SITING SLUDGE TREATMENT FACILITIES FOR THE CLEANUP OF BOSTON HARBOR: DECISION ANALYSIS AND PROBLEM FORMULATION

by

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1977

Submitted to the Department of Urban Studies and Planning
in Partial Fulfillment of
the Requirements of the Degree of
Master in City Planning

at the

Massachusetts Institute of Technology

June 1989

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ABSTRACT

Four multiattribute decision analysis models were constructed to examine a public agency's decision about where to site a sewage sludge treatment facility. The models looked at the siting problem from four different perspectives--as a technical problem, as a political problem, as a conflict resolution problem, and as a risk management problem.

The results of the models showed that the preferred choices of sites differed when the siting problem was viewed in different ways. The advantages and pitfalls of using decision analysis for controversial public policy problems were examined. The methodology is valuable as a tool for problem formulation, but is less useful for actually making public policy decisions.

Thesis Supervisor: Joseph Ferreira, Jr.

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Acknowledgments

I could not have completed this thesis without the help of several people. I am indebted to Joe Ferreira, my thesis advisor, for the hours he spent reviewing the models and explaining the perversities of utility theory to me. Joe first suggested that I use decision analysis to look at the sludge siting problem from different perspectives. His enthusiasm for the project, high standards, and belief in me kept me going through the long days of computer modeling and revision.

My friend and academic advisor, Larry Bacow, "engineered" my career at MIT. He encouraged my interest in the siting problem, and I benefited from his expertise in the subject area. He made me feel at home in the Department, and has given me excellent advice over the past two years. I always left his office with my life in order.

Nothing I have accomplished at MIT could have been done without the assistance and support of my husband, Bill Lebow. He encouraged me to apply to the program, cheerfully paid tuition, did many loads of laundry, configured all my software, took me on vacation when I needed one and listened to a lot of complaining. Best of all, he bragged about me to anyone who would listen. Somewhere along the line I must have done something right to deserve having him in my life.

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PREFACE

Facility siting will be one of the most vexing and frustrating problems facing environmental managers in the 1990s. As the need for large-scale waste management facilities--for disposal of sewage sludge, hazardous waste, solid waste, low-level and high-level nuclear waste--becomes a crisis, public opposition to these facilities mounts, resulting in the "not in my backyard" (NIMBY) syndrome being played out in every area of the nation.

How can environmental managers deal with the NIMBY syndrome? How can they make siting decisions that they can justify before regulatory agencies, legislatures, the courts and the public? In many siting situations, decision makers are faced with deadlines, little information, and intense political and public pressure. Are there any decision making aids that can help environmental managers under these circumstances? Formal analysis usually involves substantial time, information, money, and the hiring of experts. (Behn and Vaupel, 1982) Are there any tools that decision makers can use informally to try to structure their complicated siting problems and gain insights about these problems?

In this thesis I argue that decision analysis, particularly simple applications of multiattribute utility analysis, can aid decision makers in understanding complex facility siting problems. The thesis follows a hypothetical decision maker, Alexandra Smith, as she uses decision analysis models to look at a facility siting problem from four different angles. Although Smith is a fictitious character, her decision problem--where to site sludge treatment facilities for the cleanup of Boston Harbor--is a real one.

The information she uses is actual data collected by consultants for the Massachusetts Water Resources Authority (MWRA), the state agency charged with the harbor cleanup. The sites she considers and the circumstances surrounding her decisions are the same as those facing the decision makers at the MWRA. All of her judgments and values, and those of other parties involved in the problem, are hypothetical, however.

I do not attempt to draw conclusions about where the MWRA should site its facilities. The purpose of this thesis is to demonstrate how one type of mathematical model can help a decision maker formulate a siting problem. The judgments made by my hypothetical decision maker are based on my intuitions about the sludge siting problem, and should not be attributed to anyone involved in the actual siting decision.

INTRODUCTION

The Boston Harbor is the most polluted harbor in the nation. Most of the pollution results from outmoded sewage treatment plants that serve 43 communities in the greater Boston area. Sewage is not properly treated by the system--at best, when all facilities are working properly and the system is not overloaded, sewage receives only primary treatment. Solids are allowed to settle, the waste water is chlorinated, and both the solids (called "sludge") and the treated waste water are dumped into the harbor. Currently, the system dumps 500 million gallons of partially treated effluent and 70 dry tons of sludge per day into the harbor. (Save the Harbor, 1987). An additional 15 million gallons per day of raw, untreated sewage never even reach the treatment plants, and flow into the harbor through combined sewer overflows (safety drains that were designed at the turn of the century to prevent backups at the treatment plants during rainstorms; many drain sewage into the harbor during dry as well as wet weather periods). The sewage from the combined sewer overflows, the treated effluent from the plants, and the sludge are all contaminated with toxic chemicals that are contributed by households and industries.

The pollution of Boston Harbor has had substantial effects on the environment and economy of the Boston area. Over 64 percent of the shellfish beds that border the harbor are closed; use of the remaining beds is restricted to professional fishermen who send their catch to purification plants. Beaches are frequently closed due to health risks. Harbor flounder have the highest national incidence of liver and skin tumors, and about 17 percent of the bluefish in Massachusetts Bay are contaminated with polychlorinated biphenyls (PCBs). (Save the Harbor, 1987).

In 1985, a federal district court found the Metropolitan District Commission (the state agency that ran the greater Boston area water and sewer system) in violation of the federal Clean Water Act (*Conservation Law Foundation v. Metropolitan District Commission*, September 5, 1985). The court ordered the state to construct new sewage treatment facilities to comply with the Act. While the litigation was being decided, the Massachusetts legislature created a new agency to deal with the harbor cleanup--the Massachusetts Water Resources Authority (MWRA). The new agency was given authority to raise revenues through bonds and rate increases.

The federal court set a stringent schedule to bring the sewage treatment system into compliance with the Clean Water Act. (*Conservation Law Foundation v. Metropolitan District Commission*, May 8, 1986). The project includes construction of a state-of-the-art secondary treatment facility. The MWRA was ordered to stop dumping sludge into the harbor. The agency must develop a land-based method for treating sludge by 1991 and implement it by 1995.

Sludge is one component of what the MWRA terms "residuals". Residuals are materials that are removed from municipal waste water during treatment. They include grit (sand-like materials that quickly settle out of waste water), screenings (large items, such as wood and rags, that are collected from waste water in coarse screens prior to primary treatment), scum (floatable materials such as grease, oil and plastics that are skimmed from the surface of waste water as it flows through large settling tanks), and sludge (settled particulate matter and microorganisms removed by sedimentation during primary and secondary treatment). Sludge is the largest single component of wastewater residuals.

Sludge may be treated and disposed of using several technologies: incineration, composting, landfilling, and ocean dumping. The MWRA is prohibited from deep sea dumping by the federal Ocean Dumping Ban Act of 1988. Exclusive use of landfills would require more empty land than is available in the area. The MWRA is studying two technologies: incineration and composting. Incineration burns residuals to remove the water and reduces the remaining residues to ash. Composting converts residuals to a humus-like material that can be used for horticultural purposes. (MWRA, 1987).

Alexandra Smith, a planner recently hired by the Massachusetts Water Resources Authority, faces a difficult decision. Her task is to choose a site for the sludge treatment facility and to get the facility built. The agency has been studying the siting problem for two years, and a few weeks before Smith started work, her predecessor announced that his siting team had narrowed a preliminary field of 299 sites to seven candidates for further evaluation. The agency has invested a lot of time and money in site evaluation, so Smith cannot realistically start the process all over again. She must make a decision from among the seven sites recommended by her predecessor. She must also try to learn about the siting problem so that she can design a strategy to deal with any opposition to her decision.

Why Facility Siting Decisions are Difficult to Make

Smith realizes that like many planning problems, facility siting decisions are "wicked"--messy, ill-defined problems that rely upon political judgment for resolution. (Rittel and Webber, 1973). Facility siting decisions pose harder questions than simply: Where should we put our facility? Such decisions have a complicated structure--engineering, political, environmental, economic and socioeconomic considerations are all involved. A facility siting decision is like a puzzle into which many pieces must be fit. A decision maker cannot easily solve this puzzle with intuition. (Keeney, 1980).

A facility siting decision also is hard because many uncertainties exist about problem definition. (Fischhoff, et al., 1981). Is Smith's problem merely to find the best site, engineering-wise, for the facility? Since the agency is under court order to site a facility quickly, maybe her problem isn't a technical one at all, but a decision about which choice of site will allow her to implement her plan quickly. Smith is well aware of daily media reports about the "not in my backyard" syndrome, in which the implementation of carefully made siting decisions based on technical considerations are delayed or even stopped by the protest of community groups. Perhaps the sludge facility siting problem is a conflict resolution problem--one in which she must negotiate with community groups to gain their acceptance of her decision. The two technologies the MWRA is considering, composting and incineration, pose certain health risks. Is Smith's decision problem a risk management problem?

Multiple objectives are the hallmark of facility siting decisions. (Keeney, 1980). Smith wants to find a site that is good technically, but she also wants to save as much money as possible, since the MWRA's ratepayers, who are already suffering from increasing water and sewer bills as the harbor cleanup begins, will have to pick up the tab for the sludge treatment facility. Smith is also concerned with the environmental impacts of the facility. Under the National Environmental Policy Act and its state counterpart, the Massachusetts Environmental Policy Act, the MWRA must consider the impacts of its projects on the environment. The agency is also naturally concerned about environmental impacts--after all, its primary goal is to clean up Boston Harbor, and it would be ironic if it polluted another area in the attainment of that goal. Smith also is concerned about public safety--she wants to choose a site that has the fewest health impacts and the smallest traffic accident potential. The existence of these multiple objectives necessitates another complicating factor in siting decisions--the need to make value tradeoffs (Keeney, 1980). Obviously, Smith's objectives will be in conflict with one another. She cannot protect the environment to the fullest extent and also keep costs to the minimum. A technically "perfect" site may have the soils, geology and transportation network access that the facility needs, yet be located near densely residential neighborhoods. In order to make a decision, Smith must determine, either explicitly or implicitly, how much reduction in the level of achievement of one objective she is willing to accept in order to raise the level of achievement of another objective.

