THE ROLE OF COMPENSATION FOR SITING NOXIOUS FACILITIES

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The Role of Compensation for Siting Noxious Facilities:

Theory and Experimental Design*

by

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PREFACE

The research reported herein was performed under the auspices of the Interactive Decision Analysis (IDA) Project in the Systems and Decision Sciences Program. This paper reports on a class of group choice problems under uncertainty, with applications to the problem of locating public facilities such as power plants or prisons, which have potentially noxious side effects. This research complements the overall thrust of the IDA Project to study the theoretical foundations of interventions directed at improving individual and group decision processes. In this regard, the collective choice mechanisms analyzed in this paper for group bargaining problems under uncertainty should be of interest both for their theoretical properties as well as for their implications for the important practical problem of siting public facilities.

Alexander Kurzhanski
SDS Program Leader

CONTENTS

I. Introduction

Within the general field of risk management the siting of noxious industrial facilities is an especially conflict ridden issue. The magnitude of this conflict has been indicated by Gladwin (1980). He identified 366 disputes regarding industrial facility siting or expansion in the United States during the period 1970 to mid-1978. Almost one-half of these involve chemical process facilities. Furthermore, there has been considerable public opposition to establishing new offsite disposal facilities which receive hazardous materials from a variety of different sources (Goetze, 1982). This opposition has been so effective that no new off-site hazardous materials disposal facilities (HMDF) have been sited in the U. S. during the period 1980-1983. (Bacow and Milkey, 1983).

Society is unable to resolve this conflict since it faces a dilemma. On the one hand, people demand the goods and services whose production yields toxic materials as by-products. Furthermore, there appears to be widespread agreement that there is a need for properly designed and managed disposal facilities since, in the aggregate, their presence would yield benefits in excess of the risks and costs. On the other hand, public opposition is vehement when mention is made of constructing a HMDF in their "backyard." A recent opinion poll found that over 95 percent of respondents would actively protest against siting a hazardous materials facility near their home (U.S. Council on Environmental Quality, 1980).

Ironically, this inability to site new facilities is posing additional risks since the volume of hazardous materials is growing at a rate of 3 percent per year and at least 50 to 60 major new sites will be required over the next few years (U.S. EPA, 1980). Hence, society is in the extremely unfortunate position of facing a dilemma. Society is "damned if we do" develop new sites because of local opposition and "damned if we don't" since generators and disposers of hazardous materials may be tempted to engage in unsafe materials management practices, given the dwindling capacity at existing facilities.

Insight into possible solutions to this dilemma may be obtained by addressing the following question: Why do residents of potential host communities find the net risks of a HMDF to be unacceptable? The answer to this question is multi-faceted as is expected for any complex problem. We offer two reasons why local communities perceive the risks to be unacceptable and, therefore engage in local opposition. First, large uncertainties surround the impact of these facilities. For example, we lack sufficient scientific knowledge to predict the relationship between the frequency and duration of exposure to some types of toxic materials and any resultant health effects; some of which may be latent and irreversible.[1] Second, conflicts with respect to siting hazardous materials facilities arise because the external costs are spatially concentrated around the host community while the net benefits of the noxious facility tend to accrue to those communi-

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1 Consult Page (1978) and Wynne (1984) for additional discussion of the generic characteristics of toxic materials and related risk management concerns.

ties that are sufficiently distant from the site to be virtually immune from any external costs.[2] Consequently, the host community may believe that it is bearing an inequitable share of the external costs.

This paper investigates the second source of conflict. Our aim is to understand the potential of ex ante compensation to reduce local opposition to the siting of noxious facilities, such as an HMDF. By ex ante compensation we mean either monetary and/or in-kind payments provided to the host community prior to the construction and operation of a facility. Our working hypothesis is that these payments may be helpful in resolving the conflicts between the potential losers (the host community) and those who benefit from the siting of the facility, e.g., other residents of the region, industry and the developer. Thus, our research objective is to design a procedure which induces a community to reveal its true compensation requirement for accepting a facility in its jurisdiction.[3]

Finally, the problem context is the inter-community siting problem. By this we mean that communities within a region must decide: How do we locate a single, fixed-size facility that may be needed with the region, but may be unacceptable to any particular community within the region? In other words, the communities have two decisions to make. First, they must decide if they (as a group) want the facility. Then, they must decide where to locate the facility. The intra-

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2 Admittedly, the facility's impacts are stochastic. Hence, the external costs should be called risks or expected losses. However, for reasons of analytical tractability, we are assuming that the costs and benefits are deterministic.

3 The related problem of developing an appropriate disposal tax or charging scheme for industries that are responsible for producing hazardous materials will not be treated here. See Kneese and Bower (1972) and Nichols (1984) for a discussion of a tax and charging scheme for environmental regulation and pollution abatement.

community siting problem also needs to be addressed, but will not be considered here. This problem involves a number of intra-community voting and distributional issues rooted in the complex differences in preference and risk perception among community residents. For more detail see U.S. EPA, 1979, O'Hare, *et al*., 1983 and Fischhoff, *et al*., 1982.

