable adjustment for time, given the inflation rate over the period, the estimated coefficients seem different enough to suggest that additional studies to estimate external costs are needed. A second area would be estimation of transportation costs in particular distinguishing between fixed and variable costs in relation to distance for both vehicle and driver expenses. A third area would involve analysis of the legality, social acceptability and administrative costs of alternative compensation schemes. Finally, the relationships among protest, approval and external costs and the impact of compensation on protest and approval costs could be well investigated.

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