Siting problems are also complicated because in many instances, it is not clear who is the decision maker. In the sludge siting case, Smith is charged with deciding on a site, but her decision must be ratified by the MWRA's Board of Directors. If the agency decides on acquisition of private land for its site, it must apply to the state legislature for eminent domain authority. The legislature is free to review the siting decision, and could very well overturn it.

The siting problem is further complicated by other political constraints and considerations. A siting decision must be justified before regulatory agencies and the public. If environmental groups or abutters to the site sue to overturn the choice, the agency's decision is subject to scrutiny by the courts. Interest group politics can affect the acceptability of decisions. (Bidwell, et al., 1987). Facility siting decisions are often susceptible to the "passions of the moment". For example, Smith has recently heard that a group of legislators from the communities on the final sludge site list have organized to pressure the agency to choose Spectacle Island, an abandoned island in Boston Harbor, as the facility site. Suddenly, the press, politicians and citizen groups are saying that Spectacle Island is the best choice. It is tempting to Smith to give in to these pressures and make a decision without looking at the complete problem. Politics can also easily turn a specific problem--in this case, where to put a sludge treatment facility--into a much wider issue. (Bidwell, et al., 1987). Community groups and local officials, complaining that the final seven sites are all located in working class neighborhoods, have cast the sludge facility siting issue as one of class conflict.

Facility siting decisions are often dependent upon uncertainties about decisions made by other government agencies. (Keeney, 1980). For example, the MWRA must meet federal Environmental Protection Agency and state Department of Environmental Quality Engineering standards for the chemical and heavy metal content of its sludge. The MWRA's sludge is full of toxic chemicals and heavy metals, and it is working to eliminate them from the waste stream in order to meet existing regulations. However, the EPA has proposed new rules that would make the existing regulations more stringent, and there is uncertainty about whether the MWRA will be able to meet the new standards.

Facility siting decisions involve many difficult measurement problems. The MWRA is considering many criteria for siting, and the measurements of these criteria are like apples and oranges--they cannot easily be compared or combined into a single measure of a site's performance on the criteria. (Ortolano, 1984) For example, how does Smith compare the loss of a threatened species' habitat with the loss in residential property values around a site that a sludge treatment facility might cause? Siting decisions also involve many intangibles--factors for which there is no obvious way to measure the impact. (Keeney, 1980). How should Smith measure concerns about aesthetics, or the psychological "stigma" many neighbors feel would attach to them when they live near a waste treatment facility? The impacts of the facility are uncertain--will there be environmental, socioeconomic, and health impacts? How much impact will there be? How important is the impact? (Keeney, 1980). Impacts can occur over long time horizons. How can Smith measure impacts on unborn generations? How does she set bounds on the time period in which to consider the sludge facility's impacts?

Siting decisions are further complicated by the presence of many interested social groups--"stakeholders" in the decision. The costs and benefits of the sludge treatment facility will affect various groups differently. People who live around the harbor and use it for fishing or recreation will benefit from cleaner water. People who live near the sludge treatment facility may see environmental damage and declining property values, may have to put up with noise and odors, and may suffer adverse health effects. Equity issues therefore become very important and emotional in a siting decision.

Although many government and industry officials attempting to site noxious facilities often believe that the questions surrounding the choice of site are purely technical, Smith believes that they actually involve many value judgments. No overall experts exist for siting decisions. (Keeney, 1980). The decision maker may receive input from engineers, scientists, public relations specialists, financial managers, and land use planners, but there is no one person or group of experts that specializes in facility siting. Each separate group of experts brings its own values to the siting decision. Lay people also bring their values to the problem, and their attitudes about the probability of the occurrence of impacts and the magnitude of these impacts often differ radically from those of experts. (Fischhoff, et al., 1981). Value conflicts between these groups are often exacerbated by scientific uncertainty about impacts, whether due to insufficient data or contradictory findings. (Bidwell, et al., 1987). The values people hold about the siting problem may be "labile"--unformed, evolving and apt to change. (Fischhoff, et al., 1981).

Finally, siting decisions are hard to make because they involve high stakes. (Keeney, 1980). A poor decision may result in massive, irreversible environmental damage or illness or death for many people. Building facilities costs hundreds of millions of dollars, costs that in the sludge case will be borne by ratepayers already squeezed by rapidly rising rates. A politically unpopular decision could result in many costly political battles, and could cause delays in building the facility that would violate the court order. Scarce resources--staff talent, time, information, and money--could be wasted on a poor decision. Perhaps most importantly, a poor decision could cause a public already skeptical about its government's ability to solve problems competently and fairly to become further disillusioned. (Keeney & Raiffa, 1972).

Theories of Facility Siting

Smith realizes the difficulties inherent in her siting problem. She wants to make a good decision, and wants to be able to gain public acceptance for that decision. She believes that if she can gain more insight into the sludge facility siting problem, she will be able to choose a strategy to increase the probability that her decision will be accepted by the public and eventually implemented. Before she thinks about a technique to help her formulate her problem, however, she reviews the various theories about facility siting strategy.

The traditional siting process has been described as a "Decide--Announce--Defend" model. (Ducsik, 1978). Typically, the project proponent, which may be a private company or a government agency, defines the siting problem (e.g., what type of technology to use, what type of location in which to site, whether to use satellite plants or one large facility), makes a list of possible sites, screens them using technical criteria developed by its experts, then announces the final siting candidates to the public. Public participation comes into the process only when the agency prepares an environmental impact statement. The proponent's decision is usually met with loud, emotional protests, legislative attempts to exempt certain sites, and legal challenges to the environmental impact statement. (O'Hare, Bacow and Sanderson, 1983).

Often, state governments try to improve upon this process by removing control over siting from localities and placing it in the hands of a state siting agency. "Preemptive" siting is highly centralized, and its proponents usually argue that it is legitimate because only the state has the technical competence or impartiality to make a controversial siting decision. When a decision must be made that involves localized costs but regional benefits, they argue, the state is in the best position to make the cost-benefit tradeoffs.

Preemptive strategies generate as much opposition as do traditional methods, perhaps even more. (Elliott, 1984). Many people value the concept of home rule for localities, and are insulted that their communities are not allowed to determine their own fates. People often do not believe the state is an impartial and fair decision maker. Using a purely technical process to site a facility is unacceptable to many local residents--they realize that many value judgments and uncertainties are inherent in any technical process. Preemption heightens the adversarial nature of the siting process by placing the state in clear opposition to local interests.

A third siting strategy recognizes that people have legitimate interests, fears and concerns in the siting process. This strategy acknowledges that most people would oppose the siting of a noxious facility in their community. According to this theory, people rationally weigh the costs and benefits of the facility, and determine that the costs will far outweigh the benefits. Proponents of this strategy argue that if the benefits obtained by the community are increased enough to balance the costs, residents will no longer oppose the facility. They propose that project proponents pay compensation to the host community. Compensation can take several forms--monetary payments to the general town treasury; payments to provide specific services (e.g., increased fire protection); or in-kind replacement of natural resources, physical amenities or services. (O'Hare, Bacow and Sanderson, 1983). Some proponents of this strategy have suggested that if "creative" compensation is offered--jobs, better schools, parks, traffic improvements, etc.--eventually, towns will actually compete for the "privilege" of having a facility in their community. (Raiffa, 1985).

The compensation strategy is not an easy solution to the siting problem. The strategy assumes that all social costs of a facility can be compensated, rendering people neutral to the facility. In fact, these costs may not be easily monetized and compensated. Many people find the idea of putting a price on health or the environment abhorrent. (Bacow and Milkey, 1982). People may feel that they are being bribed to accept a risk that is in fact unacceptable. Most people are uncomfortable with offers of compensation when they perceive that the offers are designed to alter their decision to accept a facility or reject it. (Elliott, 1984). Attitudes in the community towards compensation may differ--people farther away from the site may like the idea of increased revenues for the town, and may pressure neighbors near the facility to drop their opposition. It is difficult for a project proponent to satisfy the compensation demands of every party who might oppose the siting decision.

Critics of these siting strategies have developed a new process, called "open siting". Open siting acknowledges people's concerns, and tries to give the interested parties in the siting debate a real role in decision making. Most open siting processes involve negotiation and mediation to resolve the factual and value conflicts surrounding siting questions. Under this theory, project proponents should acknowledge the local community's power to slow or stop the siting process; avoid implying that community opposition is irrational or selfish; help the community get the resources and information it needs to participate in siting decisions; consider issues and concerns raised by the community; consult with the community at the very beginning of the decision process; and involve the community in direct negotiation to meet its concerns. (Sandman, 1985).

The final siting theory is based on the belief that public health risk management issues are the crux of any facility siting debate. Communities see noxious facilities as a threat to their health and safety. Conflict about siting arises because of the different ways experts and lay people perceive risk. Technical risk assessments calculate risk by multiplying the probability of the occurrence of an event by the magnitude of the consequences of the event. Most scientists and other technical experts concentrate on the probability of the occurrence of an accident. Most members of the lay public concentrate on the magnitude of the consequences of an accident. Studies of risk perception in the general public have discovered the following patterns:

People are more willing to accept familiar risks than unfamiliar ones.

People are more willing to accept voluntary risks than risks forced upon them.

Risks controlled by others are less acceptable than risks under one's own control.

Undetectable risks are less acceptable than detectable risks.

Risks perceived as unfair are less acceptable than risks perceived as fair.

Risks that do not permit individual protective action are less acceptable than risks that do.

Dramatic and memorable risks are less acceptable than uninteresting and forgettable ones.

People are more willing to accept certain risks than uncertain ones.

(Fischhoff et al., 1978; Slovic, et al., 1982; Sandman, 1985).