The paper is organized as follows. Section II describes the attributes of a noxious facility and provides two examples of how *ex ante* compensation has been a successful tool for facilitating the siting process. Section III discusses the inappropriateness of the Clarke demand-revealing mechanism for the compensation revelation problem. A simple example is presented to demonstrate the inability of the Clarke mechanism to provide compensation for the siting problem in which the facility produces negative impacts to the host community and positive impacts to others. Section IV develops a sealed-(low)bid auction siting model, grounded in the theoretical work on collective choice when individual preferences are subject to misrepresentation. This model assumes that the facility's impacts are known to all communities with certainty. Several variations of this basic auction model are developed in which the community that receives the facility is compensated by the other communities who benefit from it. We conclude with a discussion of several research issues that suggest the need for additional theoretical and empirical (via laboratory experiments) studies.

II. Noxious Facilities and Compensation Arrangements

A noxious facility is a facility that is needed within a region, but is not necessarily desired by the residents at any potential site (Austin, Smith, and Wolpert, 1970). More specifically, O'Hare (1977) identifies three distinguishing attributes of a noxious facility:

* Localized. Either technological or economic constraints prevent the extensive spatial diffusion of the activity throughout the region.
* Asymmetric Spatial Distribution of Social Costs and Benefits. The social benefits are (pure public) positive externalities that are distributed throughout the relevant region. The social costs of siting a noxious facility are perceived to be large and localized exceeding social benefits to the host community.
* Extensive in Space and Will Displace Existing Uses.

Hazardous materials disposal facilities (HMDF) or trash disposal facilities provide good illustrations of a noxious facility. In particular, the facility is localized in the sense that economics of scale preclude the construction of "small scale" disposal facilities that can be widely distributed throughout the region. The facility (either a landfill or an incinerator) tends to require large parcels of land and is incompatible with or replaces existing land uses. Finally, the facility produces a number of social costs and benefits that are distributed in asymmetric fashion.

As Figure I illustrates, the social benefits consist of both a regionwide safety benefit (E_1) and a localized, nonsafety benefit (E_2). E_1 is a benefit since it is interpreted as the amount of untreated hazardous materials (M) that a community might be exposed to in the absence of the facility.

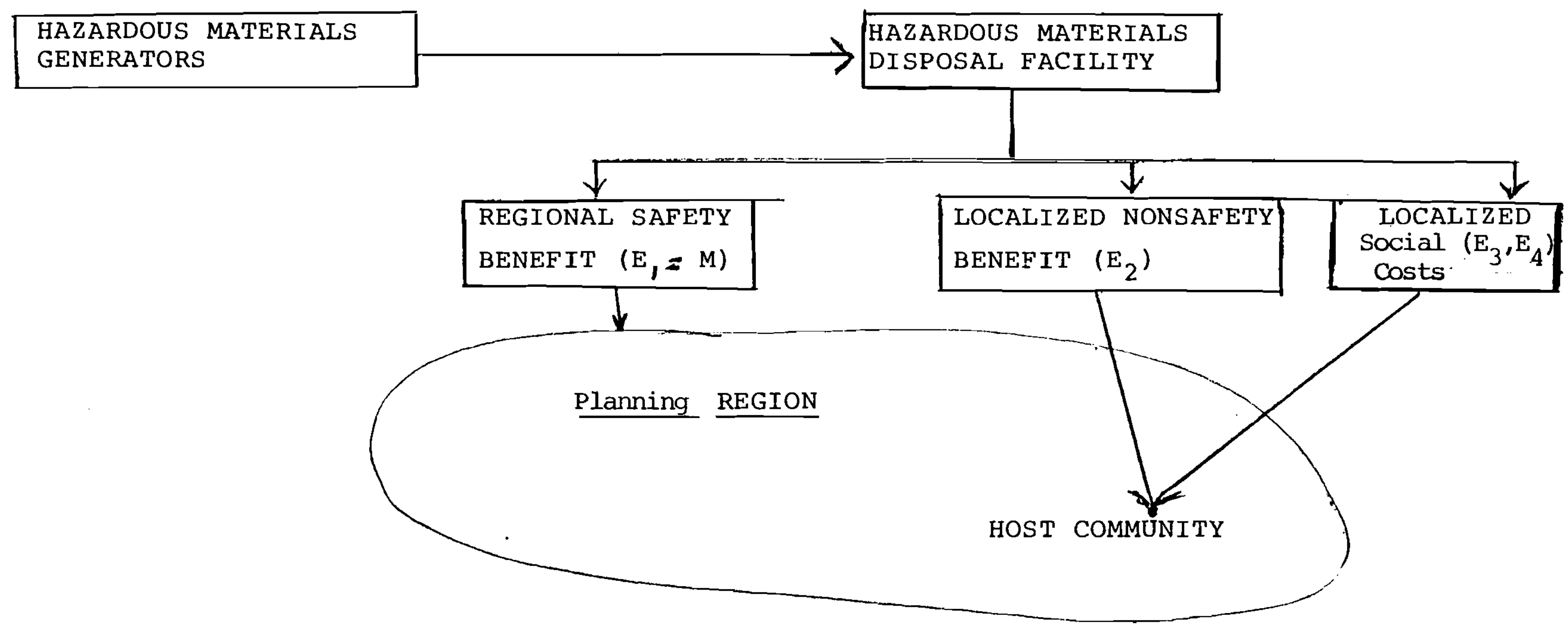

Figure I: Attributes of Hazardous Materials Disposal Facility (HMDF)