Elliott (1984) has proposed that project proponents work with these patterns of risk perception and try to negotiate a contract with a host community to site a facility. The contract would give the residents of the community an amount of control over the operation of the facility, thus making the risks posed by the facility more acceptable. Elliott argues that community residents and the facility operator need not agree on the precise likelihood of a risk in order to negotiate such a contract. They must, however, reach agreement on the characteristics of risk to be managed (e.g., risk of groundwater pollution from hazardous waste landfill leachate, risk of health effects from an incinerator). Under the contract, the operator of the facility agrees to install prevention, detection and mitigation systems.. Community residents are allowed to independently monitor these systems. If something goes wrong at the facility, the community has the power to move decisively against the hazard should the operator fail to do so. The contract should also include liability provisions and an agreed-upon structure for jointly solving problems and resolving disputes as conditions change. Because this arrangement gives the community control over the risk, people find it more attractive than offers of compensation or assurances of mitigation. (Mazmanian and Morell, 1988).

The Sludge Facility Siting Decision Problem

What strategy should Smith use to site the sludge treatment facility? Is her siting problem a technical one, to be solved by using the Decide--Announce--Defend and preemption strategies? Or is it a conflict resolution problem, resolved by negotiation with stakeholder groups, payment of compensation, and using an "open siting" process? Perhaps she has a risk management problem-- therefore she should concentrate on negotiating a shared-management contract with host communities. None of the siting theories deal with the intense political and deadline pressures Smith faces. Perhaps her strategy should be to choose the site where she believes opposition from politicians and neighbors would be the weakest--the politically easiest, most expedient site.

Smith would like to analyze the siting problem from four different perspectives. She decides to first assume that the problem is a technical one. Next, she will look at the sting decision from purely political considerations. Third, she will formulate the siting decision as a conflict resolution problem, and will try to find areas of agreement and disagreement among various stakeholder groups. Finally, she will look at the siting decision as one concerned solely with public health risk issues.

Smith decides to use formal analysis to look at the siting problem from these varying perspectives. It is clear that her decision problem is too complex to be solved using informal common sense. It would help to be able to break the problem into more manageable pieces. (Covello, 1987). She has a great deal of data and many issues to consider, and formal analysis will help her keep track of issues and information systematically. Information about the problem comes from many different sources--environmental consultant reports, agency financial analyses, public comments and statements, Smith's own political intuitions--and formal analysis provides a structure for integrating these varying types of information. (Keeney, 1980). She will eventually need a rationale and documentation to support her decision. Formal analysis could give her ideas on how to structure such documentation. (Keeney, 1980). Finally, using formal analysis will force her to so some hard thinking about the problem--to understand where value judgments are involved, where uncertainties occur, and what value tradeoffs are necessary to make a decision. (Keeney and Raiffa, 1972).

Because the sludge siting problem seems to involve many uncertainties (including uncertainty about what type of problem the decision is), Smith will use a specific type of formal analysis designed to explicitly treat uncertainty--decision analysis--as a tool to gain insight into her decision problem.

Decision analysis is a set of philosophies, axioms and methods to analyze decision problems. The axioms imply that the attractiveness of alternatives should depend on the likelihoods of the possible consequences of each alternative and the preferences of the decision makers for those consequences.[1]

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1. Keeney (1982) summarizes the axioms of decision analysis as follows:

> Axiom 1a (Generation of Alternatives). At least two alternatives can be specified.
>
> Axiom 1b (Identification of Consequences). Possible consequences of each alternative can be identified.

Decision analysis involves eight steps:

1. Identifying alternatives.

2. Defining objectives.

3. Defining ways to measure each alternative's performance on each objective.

4. Identifying uncertainties.

5. Assessing the probabilities that outcomes will occur.

6. Assessing preferences for outcomes and tradeoffs among objectives.

7. Integrating components of the analysis and evaluating alternatives

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Axiom 2 (Quantification of Judgment). The relative likelihoods (i.e., probabilities) of each possible consequence that could result from each alternative can be specified.

Axiom 3 (Quantification of Preference). The relative desirability (i.e., utility) for all the possible consequences of any alternative can be specified.

Axiom 4a (Comparison of Alternatives). If two alternatives would each result in the same two possible consequences, the alternative yielding the higher chance of the preferred consequence is preferred.

Axiom 4b (Transitivity of Preferences). If one alternative is preferred to a second alternative and if the second alternative is preferred to a third alternative, then the first alternative is preferred to the third alternative.

Axiom 4c (Substitution of Consequences). If an alternative is modified by replacing one of its consequences with a set of consequences and associated probabilities (i.e., a lottery) that is indifferent to the consequence being replaced, then the original and the modified alternatives should be indifferent.

8. Conducting sensitivity and value-of-information analyses. What if probability judgments were changed? What if preferences were different? What if different tradeoffs among objectives were made? Would obtaining further information about uncertainties change the results?

(Covello, 1987).

Smith believes that decision analysis is the best formal tool to apply to the sludge facility siting problem. She realizes that the problem involves many subjective judgments. Decision analysis incorporates subjective judgments into its methodology. (Keeney and Raiffa, 1972). Decision analysis explicitly deals with uncertainty and with conflicting objectives--both of which are abundant in the siting decision. Smith also likes the fact that decision analysis measures preferences in the commensurable units of "utiles"--she is uncomfortable with having to reduce intangible values into monetary terms, which she would have to do if she chose cost-benefit analysis as her tool. (Covello, 1987). Finally, decision analysis will allow her to perform value-of-information analyses. The results of these analyses will help her decide where to expend her limited budget of time and money to seek more information to resolve the uncertainties in the problem.

Smith decides to use decision analysis techniques to model the sludge facility siting problem four different ways--as a technical problem, a political expediency problem, a negotiation problem, and a risk management problem. She does not intend to rely on these models to provide a solution to the siting decision; instead, she will try to see what insights about the nature of the problem she can gain by using decision analysis to look at the problem through four different lenses. Where do uncertainties exist in the decision? How much more information does she need to inform her decision? What are the implications of the tradeoffs she must make? Are there any sites she can confidently eliminate from further study? Is the choice of preferred site clear? Which problem formulation is she most comfortable with?

The following four chapters describe the models Smith builds. The seven sites she considers are:

DEER ISLAND: a 200 acre peninsula off the town of Winthrop. Legally part of the city of Boston, Deer Island is owned by the MWRA. The MWRA's primary sewage treatment plant is located here, and the secondary treatment plant will also be built on this site. The site also contains a prison, and is near Logan International Airport. The closest residential community is Point Shirley, part of Winthrop, directly north of the site.

LYNN: a 48 acre industrial site on Lynn Harbor. Located next to a dairy plant, the city of Lynn's sewage treatment plant, and its sludge/ash landfill. The site contains a closed landfill. Lynn is not a member of the MWRA's sewage and water service district.

QUINCY: 150 acres on the Weymouth Fore River. Previously owned by General Dynamics, was a major shipyard. Now owned by the MWRA, which will use part of the site for interim sludge treatment projects and as a staging area for construction of the secondary treatment plant on Deer Island. The site is contaminated with hazardous waste. The Massachusetts Shipbuilders Corporation proposes to lease 50 acres to operate an active shipyard. Well-established marine and rail transport facilities exist on the site. Several major industrial projects are proposed for areas nearby, particularly a hazardous waste incinerator directly south of the site in Braintree and an electrical power plant across the river.

SPECTACLE ISLAND: A 97 acre island in Boston Harbor. 35 of its acres have been added through the dumping of trash by the city of Boston. Owned by the City and the Commonwealth of Massachusetts. Has at different times been used as the site of a quarantine hospital, resort hotels, a grease extraction plant, and a repository for salvage firms. The site is covered with trash, and has been proposed as the disposal site for fill from Boston's Central Artery reconstruction project. This fill could stabilize the island, which has also been proposed to be developed into a state park.

STOUGHTON: 90 acres of industrially zoned land covered by gravel and asphalt operations and forest. The site abuts an industrial park and small industries. The area used to be a rural, low density residential community until Route 24 was built. It is now an industrial park district containing scattered residences.

WALPOLE: 74 acres of mostly forested land zoned for limited manufacturing. The site was formerly the Bird family estate. It is adjacent to single family residences and an abandoned industrial facility, and is located near the Neponset River.

WILMINGTON: 50 acres, 90 percent of which are zoned residential. The eastern portion of the site is being developed as a 43 unit subdivision. Abutters include an industrial park, an office park, light industrial and commercial uses, and residences.

The consultants hired by the MWRA have produced thick, heavy reports containing environmental and engineering information about each site. Since Smith is trying to gain some understanding about the nature of her problem and to decide what further information is necessary to make a decision, she decides to use only the information in the reports and her current knowledge about the sites in her models. The consultants' reports contain the following information:

The availability of potable water, sewer, electricity, and natural gas utilities on the site.

A description of access route characteristics.

A list of regional burdens already hosted by each community.

A list of federal and state environmental permits required to construct the facility.

An evaluation of whether construction at a site would require unique or scarce labor or material resources.

A description of other public and private uses proposed for each site.

Information about the cost of building each type of facility (not site-specific).

A description of the geology at each site.

The location of surface water bodies on or near the site, and the water quality of these bodies.

A characterization of ground water on and near the site, including the type of aquifer, depth to ground water, and water quality classification.

The location of existing public water supplies on or near the site.

The presence of threatened, endangered or special concern plants and wildlife on or near the site.

A general characterization of the plants and wildlife on each site.

The location and type of wetlands on each site.

A description of any fisheries resources located on or near the site.

Details on climatology and meteorology of the eastern Massachusetts area.

Air quality at the site.

Noise levels on and near the site.

The distance from the site to sensitive noise and odor receptors.

The presence of air emissions interaction sources within 3 kilometers of the site.

A classification of the site as being of low, moderate or high archaeological sensitivity.

The presence of historical resources on or near the site.

Land uses on the site and within one mile.

Land uses on proposed transportation routes.

Preliminary dry deposition rate maps for airborne particulates.

(MWRA, 1988a, b, c).

THE TECHNICAL MODEL

For her first cut at the siting problem, Smith decides to frame the problem as a technical one--where is the best site, technically, for a sludge treatment facility? What are the geological, physical and institutional needs of the facility? What laws and regulations must be satisfied to obtain permits to build the facility? What costs--construction and operating--are involved in building and running the facility?

The technical decision is complicated by the fact that Smith is not sure what type of processing technology the MWRA will actually end up using--composting or incineration. While the agency prefers to use composting, it may not be able to market its composted sludge unless it is able to reduce the amount of heavy metals in the sludge. To do so would involve an expensive and aggressive pretreatment permit enforcement program. Smith is unsure whether the agency has the resources to implement such a program, and whether the program would succeed in removing adequate amounts of metals from the sludge even if enforcement resources did exist. The uncertainties surrounding the technology choice are further complicated by the fact that the United States Environmental Protection Agency (EPA) has proposed stringent rules to control the land application and marketing of sludge. (U.S. EPA, 1989). Smith is unsure whether the agency's sludge will even be able to meet the standards for compost marketing. She decides to treat the technology choice not as a choice at all, but as an uncertainty over which she has no control.

Smith summarizes the decision before her in a decision tree (Figure 2-1). The seven sites--her decision alternatives--emanate from a decision node, labeled "D" in the figure. The uncertainties in the decision--what the technology will be--are located on the chance branches, off the node labeled "C". Smith judges that there is a 50 percent probability that the agency will be able to compost its sludge.

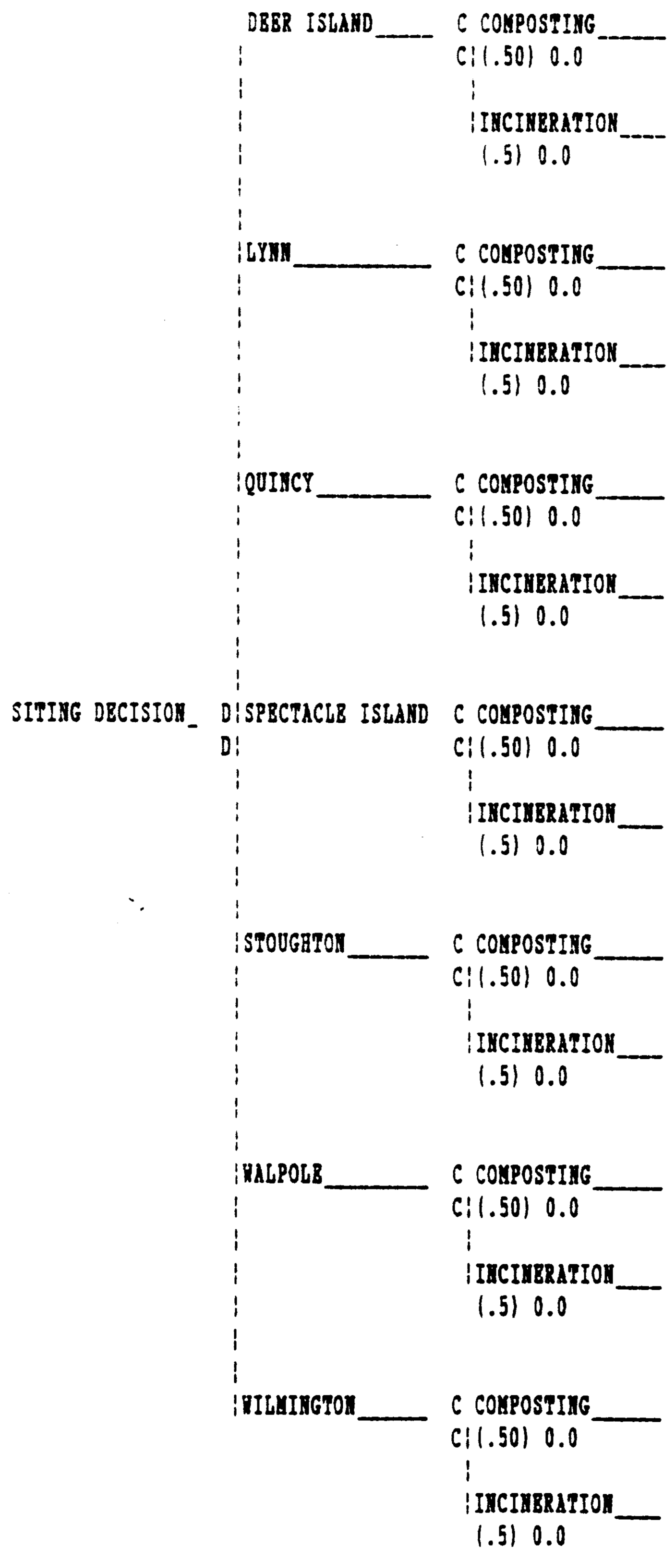
Smith realizes that many different criteria will go into her modeling of the problem, so she decides to use a multiattribute model to find utility rankings for each site under each possible technology. She will feed these results into the decision tree to find the expected utility of each site given the technology uncertainties.

Structuring Objectives for the Decision

First, Smith tries to structure her objectives for the siting decision. Objectives can be broad (e.g., protect the environment) or narrow (e.g., minimize damage to endangered species habitats). Most objectives have two components--a general concern (e.g., protect wetlands) and an orientation for preferences (e.g., minimize adverse effects on wildlife or maximize ease of implementation). (Keeney, 1980). The collection of broad and narrow objectives forms an "objectives hierarchy". The objectives hierarchy for any decision is not unique--there is no "correct" objectives hierarchy. It is based on the judgments of the decision maker as to what is and is not important. (Keeney, 1980).

Objectives can be identified in several ways. The decision maker can perform a literature search. What objectives have other siting studies used? What are the regulatory requirements a facility operator must satisfy

FIGURE 2-1
DECISION TREE STRUCTURE FOR THE TECHNICAL MODEL



to obtain construction and operating permits? (Keeney, 1980). The decision maker can also identify objectives by specifying a broad objective and then breaking it down into narrower objectives. (Keeney and Raiffa, 1976). For example, a decision maker might identify "protect the environment" as a broad objective, and break it down into several narrower objectives, such as "minimize damage to wetlands", "minimize air pollution", "minimize impact on ground water", etc. Finally, a decision maker can identify objectives by using "casual empiricism"--by observing how people who are involved in the problem are thinking about it. (Keeney and Raiffa, 1976). For example, engineers involved in the sludge facility siting decision may be analyzing the soil quality at each site, and the agency's financial analysts may be thinking about the problem in terms of construction and operating costs.

Smith uses these techniques to identify twelve objectives:

1. Choose the most reliable site--the site where the facility can best operate consistently and effectively throughout the life of the project. What amount of "down time" will the facility have? What backup processing will be required? How accessible is the site to the trucks and barges that will be delivering the sludge from the sewage treatment plant?

2. Choose the most flexible site--the site that can accommodate either processing technology, and can accommodate fluctuating quantities of sludge.

3. Choose the site where construction will be easiest--where extensive blasting or reconfiguration of the site is not necessary, and where new roads or piers would not have to be built.

4. Choose the site where the utilities needed by the facility--potable water, sewers, electricity and natural gas--are already connected to the site.

5. Choose the site that will require the smallest staff when the facility is operational.

6. Choose the site that poses the least amount of danger to workers and people living along the transportation routes.

7. Choose the site that best complies with state and federal environmental permit requirements, so that the agency can obtain these permits easily and quickly.

8. Choose the site that has no demand for unique or scarce construction resources, such as specialized labor or scarce materials.

9. Choose a site that has no competing public use.

10. Choose a site where the project can be implemented in a timely manner--where delays will not cause the MWRA to violate the court-ordered construction schedule.

11. Choose the site with the lowest construction costs.

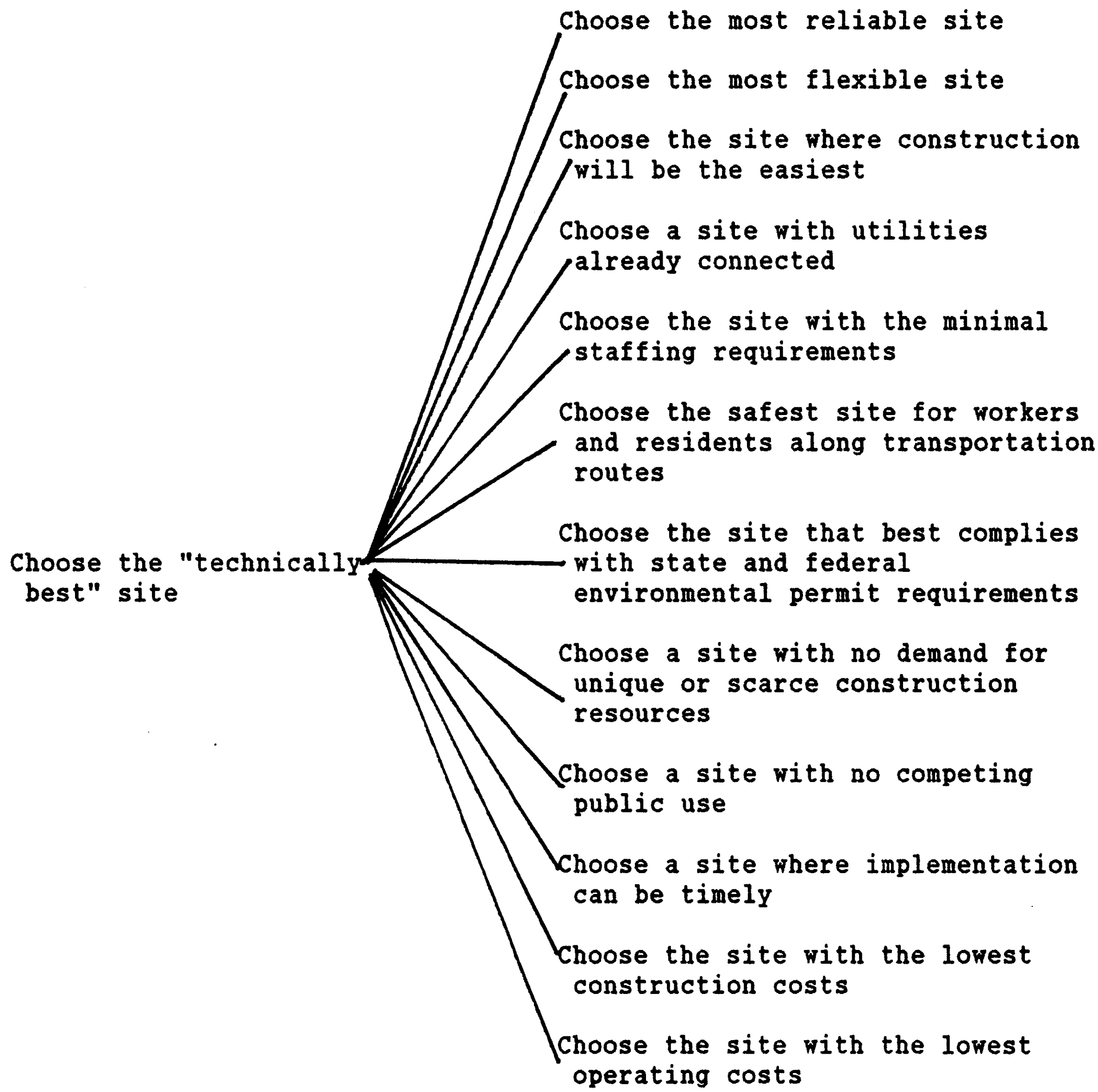
12. Choose the site with the lowest operating costs.