The externality is also undepletable, i.e., community A's consumption of the externality does not prevent community B from consuming the same level of foregone "exposure." In contrast, E_2 is a set of the localized nonsafety benefits. The set includes such beneficial consequences as net employment creation and increased tax revenues. These are assumed to accrue only to the host community and, therefore, are "localized." In other words, the nonsafety benefits are assumed to not spill over into abutting communities.

The social costs consist of both non-catastrophic and catastrophic consequences. The noncatastrophic costs, E_3, are those associated with, for example, increased truck traffic that creates noise and dust in the process of delivering untreated waste materials to the facility. Catastrophic costs E_4, are those high loss events such as explosions, fires, or landfill liner rupture. We assume that the social costs do not spill over into abutting communities.[4]

Compensation Arrangements

As a policy tool for siting facilities, compensation is used to achieve the social objectives of Pareto efficiency and equity. Efficiency refers to the optimal allocation of resources, such as accident prevention expenditures, associated with selecting one of the potential sites. Note that in the siting problem, market forces cannot induce efficiency since the negative consequences of disposal are not market-traded, as in the case of unsafe jobs or products.[5]

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4 In reality, the social costs may spill over into abutting communities, particularly if the facility is located near the community's border. However, this possibility does not affect the performance of the compensation procedure developed in Section IV.

5 See Viscusi (1983) for a discussion of the role of market forces in generating efficient levels of accident prevention when the risks, i.e., stochastic negative consequences, are market-traded.

The Equity criterion is concerned with the impact of the siting decision on the distribution of net benefits or "gains" among communities within the region. The specific problem is to determine a fair division of the gains from appropriate disposal among the host community and the remaining communities. Cerny (1984) points out that there are three ways of defining equity for determining whether the site selection decision was a fair one. Allocative equity refers to the distribution of costs and benefits between different interested parties. Vertical equity refers to the current distribution of wealth and whether it is fair to site facilities disproportionately in poorer communities since they may either demand less compensation or have less political clout than more affluent areas. Finally, intergenerational equity refers to the impact of a facility on future generations.

Ex ante compensation may take the form of monetary payments and/or payments-in-kind.[6] Ex post compensation for losses can be provided in the form of insurance and liability payments.[7] An example of in-kind, ex ante compensation in the United States is the bird sanctuary provided by the Missouri Basin Power Project, a consortium of six utilities. This consortium proposed a $1.6 billion coal-fired utility plant on the Laramie River in Wyoming. However, a lawsuit had enjoined construction of the plant because of the potential damage to the surrounding environment. The suit was settled after five years of

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6 Other forms of compensation may supplement or substitute for ex ante payments. For example, after a facility has been constructed, there may be some form of on-going compensation to the community to reimburse residents for any special costs that the facility may impose, such as decreases in property values.

7 There is a growing literature on the role of insurance and alternative liability rules in providing payments for losses. See Baram (1982), Goetze (1982), and Meyer (1983), who argue that individuals receive relatively limited protection from existing liability rules associated with siting noxious facilities.

negotiation, when the utility companies agreed to establish a $7.5 million trust fund for the sole purpose of preserving a 60 mile stretch of the Platt River; the habitat of several species of migratory birds, including the whooping crane. Note that an initial offer of $15 million to the environmentalists was rejected because it had the appearance of a bribe. The coal plant was completed in 1981 and is fully operational.

The provision of compensation to the host community faces severe implementation problems. One of the most difficult is that communities may have an incentive to not only exaggerate their compensation requirements, but also to underreport their willingness to pay other communities to take the facility. By doing so, developers may be unable to simultaneously pay compensation and provide inexpensive, safe disposal services. An additional concern is that some generators may decide, given the relatively higher disposal fees induced by exaggerated compensation requirements, to return to inappropriate disposal practices and take the chance of either not being arrested or, if arrested, paying relatively small fines.

Consequently, one of the emerging noxious facility siting issues is that of <u>compensation revelation</u>. Can one design decision procedures that provide communities with economic incentives to truthfully reveal their compensation requirements?[8] O'Hare (1977) is one of the first to recognize the desire for preference misrepresentation in the form of

[8] There is a strand of literature in noxious facility location theory that addresses the importance of compensation in dealing with community opposition [Austin, Smith, and Wolpert (1970); and Wolpert (1976)]. However, these papers do not address the possibility of strategic misrepresentation of compensation requirements by communities.

exaggerated claims for compensation. He suggested that a Vickrey-type, second-price auction procedure might eliminate the incentive for preference misrepresentation, but did not develop a formal model.