Smith groups these objectives into the hierarchy shown in Figure 2-2.

Next, Smith asks herself if all of these objectives are really important. In order for objectives to be included in a logical, simple, yet comprehensive objectives hierarchy, there must be a difference in the degree to which the objective might be achieved by at least two candidate sites. In other words, the objectives must measure qualities that are site-specific. The difference between sites on an objective must be significant relative to the other differences between the sites, and the likelihood of the difference must be large enough to justify inclusion. (Keeney, 1980).

Smith determines that three of the objectives in her hierarchy--flexibility, staffing needs, and operating costs--are not site-specific. All seven sites will be able to accommodate either technology, and will be able to process fluctuating amounts of sludge. Facilities at all sites will need the same number of staff and have the same operating costs. She also determines that two of the elements of the reliability objective are not site-specific. The amount of down time a facility will have and the need for

FIGURE 2-2
FIRST VERSION OF THE OBJECTIVES HIERARCHY FOR THE TECHNICAL MODEL

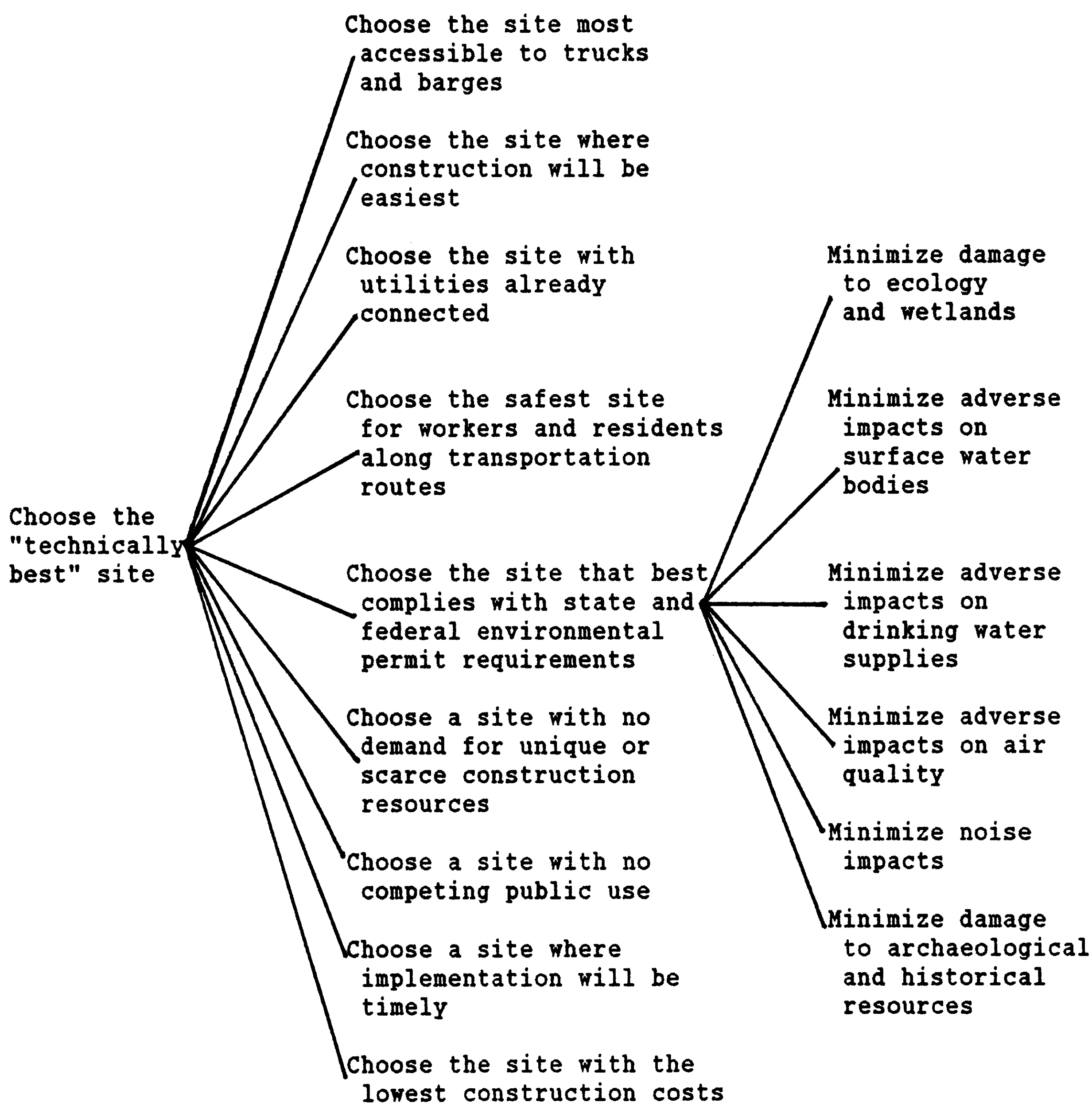


backup processing depend on the type of facility, not on the facility site. However, the third component of reliability--the accessibility of the site to trucks and barges--is site-specific, so Smith decides to include the objective "choose the site most accessible to trucks and barges" in the objectives hierarchy.

At this stage, Smith checks to see if any of the broad objectives in her hierarchy can be broken down into narrower objectives. One objective--"choose the site that best complies with state and federal environmental permit requirements" seems especially broad. What permits must the agency obtain? What environmental safeguards must the agency implement before it can obtain these permits? Smith determines that the sludge treatment facility will need permits relating to air quality, surface water, drinking water, and alteration of wetlands. In addition, environmental permitting authorities are concerned with potential damage to threatened and endangered species, destruction of habitats, noise impacts, and the impacts of a facility on archaeological and historical resources. Smith adds these considerations to the second version of the objectives hierarchy, which is shown in Figure 2-3.

Smith is still not satisfied with her objectives hierarchy, however. Many of the objectives seem to be interrelated and redundant. She reexamines the objectives to see if any can be combined. She believes that transportation reliability and safety are related--after all, the agency's real concern with reliability of access is safety. She combines these two objectives into one. Several objectives seem related to construction costs--building a facility on a particular site will cost more if construction conditions are not the best, or if utilities must be connected to the site.

FIGURE 2-3
SECOND VERSION OF THE OBJECTIVES HIERARCHY FOR THE TECHNICAL MODEL



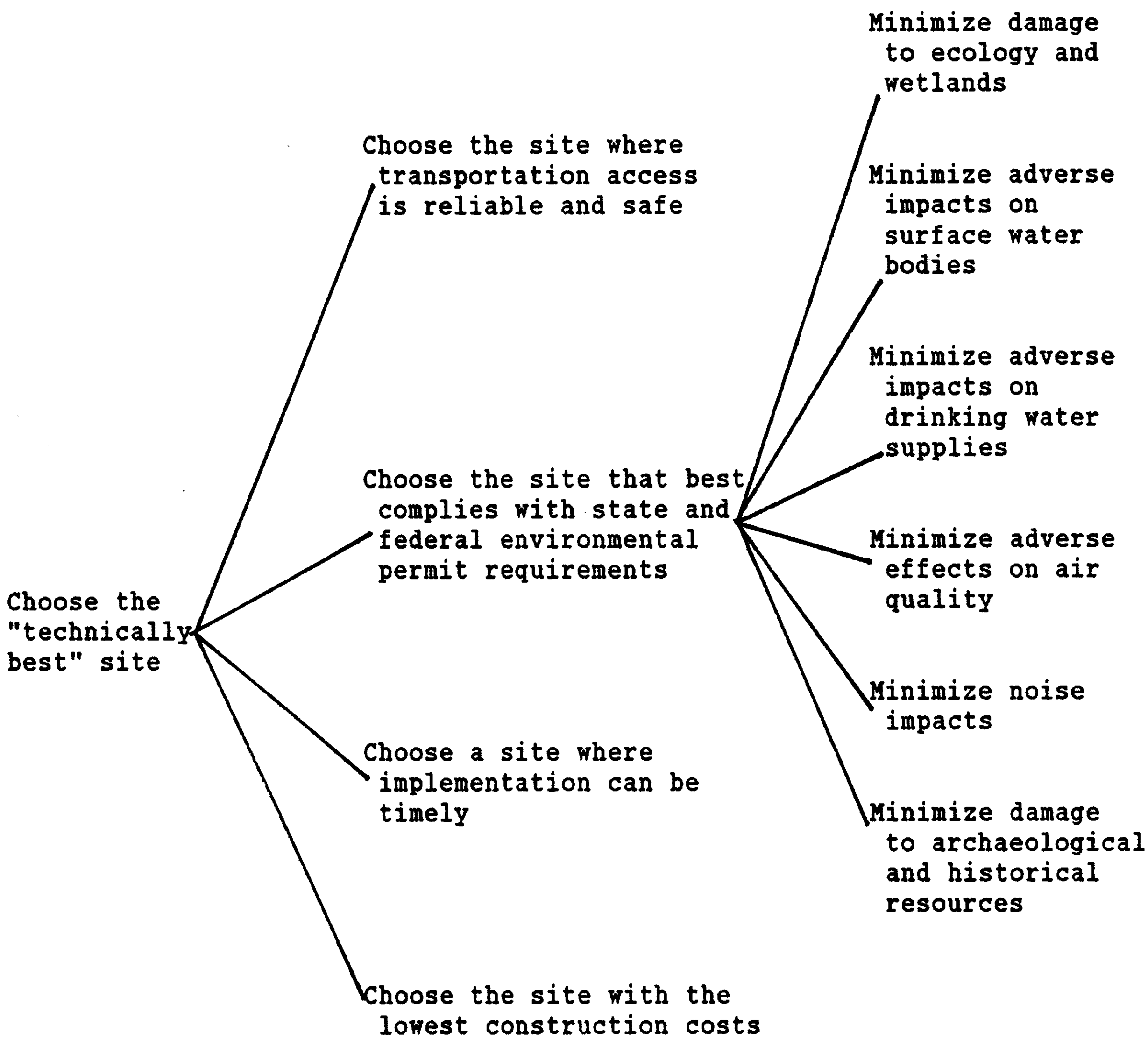
Similarly, a site's demand for unique and scarce resources affects costs. Smith assumes that the agency will pay whatever it has to for these resources. She combines these three objectives into the construction cost objective. Finally, the MWRA's concern with competing public uses for sites seems related to the timely implementation objective. If another agency wants to use a site, the MWRA will have to negotiate with that agency or engage in political battles to obtain the site. This could delay timely implementation of the project. Smith combines the competing public use objective with timely implementation. She is left with four broad objectives for her final objectives hierarchy, shown in Figure 2-4.

Defining Attributes and Performance Measures

Next, Smith must define attributes--measures of effectiveness--for each objective. There are two types of attributes, direct and proxy. Direct attributes measure the degree to which an objective is achieved. (Keeney, 1980). Proxy attributes are indirect measures of an objective that cannot be measured directly. They reflect the degree to which the unmeasurable objective is met (Keeney and Raiffa, 1976). For example, an objective in a facility siting analysis might be "avoid damage to public health". "Public health" is not a quality that can be measured directly. Components of it, however, can be studied--the number of cancer deaths per year, the number of new lung disease cases, the number of work days missed due to illness, etc. These measures are proxy attributes for public health.

Attributes, whether direct or proxy, must be both comprehensive and measurable. An attribute is comprehensive if by knowing its level in a particular situation, the decision maker has a clear understanding of the extent to which the attribute's associated objective is achieved. An

FIGURE 2-4
FINAL OBJECTIVES HIERARCHY FOR THE TECHNICAL MODEL



attribute is measurable if the decision maker can make probability and preference judgments about it. (Keeney and Raiffa, 1976).

A site's performance on attributes can be measured using natural or constructed scales. A natural scale is one which measures performance on an attribute according to widely accepted measurement scales. For example, construction costs are often measure in dollars, and the distance from a facility to sensitive noise receptor groups is measured in feet or miles. A constructed scale is built specifically for the decision problem being addressed. (Keeney, 1980). It is used when no simple natural scale exists, often because the attribute to be measured consists of several components or is difficult to measure. An example of such an attribute is "aesthetic impacts". No commonly accepted scales for measuring aesthetics exist, and any that did would involve many value judgments. If a decision maker uses constructed scales, he or she must define and explain the points on the scale very carefully and thoroughly. (Keeney, 1980).

Smith now begins to define attributes and measurement scales for her objectives. Her first objective is to choose the site where transportation access is reliable and safe. She believes that there are two considerations that go into measuring achievement of this objective--the nature of the access roads at the site (whether they pass through residential areas, or are commercial/industrial strips), and whether there are road geometry or other physical problems on the access route that could increase the likelihood of accidents. She decides to combine these two components into a proxy attribute for reliable, safe access--"ease of access". She builds a constructed scale that combines the two components. The constructed scale for this attribute is found in Table 2-1. [2]

Smith's second objective is to choose a site that best complies with state and federal environmental permit standards. She has already broken this objective into six attributes--ecology and wetlands, surface water bodies, ground water drinking water supplies, air quality, noise, and archaeological resources. From the environmental reports before her, she determines that there are four areas of concern about ecology and wetlands: alteration of wetlands; damage to species of plants or wildlife that are protected by state or federal statute; loss of habitats for any species--plant or wildlife--that live on the site; and possible damage to aquatic ecology off the site due to runoff from a compost pile or the deposition of airborne contaminants from an incinerator.

Designing a constructed scale to measure impacts on ecology and wetlands involves many value judgments. Smith has four types of impacts to consider. Are they all of equal value? Is the minor alteration of wetlands the same as no damage to endangered species, or no loss of habitat, or no damage to off-site aquatic ecology? She balances the four types of impacts until a scale that seems logical and fair to her is constructed. The scale is displayed in Table 2-2.

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2. All of the constructed scales measure impacts along a continuum. Therefore, if a site's impacts are rated level 1, the fall between levels 0 and 1, if they are rated level 2, they fall between levels 1 and 2, and so on. Where several criteria make up an impact level definition, an impact is judged to be at a specific impact level if it satisfies one or more of these criteria.

TABLE 2-1
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_1: TRANSPORTATION ACCESS

Impact Level	Impacts in the Affected Area
0	No roads used to reach site
1	Access roads lined with commercial or industrial uses; no road geometry or other physical problems exist
2	Access roads lined with residential uses; no road geometry or other physical problems exist
3	Access roads lined with residential uses; road geometry or other physical problems exist

TABLE 2-2
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_2: ECOLOGICAL IMPACTS

Impact Level	Impacts in the Affected Area
0	No or minor alteration of wetlands; no damage to species of plants or wildlife that are of special concern[1], threatened[2] or endangered[2]; no loss of habitat to any on-site species, or habitat loss that is easily replaceable off-site[3]; no damage to off-site aquatic ecology due to runoff or airborne contaminants
1	Moderate alteration of wetlands; damage to species of plants or wildlife that are of special concern; habitat loss that is moderately replaceable off-site; impacts on off-site aquatic ecology of local importance due to runoff or airborne contaminants
2	Heavy alteration of wetlands; damage to species of plants or wildlife that are threatened or endangered; habitat loss that has limited replaceability off-site; impacts on off-site aquatic ecology of regional importance due to runoff or airborne contaminants

[1] As listed by the Massachusetts Division of Fisheries and Wildlife
[2] As listed by the United States Fish and Wildlife Service
[3] This criterion does not mean that the agency should rebuild habitats off-site; rather, it refers to the ease with which migrating species can find replacement habitats off-site

A sludge facility can have adverse impacts on surface water bodies on or off the site, through stormwater runoff pollution from a compost pile or the deposition of airborne contaminants from an incinerator. Because the impacts are different for the composting and incineration technologies, Smith develops two constructed scales to measure performance of the surface water attribute. These simple scales, shown in Tables 2-3 and 2-4, measure whether the potential for runoff or airborne contaminants to pollute surface water bodies is low, moderate, or high.

Smith also needs separate scales for each technology to measure a facility's impacts on ground water that is used or may be used for drinking water. As with the surface water attribute, the danger from a compost pile is that rain water might cause pollutants to run off the pile into ground water. Airborne contaminants from incinerators may land on areas of ground water that recharge important aquifers. The potential for pollution is measured as either non-existent (no drinking water supplies nearby), low, moderate, or high. The scales are found in Tables 2-5 and 2-6.

Air quality impacts are also technology-dependent. A composting facility's major impact on air quality is the odors it produces as the sludge decomposes. Odors are annoying only if people live nearby to smell them, so Smith wants to determine whether odors from the facility will reach "sensitive receptors"--residences or institutions where people congregate. She has her environmental engineers' predictions about how far odors will travel from a facility on each site, and her land use planner's data about how close any sensitive receptors are to each site. Using this information, she can determine whether odors will impact people living near the site. She does not need a constructed scale for this attribute; her impact assessment

TABLE 2-3
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_3: COMPOSTING FACILITY IMPACTS ON SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for surface water contamination due to stormwater runoff
1	Moderate potential for surface water contamination due to stormwater runoff
2	High potential for surface water contamination due to stormwater runoff

TABLE 2-4
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_3: INCINERATION FACILITY IMPACTS ON SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for surface water contamination due to deposition of airborne contaminants
1	Moderate potential for surface water contamination due to deposition of airborne contaminants
2	High potential for surface water contamination due to deposition of airborne contaminants

TABLE 2-5

CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_4: COMPOSTING FACILITY IMPACTS ON DRINKING WATER SUPPLY

Impact Level	Impacts in Affected Area
0	No potential for water supply contamination due to facility runoff
1	Low potential for water supply contamination due to facility runoff
2	Moderate potential for water supply contamination due to facility runoff
3	High potential for water supply contamination due to facility runoff

TABLE 2-6

CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_4: INCINERATOR FACILITY IMPACTS ON DRINKING WATER SUPPLY

Impact Level	Impacts in Affected Area
0	No potential for deposition of airborne contaminants on aquifer recharge areas
1	Low potential for deposition of airborne contaminants on aquifer recharge areas
2	Moderate potential for deposition of airborne contaminants on aquifer recharge areas
3	High potential for deposition of airborne contaminants on aquifer recharge areas

for each site will be a simple "yes" or "no" answer to the question: " Will odors reach sensitive receptors?" [3]

The threat to air quality from an incinerator is the possibility that its emissions may interact with emissions from other sources and produce air pollution levels above those allowed by the federal Clean Air Act. Smith has information about possible sources of emissions within three kilometers of each site. She can use this information to answer the question: " Are there any interaction sources near the site?"