The next section demonstrates that the Clarke demand-revealing mechanism, which uses a Vickrey-type auction to induce truthtelling for the pure public goods allocation, is inappropriate for the noxious facility problem. Thus, in Section IV we propose a sealed bid auction siting model and several variations thereof.

III. Inappropriateness of the Clarke Mechanism

The literature on demand-revealing mechanisms initially appears to be appropriate for analyzing the noxious facility siting problem. Specifically, under certain assumptions, the mechanism developed by Clarke (1971, 1972) induces individuals to declare their true preferences for a pure public commodity by charging a tax which is dependent, in part, on the impact of their responses on the final outcome. Even though the Clarke mechanism is incentive compatible, it has several weaknesses (Groves and Ledyard, 1977). For example, in order to induce truthful preference revelation, the mechanism generates surplus tax revenues that must be discarded rather than returned to the individuals. Thus, the outcome of this procedure is not fully Pareto optimal.

On closer inspection, one finds that the Clarke preference revelation mechanism requires that the public commodity being allocated has a positive value to each of the individuals so that there is a net surplus after the commodity tax is levied. However, in the noxious facility problem each community has a negative value associated with having the facility in its jurisdiction. Hence, the Clarke mechanism may create a negative level of welfare for all the communities, since the community "harmed" by the collective decision cannot be compensated without eliminating the truthtelling incentive.[9] Furthermore, since the surplus taxes cannot be returned to the communities, no community will want to host the facility, even though it may create a net social benefit to the entire region.

An Example

We now present a simple example to illustrate the difficulties in using the Clarke mechanism for the noxious facility problem. Assume that sites A, B, and C are associated with communities 1, 2, and 3, respectively. The value matrix (Table I) indicates that each community will prefer to have the facility located elsewhere, rather than in its jurisdiction, unless it receives compensation. For example, Table I indicates that community 1 is $8 dollars worse off if the facility is in its backyard, so its true willingness to accept (WTA) = $8. It is $4 dollars better off if the HMDF is located in one of the other two communities, so its true willingness to pay (WTP) = $4.

Based on the above value matrix, one can compute the appropriate Clarke tax for each of the communities under the assumption that each community reveals its true WTA for the site and its true WTP for the facility to be located elsewhere.[10] The WTA is the minimum amount of income that the community is willing to accept in order to leave the community as well off, after the facility is located in its boundaries, as before the facility was constructed. In contrast, the WTP is the maximum amount of income that the community is willing to pay to avoid having the facility in its boundaries (Just, et al., 1982).

[9] This limitation was first pointed out by Tideman and Tullock (1976).
[10] See Mueller (1979, Chapter Four) or Tideman and Tullock (1976) for a detailed explanation as to how these taxes are computed.

TABLE I: Value Matrix for the Three Community Location Problem

	Site		
Community	A	B	C
1	-8	4	4
2	4	-5	4
3	7	7	-8
Net Benefits	3	6	0

The Clarke procedure adds the WTP and WTA figures for each community and selects the one with the largest net benefits (Community 2, or equivalently, Site B) as the "winner". Each community is then taxed only if its stated WTA and WTP are decisive in changing the outcome. For example, as shown in Table II, if one eliminated Community 1's WTP and WTA (Row 1 was eliminated from Table I), then Community 1 (Site A) would be chosen as the site and the net benefit of this facility would be $11 (i.e., $4 + $7; the WTP for communities 2 plus 3, respectively). Community 1 would be taxed an amount of $11-$2=$9, representing the difference between the net benefits from Community 2 (the best site) and Community 1 if its preferences were not considered. Community 3 would pay a tax of $8-(-$1)=$9. Community 2 would not have to pay a tax since it would still be chosen when its own preferences were eliminated from consideration.

A little reflection on these outcomes reveals that all communities will be decidedly unhappy with their post-Clarke tax situation. By bidding their true preferences, they are taxed an amount which leaves them worse off than under the status quo. Hence, they will not want to site a facility using this procedure even though aggregate net benefits may be positive.

The siting of a noxious facility thus differs from the pure public goods problem in a fundamental way. In siting a public good, such as a park, the entire region as well as the host community receives net benefits. The only question is where the public good should be located to achieve efficiency. In the case of a noxious facility, however, the host community will tend to suffer a loss while the remaining communities w_thin the region will tend to benefit. Hence, there is a need to

TABLE II: Clarke Tax Computation

Community		A	B	C	Tax
1:	2+3	11	2	-4	11-2=9
2:	1+3	-1	11	-4	11-11=0
3:	1+2	-4	-1	8	8-(-1)=9

develop a bidding procedure which specifically links each community's WTA bid (for hosting a facility in one's jurisdiction) to its announced willingness to pay for locating it elsewhere.