The next environmental attribute, noise, is measured like odors, by its impact on sensitive receptors nearby. This time, Smith does not have any engineer's predictions about how far noise from the facility will travel. She has a lot of measurements of current noise levels at each site, but she decides that this information is not useful for measuring potential impacts. She must be satisfied with measuring noise impacts with the proxy attribute "distance to sensitive receptors". While this attribute will not measure noise impacts precisely (individuals tolerate noise differently; facility noise may impact residential areas more than commercial or industrial ones), it will give Smith a general idea about what the noise impacts will be. If noise impacts turn out to be important to her decision, she can order further studies to predict the level of noise the facility will produce and its more precise impacts.

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3. Smith is not totally satisfied with this measure of odor impacts. The consultants' reports are unclear as to how the distance odors will travel was calculated. Smith would like to obtain information on wind-scaled distances and judgments about the number of times odors will reach sensitive receptors--e.g., every day, once a month--in order to measure odor impacts accurately.

The final environmental attribute measures a facility's impacts on archaeological and historic sites. Smith does not have a lot of information about the presence of archaeological and historic resources on the sites. Such information can be obtained only by expensive, time-consuming field studies. She does, however, have a judgment from the state's historical commission staff members that a site is located in an area of low, moderate, or high archaeological sensitivity. For example, if archaeological artifacts have been discovered on or near the site, or the site is located in a broader area where many artifacts have been found, the site is rated as highly sensitive. Smith also has information about any historic houses, buildings or ruins located on each site. She builds a simple constructed scale (Table 2-7) combining each site's archaeological and historic sensitivity into a ranking of low, moderate or high cultural sensitivity.

Next, Smith considers her third major objective, to choose a site where implementation can be timely. She sees two possible technically-related threats to timely implementation. First, many sites contain hazardous waste, which must be cleaned up before federal and state agencies will issue construction permits for the sludge facility. Second, if another agency wants to use a site for a competing public purpose, the MWRA may have to negotiate with the agency or even battle over the site, which could cause delay. Smith designs a constructed scale that rates anticipated delays as non-existent, minor, moderate, or major. (Table 2-8).

Finally, Smith determines how to measure each site's achievement of her fourth major objective, low construction costs. Typically, a decision maker would measure construction costs using a natural scale--dollars. He or she could choose a base cost, and rank the sites according to how much

TABLE 2-7
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_7: CULTURAL IMPACTS

Impact Level	Cultural Sensitivity
0	Low archaeological and historic sensitivity
1	Moderate archaeological and historic sensitivity
2	High archaeological and historic sensitivity

TABLE 2-8
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_8: TIMELY IMPLEMENTATION

Impact Level	Delays Anticipated
0	No delays anticipated
1	Minor delays anticipated
2	Moderate delays anticipated
3	Major delays anticipated

they exceed the base. Unfortunately, Smith does not have any site-specific information about construction costs. She has data about how much it costs to build each component of each technology, but not how much it would cost to build each component of each technology on each site. Instead, she has some basic information about various characteristics of each site that could contribute to excessive construction costs. First, she has data characterizing the geology of each site. She therefore knows whether the construction crews will have to blast bedrock or remove ground water before beginning construction. Either of these tasks would be expensive. Second, she knows that some sites contain contaminated soils and water, which must be cleaned up before construction can begin. A cleanup project could be moderate or extensive, and would be priced accordingly. Third, she has her transportation engineers' predictions of whether improvements would have to be made on access routes--bridges raised, roads widened or constructed, slopes leveled. Fourth, she knows whether or not the MWRA will have to pay to bring sewer, water, electric and natural gas lines to the site. Finally, she has information about whether construction of a facility at a specific site will require scarce or unique resources, such as special blasting tools, expensive clay to cap landfills, or skilled workers to clean up contaminated soils.

Smith uses the information she has to construct a scale to give her an idea about which sites might be more expensive to build on than others. To simplify her scale, she assumes that each condition at a site causing extra costs will cost the same. For example, cleaning up moderately contaminated soils on a site will cost the same as making transportation improvements on another site. She then lists the conditions that could make costs rise (see Table 2-9). Her scale consists of a numerical score relating

TABLE 2-9
SPECIAL CONDITIONS AT A SITE THAT COULD RAISE CONSTRUCTION COSTS

Need for blasting
Moderate soil cleanup
Extensive soil cleanup
Moderate water cleanup
Extensive water cleanup
Need for dewatering
Need for transportation improvements
Demand for unique or scarce resources
Need to install site utilities

to how many conditions result in extra costs exist on each site. If a site requires extensive cleanup of contaminated soils or water, that site is judged to have two extra cost conditions (moderate cleanup plus the extra work that is required for extensive cleanup). Thus, a site could have between 0 and 9 conditions that would increase construction costs.

Smith has now finished defining attributes and performance scales for each objective on her hierarchy. She summarizes her work in a table (Table 2-10), and then turns her attention to determining how each site performs on each attribute scale.

Assessing Impacts and Probabilities

Smith now uses the consultants' and staff reports to make judgments about how each site should be rated on each attribute scale. First, she looks at the data about transportation access. She determines that the Deer Island and Spectacle Island sites will fall under impact level 0, because they are both islands, and will be accessed by barge, not truck. The Stoughton site is rated under level 1, because it has no geometry or physical problems and the access road is a retail--commercial highway. The Quincy site is rated 2, because although there are no geometry problems, the access roads go through residential areas. Both the Lynn and Walpole sites are rated at the worst level, level 3, because their access roads go through residential areas and are deemed to be less safe because of geometry of physical problems. Smith decides that there are no uncertainties surrounding these ratings. There is slight uncertainty surrounding the rating of the Wilmington site, however. There are two possible access routes to this site, one a commercial strip and the other a residential road. The town of Wilmington may widen and repair the commercial strip, requiring the sludge trucks to use

TABLE 2-10
ATTRIBUTES AND PERFORMANCE MEASURES FOR THE SITING DECISION

Objective	Performance Measure
<u>Technical</u>	
1. Maximize ease of transportation access	X_1: Constructed scale
<u>Environmental</u>	
2. Minimize adverse ecological impacts	X_2: Constructed scale
3. Minimize adverse impacts on surface water bodies	X_3: Constructed scale
4. Minimize adverse impacts on drinking water supplies	X_4: Constructed scale
5. Minimize adverse air quality impacts	X_5: Presence of interaction sources (incineration) Will odors reach sensitive receptors (composting)
6. Minimize noise impacts	X_6: Distance to sensitive receptors (in feet)
7. Minimize adverse archaeological, historical or cultural impacts	X_7: Constructed scale
<u>Institutional</u>	
8. Minimize delay of implementation	X_8: Constructed scale
<u>Economic</u>	
9. Minimize construction costs	X_9: Constructed scale

the residential road for some time. But Smith is not sure whether the town will perform these repairs, when it will perform them, or how long the road construction will last. She deals with these uncertainties by assessing probabilities for each consequence--judgments about the possibility that each road will have to be used. She believes that it is more probable than not that the town will repair the commercial strip, but she cannot be certain that the probability of repair is very high. Budget constraints or new priorities in the town might prevent the town from repairing the road. She finally settles on a judgment that the probability that the town will not repair the road, and that the MWRA can use the commercial strip as an access road (impact level 1), will be 60 percent. The probability that the sludge trucks will have to use residential roads (impact level 2) is judged to be 40 percent.

Smith believes that the ecological impacts of building a sludge treatment facility on each site are extremely uncertain. Site configuration plans have not been finalized, so Smith is not certain whether construction of the facility will alter wetlands. Some uncertainty surrounds the assessment of whether statutorily protected species live on sites--biologists have observed some such species on several sites in the past, but when they returned for a more formal study, could not find evidence of habitats. It is also not clear whether wildlife that currently lives on the sites will be able to relocate and find new habitats off-site. Finally, Smith is not sure how adequately the agency can prevent facility runoff or airborne contaminants from damaging nearby aquatic ecology. She therefore must make probability judgments about whether the impacts will fall under the different levels on the constructed scale.

At the Deer Island site, Smith assigns a 70 percent probability that the impacts will be severe, level 2. The site receives such a low rating because she does not believe that wildlife living on the site will be easily able to migrate off the site and find new habitats. She assigns a probability of 30 percent that the impacts will fall under level 1. The impacts on the Lynn site are judged to be less severe--here, the only problem is that some wetland areas may have to be altered during construction. Smith assigns a 50 percent probability that the wetlands will not have to be altered, making the impacts fall into level 0, and a 50 percent probability that they will have to altered, bringing the impacts down to level 1.

While looking at reports on the Quincy site, Smith notes that although there are no threatened or endangered species on site, harbor seals have been spotted in the river next to the site. She also notes that any runoff from the facility would affect the Fore River salt marsh, an area of regional ecological importance. She does not believe that the probability of the facility damaging the seals or the salt marsh is particularly high, however, so she assigns an 80 percent probability that the impact level will be 0, a 10 percent probability that it will be 1 and a 10 percent probability that it will be at the worst level, level 2.

Ecological impacts on Spectacle Island have the potential of being the most severe among the sites. Because the site is on an island, any small mammals living on the site will not be able to relocate, and will be destroyed by construction. In addition, runoff from the site would flow into the Boston Harbor. The area around the island is a fertile lobster trapping ground. Smith judges that the probability that the impact level will be 1 is 20 percent, and that the impacts will be more severe, level 2, at 80 percent.

At the Stoughton site, the only ecological problem is the possible destruction of a large wetland area. She judges that the probability that the wetlands will be altered, making an impact level of 2, is 50 percent. There is a 50 percent probability that the impact level at the Stoughton site will be 1. Ecological impacts at the Walpole site involve habitats that are only moderately replaceable, and a chance that runoff will contaminate the Neponset River, a regional resource. Smith assigns a 20 percent probability that the impact level will be 0, a 70 percent probability that it will be 1, and a 20 percent probability that it will be 2. At the Wilmington site, habitats will be difficult to replace. She judges that the probability that the impact level will be 1 is only 30 percent, but that it will be more severe, level 2, is 70 percent.