IV. Auction Siting-Compensation Model

This section presents a sealed-(low)bid auction model for selecting and compensating the community that hosts a single, fixed-size hazardous facility.[11] The key idea is to create a limited incentive for individuals to misrepresent their preferences by linking the localized social benefits of the facility to its pure public social benefits. We do so by stipulating that the tax payment for not hosting the facility is (1/n-1) of a community's announced compensation requirement, i.e., its acceptance bid, when n communities are candidate sites. Finally, note that the siting-compensation model is not a typical auction model since we do not specify a relationship between the bidder's probability of winning and his bid. Also, we do not specify a (common) probability distribution from which the bidders' "reservation values" are drawn, as is commonly assumed in the auction literature (e.g., Myerson, 1981; Riley and Samuelson, 1981; or Vickrey, 1961).

A. Notation and Assumptions

The notation and assumptions of the model are as follows:

i = one community among a finite set, N, of communities numbered i,j = 1,2, . . ., n;

k = a potential site (one per community) among a finite set, K, of mutually exclusive alternative sites, numbered k = 1,2, . . . , n with typical elements $i,j,k \in K$;

[11] As indicated above, the use of auctions for siting noxious facilities seems to have been suggested originally by O'Hare (1977). Related bargaining problems are discussed in Raiffa (1982).

$t_i(k)$ = a transfer function indicating the amount of money received or paid by community i if site k is chosen; for i,k = 1,2, . . ., n;

$U_i(k,t_i(k))$ = preferences of each community i are represented by a quasi-linear (in money) multi-attribute utility function of the form $U_i(k,t_i(k)) = V_i(k) + t_i(k)$; for all i,j, = 1,2,. . ., n;

$V_i(k)$ = community i's true value or willingness to pay for site k. We are assuming that the preferences of each community are such that $V_i(k = i) < 0$ and $V_i(k = j) > 0$.[12] That is, we assume that each community requires compensation to host the facility but is willing to pay another community to host it;

$X_i(i)$ = community i's acceptance bid for locating the facility in its jurisdiction. We assume that $X_i(i) < 0$, for all i = 1,2, . . ., n. This assumption indicates that each community will announce that it requires compensation for hosting the facility;

$X_i(j)$ = community i's bid for having the facility located in community j. We assume that $X_i(j) > 0$ for all i,j = 1,2, . . . , n .

Stating payoffs for alternative sites in terms of a single value $U_i(k,t_i(k))$ can be justified only if the following assumptions are made. First, we assume that each community is perfectly informed about the facility's consequences at each alternative location. For simplicity, and without loss of generality, we assume that each community is of equal size and has an identical income distribution.[13]

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[12] The specification of $V_i(k=j) > 0$ reflects the assumption that the negative consequences of the facility do not spillover into adjacent communities.

[13] A more realistic set of assumptions would, of course, address such issues as: community planning grants and other information generation procedures which enable communities to estimate the "value" they place on alternative sites [See Kleindorfer (1984) for a discussion of these points].

B. The Problem

The basic structure of the problem is as follows. The regional siting agency has the task of determining which one of the communities will be chosen. To do so, it elicits an acceptance bid, $X_i(k=i) < 0$, from each community $i=1,2, \ldots, n$. This bid represents the minimum compensation required by community i to site the facility within its jurisdiction, i.e., k=i. If the facility is eventually sited in community j*, then community i must pay an amount, $t_i(j^*)=-X_i(k=i)/(n-1)$, to compensate the "winning" community, j*.

Several different criteria can be utilized for choosing a site including: lowest acceptance bid, maximum budget surplus, or random choice (e.g., lottery). Each of these criteria may induce different acceptance bids by the communities. We first consider the case in which the objective of the regional agency is to locate the facility at the site with the lowest bid subject to the constraint that there is no budget deficit.

The agency's problem, corresponding to this objective, may be stated in terms of the acceptance bids as follows:

Choose the minimum element of

$$\{X_i(i) \mid i = 1,2, \ldots, n\} \qquad (1)$$

subject to:

$$\sum_{j \neq i} t_j(i^*) - X_i(i) \geq 0, \quad i,j = 1,2, \ldots, n.$$

That is, select the community with the lowest feasible bid, where feasibility means other communities are willing to pay total compensation at least equal to the acceptance bid required by the candidate community.

An alternative criterion would be to maximize net surplus, subject to the same non-deficit constraint. In this case the agency's problem is:

$$\max_{i} \left[\sum_{j \neq i} t_j(i) - X_i(i)\right] \qquad i,j = 1,2, \ldots, n \tag{2}$$

subject to

$$\sum_{j \neq i} t_j(i) - X_i(i) \geq 0 \qquad i,j = 1,2, \ldots, n$$

A reasonable assumption is that each community would like to be at least as well off after the site selection process than if no site were chosen (the status quo). We formally express this assumption by stating that communities will submit acceptance bids satisfying the following individual rationality constraints:

$$\text{Facility in i: } X_i(i) + V_i(i) \geq 0 \qquad i,j = 1,2, \ldots, n \tag{3}$$

$$\text{Facility in j: } t_i(j) + V_i(j) \geq 0$$

where we associate the value "0" with the status quo.

The two preceding selection criteria are, of course, only examples. The point is that the regional agency must choose acceptable criteria before gathering each community's bids, $X_i(i)$ and $X_i(j)$, on each feasible site since each community will announce its bids in response to the site selection and transfer rules. Thus, the fundamental design problem is the specification of rules that induce fair and efficient outcomes.

To find a solution to this problem, the regional agency needs to design a set of transfer, i.e., compensation and tax, rules which limit a community's incentive to drastically distort its preferences for alternative sites. However, each community has an incentive to misrepresent its preferences by overstating its "acceptance bid" and understating its willingness to pay if it believes that it won't be penalized by this action. For example, suppose community i knew that all other communities would bid \$100,000 or more as an acceptance bid. If the residents of community i were willing to accept the facility for only \$50,000, they would still want to bid up to \$99,999, assuming that the "winner" was the community making the lowest bid.

Hence, the selection of community i with the exaggerated bid of \$99,999 is an <u>ex post</u> Pareto-<u>inefficient</u> location (even though it solves the first problem), since the remaining $j \neq i$ communities are assessed an additional \$49,999 in tax payments. These taxes would not have to be paid if community i was induced to submit a truthful bid of \$50,000.

C. <u>Variations of the Auction Model</u>

Our proposed bidding procedure links the localized social costs of a facility to its social benefits by requiring that $t_i(j) = -X_i(i)/(n-1)$, where n is the number of communities in the region. Thus, if a community submits a higher acceptance bid, $X_i(i)$, it will have to pay a larger tax, $t_i(j)$, to the regional agency if the facility is sited in another community $j \neq i$. For this reason there is a limited incentive to misrepresent one's preferences by bidding $X_i(i) \neq V_i(i)$. Furthermore, the mechanism guarantees a tax surplus if the facility is located in the community with the lowest bid. The performance of several variations on this basic bidding model, all assuming $t_i(j) = -X_i(i)/(n-1)$, can be examined both theoretically and empirically (via controlled experiments). Note, that a common assumption for all variations is that the facility's external costs are localized. These variations are as follows:

1. One-Shot Sealed-(Lowest) Bid Auction

In this procedure each community bids an amount $X_i(i)$ required for accepting the facility. The lowest bid is chosen as the site. When each community knows its own preferences, but has no information on others, then a maxi-min bidding strategy appears to be desirable. For this problem, this means that the community will choose $X_i(i)$ so that

$$V_i(i)+X_i(i)=(\underset{j\neq i}{\text{minimum}}\ V_i(j))+t_i(j)=(\underset{j\neq i}{\text{minimum}}\ V_i(j))-X_i(i)/(n-1) \quad (4)$$

for all $i,j = 1,2,\ldots, n$ and $i\neq j$.

Note that the transfer rule, $t_i(j) = -X_i(i)/(n-1)$, is an exogenous specification.

It is easily verified that (4) is an equilibrium maxi-min strategy. The first expression on the left hand side of (4) represents the payoff to community i if site i is selected, while $V_i(j) + t_i(j)$ is the payoff if some other site $j\neq i$ is selected. As $X_i(i)$ is increased, $X_i(i)+V_i(i)$ increases and $V_i(j)+t_i(j) = V_i(j)-X_i(i)/(n-1)$ decreases. The maxi-min payoff occurs when equality is achieved between the site i payoff, $X_i(i) + V_i(i)$, and the worst possible alternative site $j\neq i$ payoff, $V_i(j) - X_i(i)/n-1$. This is what (4) indicates.

We can solve (4) for $X_i(i)$ to obtain:

$$X_i(i) = \frac{n-1}{n}\,[(\underset{j\neq i}{\text{Minimum}}\ V_i(j)) - V_i(i)] \quad \text{for all } i,j = 1,2,\ldots,n \text{ and } j\neq i. \quad (5)$$

From (5) the individual rationality conditions (3) are satisfied for the maxi-min strategy precisely when

$$V_i(i) + X_i(i) = \frac{n-1}{n}\,(\underset{j\neq i}{\text{Minimum}}\ V_i(j)) + \frac{1}{n}\,V_i(i) \geq 0 \quad (6)$$

since, if $X_i(i) + V_i(i) \geq 0$, then by (4) $V_i(j) + t_i(j) \geq 0$ will obtain for all j. Note that (6) can be rewritten as

$$\frac{-V_i(i)}{n-1} \leq \underset{i\neq j}{\text{Minimum}}\ V_i(j) \quad \text{for all } i,j = 1,2,\ldots, n \text{ and } i\neq j \quad (6a)$$

i.e., the average tax, which must be levied on community i to compensate community j for hosting the facility, cannot be any larger than the minimum of community i's true willingness to pay to have the facility sited outside its jurisdiction. For the maxi-min procedure to be feasible, (6) would have to be satisfied for all potential sites $i=1,2, \ldots, n$.[14]

In sum, the one-shot, sealed-(low)bid auction is an individually rational and coalition-free mechanism. It is not incentive compatible, but communities are dissuaded from greatly exaggerating their compensation requirements. Also, it generates a tax surplus (net of compensation). The procedure is coalition free since each community's transfer function is independent of any other community's acceptance bid. Thus, two or more communities cannot strategically link their bids in order to extract mutual gain from the auction procedures.[15] This latter characteristic contrasts with the Demand Revealing Mechanisms' inability to prevent a coalition of consumers from strategically misrepresenting their collective demand and, thereby, eliminating the incentive compatibility of these mechanisms (Groves and Ledyard, 1977).

2. Lottery cum Auction

This procedure resembles the one-shot auction except for the following variation. Stage 1 consists of a lottery in which each community submits a bid $X_i(i)$. Then one community is randomly chosen as a potential site. This community's bid is publicly posted . Then

[14] If a community was using a maxi-min bidding strategy and (6) were violated, the community would presumably perceive that it might end up worse off than with the status quo. In this case it may prefer not to be a candidate site.

[15] Communities may have an incentive to collude if they were permitted to make side payments.

Stage 2 consists of a sealed-bid auction in which the remaining n-1 communities can bid again while the community chosen in Stage 1 must maintain its initial bid. The ultimate winner is the commmunity with the lowest bid at the end of Stage 2. All other communities must pay an amount $-X_i/(n-1)$ based on their bid in Stage 1.

The Lottery cum Auction is designed to address the equity issues associated with siting hazardous facilities. The poorest communities can make a very low bid in Stage 1 guaranteeing that they will only have to pay a small, relatively affordable amount if they are not selected to host the facility. If they are not chosen as the potential site in Stage 1, they can then raise their bid above the posted value, thus guaranteeing that they will not host the facility.

If $X_i(i)$ truly reflected the preferences of the communities, then we would expect the same result from the two-stage lottery as from the one-shot sealed-bid auction. However, if some communities bid a very small amount in Stage 1 (relative to the bid submitted by the lottery winner)and subsequently raise their bid in Stage 2 above the posted bid, then this procedure may not be budget-balancing for a particular outcome. However, on average, the two-stage lottery will be budget-balancing, since a community which submits a relatively low bid will be chosen in Stage 1 with 1/n probability.

3. Multiple Round Sealed-Bid Auction

In this procedure, each community makes an initial bid, $X_i(i)$, knowing that it can change its bid in the next round. Bidding stops in the r+1 round if the bids of all communities are identical to those in the previous round r, i.e., $X_i^r(i) = X_i^{r+1}(i)$, i=1 . . . n. The community with the lowest bid receives the facility and all other potential sites are charged $t_i(j) = -X_i/(n-1)$.

From a theoretical point of view our interest is in the existence of a stable Nash equilibrium for this procedure. Existence depends on the type of information that the regional siting agency presents to each of the potential sites. At one extreme the bids of all the participants could be made public; at the other extreme the regional authority could reveal the magnitude of the lowest bid at the end of each round without identifying the site. We are interested in learning if convergence will take place; the types of strategies utilized by communities in specifying their bids across rounds; and, the properties of the equilibrium if there is convergence.

4. Sealed-Bid Auction (Perfect Information)

When all participants have perfect information about the values $V_i(i)$ and $V_i(j)$ for every community, then the equilibrium bids will reflect this knowledge. More specifically, one can show that there are a number of stable Nash equilibrium but the one that is likely to prevail resembles the optimal payment from a Vickrey (1961) second-price auction. To determine this equilibrium, one must first calculate the maxi-min solutions with no information. The community chosen under this procedure, say community j, can now specify a bid, denoted by X_j^*, which is δ units below the second lowest bid, X_i^{**}, and still obtain the facility, while making a greater profit in the process. All other communities have an incentive to bid X_i^{**} insuring that they will not get the facility but have to pay as little as possible for it to be located elsewhere.

This Nash equilibrium has the attractive characteristic of being essentially budget balancing (i.e., $\sum_{i \neq j} X_i^{**} - X_j^{*} = \delta$). The community which receives the site will make a "profit", identical to the amount obtained from a Vickrey auction, since its payment is determined by the second lowest bidder. Using controlled laboratory experiments, one could investigate bidding behavior under perfect information, using either a one-shot sealed-bid auction or a multiple trial sealed-bid auction.

D. <u>An Example</u>

Let us now turn to an example of a sealed-bid auction mechanism considered in Table I. The example illustrates the nature of maxi-min (Nash) solutions when each community has either no information or perfect information on the remaining communities' willingness to pay values, $V_i(i)$ and $V_i(j)$. Table III presents each community's optimal bids and net values for the "no information" and "perfect" information cases, assuming that a maxi-min strategy is utilized by all participants.

Under the case of no information, each community bids so that it is indifferent between accepting the facility or having it elsewhere. The net values reflect this strategy. In contrast, when there is perfect information, community 2 bids one cent below the maximum bid of Community 1 (the second lowest bidder) and makes an additional profit of \$1.99. Its total profit of \$2.99 is the same as if one had utilized a Vickrey auction for a private good where there were no external benefits, i.e., $V_i(j) = 0$. Community 3 is able to make an additional \$1 profits by lowering its bid from 10 to 8 and, thereby, reducing its tax payment from \$5 to \$4. Community 2 is still chosen as the site.

TABLE III: Optimal Maximin Bids and Net Value for Sealed-Bid Auction

	No Information		Perfect Information	
Community	Bid: $X_j(.)$	Net Value	Bid: $X_j(.)$	Net Value
1	8	0	8	0
2	6	1	7.99	2.99
3	10	2	8	3

V. Future Research

The sealed-bid auction mechanisms developed in this paper are complementary to the large body of empirical work designed to measure willingness to pay and willingness to accept values for public and private goods as well as externalities (Brookshire, Coursey and Schulze, 1985). In particular, we can use controlled laboratory experiments to test the hypothesized performance of each of the mechanisms which use the exogenous transfer relationship, $t_i(j) = -X_i(i)/(n-1)$. In this way, we can identify each mechanism's strengths, limitations, and robustness, using both process and outcome efficiency measures. Some of these measures include:

*Information Processing Costs--How difficult is it for communities to process information for a given procedure?

*Efficiency--How close does the proposed solution come to making everyone in the region better off without making anyone worse off (Pareto efficiency)?

*Budget Balancing--How close does the proposed solution come to balancing the tax and compensation transfers?

*Equity--Is the proposed solution perceived to yield a fair distribution of net benefits among the communities?

*Time to Solution--How much time will a multi-round procedure require to reach a solution? When will a multi-round procedure fail to converge so that the undesirable status quo is maintained?

*Misrepresentation of Preferences--Will a particular procedure lead communities to misrepresent their preferences for alternative sites and associated compensation payments.

A possible experimental design for testing the hypothesized performance of the auction procedures is suggested by Vernon Smith's (1977) Auction Election (AE) mechanism for both continuous and discrete public commodities. The AE mechanism would work in our siting problem context as follows. Each community would submit a bid for its site, say $X_i(i) < 0$, and for each of the other sites, say $X_i(j) > 0$. The bidding is terminated as soon as there is one site i where $\sum_{i \neq j} X_i(j) + X_i(i) > 0$. The AE mechanism relies on budget-balancing to induce "reasonable" bids by each of the participants. However, (as Smith recognizes) it does not induce truthful preference revelation. Coursey and Smith (1985) recently combined this mechanism with a competitive sealed bid auction in order to allocate a good whose aggregate production yields external benefits or costs for each agent. It may be useful to contrast these approaches with the bidding procedures proposed in this paper.

Finally, our proposed experiments can be contrasted to those undertaken by Coursey, Hovis, and Schulze (1984). They exposed subjects to an unpleasant chemical substance and subsequently asked them to indicate their willingness to pay (WTP) value to avoid tasting the substance, as well as their willingness to accept (WTA) value for tasting the substance. In contrast to the noxious facility problem, subjects did not receive any direct benefit from having someone else taste the substance. One would thus expect to not find differences between WTA and WTP in the Coursey *et al.* setting, while such differences would be hypothesized for the noxious facility problem.

In addition to concerns about efficient allocation, we are convinced that equity considerations must be taken into account when designing a compensation mechanism whose implementation requires political support. This concern has been reinforced by a recent series of experimental studies which concluded that equity considerations are very important to individuals involved in bargaining games where the gains to some imply losses to others (see Roth, 1983; Yaari and Bar Hillel, 1984).

The bidding procedures developed in this paper have the limitation that they may exclude certain communities from consideration when the maxi-min solution may yield a value: minimum $V_i(j) + t_i(j) < 0$, even though there will be a potential site k where $V_i(k) + t_i(k) > 0$. In this case, one would have to design some type of cross-subsidization procedure for keeping community k as a potential candidate for siting. Note that if the $V_i(j)$ are identical across j, such a siting opportunity will not exist.

The mechanisms described in this paper can also be extended to the incomplete information case in which each community has a priori beliefs regarding other communities' willingness to pay and willingness to accept. In this case, the WTP values can be described by a subjective probability distribution. Bids would then be made in the same manner as specified above. Optimal auction and compensation procedures, such as those specified by Meyerson (1981) and d'Aspremont and Gerard-Varet (1983), may be appropriate for analyzing this problem.

Finally we have assumed that the noxious facility's negative consequences are deterministic, i.e., there is no risk in the problem. This is a very strong assumption since our results might tend to be highly sensitive to the introduction of risk and uncertainty into the auction procedures. Future experimental research might incorporate uncertain outcomes into the design. An appropriate starting point would be the elicitation procedures utilized by Kerry Smith, et al. (1985) in a recent field survey. The purpose of the survey is to determine an individual's valuation of the expected reduction in risks of hazardous materials. By incorporating uncertainty explicitly into the analysis, one can investigate the impact that context and framing effects may have on a community's bids.

* * *

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