Smith now turns to the third attribute, surface water impacts. The constructed scale for this attribute measures a facility's potential impacts on nearby surface water bodies such as rivers, streams and lakes. The scale rates the potential for impacts as low (level 0), moderate (level 1) and high (level 2). The MWRA's environmental consultants have provided Smith with their judgments about what the potential for surface water impacts will be from each type of facility at each site. Smith uses these expert judgments to rank each site according to the constructed scale. At the Deer Island site, runoff from a compost pile or airborne contaminants from an incinerator could pollute an important surface water body, the Boston Harbor. The environmental experts have judged the potential for such contamination to be high. [4] Smith assigns a 90 percent probability that the impacts will be

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4. As with odor impacts, Smith's information from her experts about surface water impacts is incomplete. She has the experts' judgments that potential for surface water contamination will be low, moderate or high,

level 2, and a 10 percent probability that impacts will be less severe, at level 1.

The Lynn site borders on Lynn Harbor. However, the experts have determined that the potential for a facility to contaminate Lynn Harbor is low to moderate. Smith thus assigns a 50 percent probability that the impacts will be low (level 0) and a 50 percent probability that they will be moderate (level 1). The Quincy site borders the tidal section of the Weymouth Fore River, and there are some minor ponds and creeks within one mile of the site, but again the experts expect only low to moderate potential of surface water pollution. Smith uses the same probability assessments as for the Lynn site, 50 percent.

Runoff from a compost pile or airborne contaminants from an incinerator on Spectacle Island could pollute Boston Harbor. The experts have informed Smith that the potential for such contamination is high. She therefore assigns a probability of 90 percent that impacts will fall under level 2, and only a 10 percent probability that they will be moderate, at level 1. The Stoughton site is located near a large brook that drains into a regionally important reservoir. Several ponds and streams are located within one mile of the site. The experts believe that the potential for pollution of these water bodies is moderate to high. Smith judges that the probability that the impacts will be at level 1 is 50 percent, and that they will be at level 2, 50 percent. Experts predict low to moderate impacts at the Walpole site, so Smith assigns a probability of 50 percent that the impact level will be 0 and a 50 percent probability that it will be 1. Finally, the experts

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but she has no information about what factors entered into these judgments.

have judged that impacts at the Wilmington site, which is located near several ponds and streams, will be moderate. Smith decides that the probability that impacts will be at level 1 is 80 percent. She is not certain about which direction the uncertainties will go, however--whether the impacts could be low or high--so she creates a "buffer" of 10 percent at level 0 and at level 2 to treat this uncertainty.

Smith uses her experts' judgments to assess probabilities for the uncertainties surrounding the next attribute, drinking water impacts. Once again, the experts have rated the potential that a sludge treatment facility could pollute ground water drinking water supplies as non-existent, low, moderate or high. Smith decides to assess different probabilities for the composting and incineration facilities on this attribute. The measure for incinerator impacts is whether airborne contaminants will land on aquifer recharge areas, while the measure for composting is whether runoff will contaminate ground water. Since airborne contaminants obviously travel farther than runoff, Smith believes that the potential for contamination from an incinerator will be slightly greater than that from a compost pile. She decides to adjust her probability judgments accordingly.

The experts have judged that there is no potential for contamination at the Deer Island, Quincy, and Spectacle Island sites. No public water supplies exist within one mile of each of these sites. Development of future water supplies at or near these sites is infeasible. They are all located near low yield aquifers, and since they are all coastal or island sites, salt water intrusion would ruin any ground water's drinking potential. However, Smith is not certain about these predictions--techniques could be developed to prevent salt water intrusion if new water supplies were desperately needed. She therefore assigns a probability of 90 percent that the impact level of a compost pile at these sites will be 0, and protects herself by judging that there is a 10 percent chance that the impacts could be somewhat adverse, at level 1. She judges that the probability that airborne contaminants from a incinerator would have low impacts on drinking water to be 20 percent, and that they would have no impacts at all to be 80 percent.

The engineers have told Smith that the potential for drinking water contamination from a facility at the Lynn, Walpole and Wilmington sites will be low. Using the "buffer" technique she used for her surface water probability assessments, she judges that the probability that the impacts from a composting facility at these sites will be non-existent (level 0) is 10 percent, that they will be low (level 1) is 80 percent, and that they will be moderate (level 2) is 10 percent. She believes the impacts from an incinerator will be a little more severe, however, and assigns the probability that impacts will be level 0 as 10 percent, level 1 as 70 percent, and level 2 as 20 percent for the Lynn and Walpole sites. The Wilmington site is located near several high aquifer areas, and although runoff from a compost pile would not affect these resources, airborne contaminants from an incinerator might reach them. Smith believes that the probability that impacts from an incinerator in Wilmington would be low (level 1) are 10 percent, moderate (level 2), 70 percent, and high (level 3), 20 percent.

The Stoughton site is located near several public wells and a major drinking water supply, the Brockton Reservoir. The experts have judged that the potential for contamination of these resources from a composting facility or an incinerator is moderate to high. Smith thus assigns a probability of 50 percent that impacts will be moderate, at level 2, and a 50 percent probability that they will be high, at level 3, for both technologies.

Air quality impacts (attribute five) are assessed very differently for the two technologies. First, Smith looks at the air quality impacts from an incinerator. As explained above, she measures these impacts by asking whether an interaction source exists near the site. The staff reports show that interaction sources exist near the Deer Island and Lynn sites. No interaction sources exist near the Spectacle Island, Stoughton, Walpole, or Wilmington sites. Some uncertainty surrounds the Quincy site. Right now, no interaction sources exist, but a hazardous waste incinerator and an electrical plant are proposed to be built in the area within the next five years. Smith assigns a "no" score to Quincy, and decides to change this judgment during her sensitivity analysis of the model results, to see if the presence of these interaction sources might change the results.

To measure air quality impacts of a composting facility, Smith uses information from the staff reports that judge how far the odors will travel from a composting facility on each site. Unfortunately, she has no information for Deer Island, Lynn and Walpole sites. She decides to calculate her own estimates of these measures. She finds the mean distance and the standard deviation for the remaining sites, and assigns a range of one standard deviation either way for the unknown sites. She then compares these measurements with information about how far away the nearest sensitive receptors are from the site. These comparisons are shown in Table 2-11. She determines that there will be no odor impacts at the Deer Island or Spectacle Island sites, but that odors will reach sensitive receptors at the Lynn, Quincy, Stoughton, Walpole and Wilmington sites. The Lynn and

TABLE 2-11
CALCULATION OF ODOR IMPACTS

Site	Distance Odors Will Travel	Distance to Nearest Sensitive Receptor	Odors Will Impact Sensitive Receptor
Deer Island	734--2217*	5280	No
Lynn	734--2217*	2000	Yes**
Quincy	656--984	500	Yes
Spectacle Island	1640	4000	No
Stoughton	656--984	800	Yes**
Walpole	734--2217*	500	Yes
Wilmington	2624	1000	Yes

* Estimate based on mean distance at other sites plus or minus one standard deviation
** Uncertain because of range

Stoughton results are uncertain, however, because the range of impacts was estimated. Smith makes a note to perform sensitivity analysis on these results after the model is completed.

Attribute number six, noise impacts, is measured in much the same way as odor impacts. Here, Smith simply uses the distance from the site to the nearest sensitive receptor. The measurements for each site are found in Table 2-12. The seventh attribute, cultural impacts, is measured using a constructed scale. Smith has judgments from staff members of the state's historical commission about whether each site's archaeological and historical sensitivity is low, moderate or high. She uses these judgments in her model. At Deer Island, archaeological sensitivity is judged to be low because the site has been highly disturbed by construction. However, there are remains of an old fort on the site. Smith judges that the probability that the facility's impacts on cultural resources will be low is 50 percent, and that they will be moderate is 50 percent.

The Lynn site has low archaeological sensitivity because it is a filled-in portion of Lynn Harbor. Smith sees no uncertainties with this site, and assigns it a score of 0 (low sensitivity). The Quincy site also has low archaeological sensitivity, but portions of the shipyard might have historical significance. She assigns a 50 percent probability that the facility's impacts will be at level 0 and 50 percent that they will be at level 1 (moderate). Cultural impacts will be high at the Spectacle Island site. An archaeological site has already been discovered on the island. Smith rates Spectacle Island at level 2. The Stoughton site is located in an area of moderate archaeological sensitivity, so Smith scores it at level 1. The Walpole site is judged to be of high archaeological sensitivity by the experts, and also

TABLE 2-12
DISTANCE FROM SITE TO SENSITIVE NOISE RECEPTORS

Site	Distance to Sensitive Receptors (in feet)
Deer Island	5280
Lynn	2000
Quincy	500
Spectacle Island	4000
Stoughton	800
Walpole	500
Wilmington	1000

contains an historic mansion eligible for the National Register of Historic Places. Smith therefore judges that the impact level for Walpole will be 2. The impacts at the Wilmington site are uncertain. No archaeological artifacts have been found on the site itself, but the site is located in an area that was a core of prehistoric activity. Twenty-four prehistoric sites have been found in close proximity to the site. Smith judges that the probability that impacts will be moderate (level 1) is 30 percent, and that the probability that they will be high (level 2), is 70 percent.

Two elements are analyzed in the constructed scale for attribute eight, timely implementation. First, Smith judges that permitting for the Quincy, Lynn and Spectacle Island sites could take longer than that for the rest of the sites because these sites are contaminated by hazardous waste. The agency will have to clean up these sites before permits will be issued. Second, she judges that Spectacle Island might involve delays because of competing public uses. The state's Secretary of Transportation has proposed using the island as a dump for fill from a new highway construction project. The president of the State Senate has proposed making the island a harbor park. If the MWRA has to negotiate over the use of this site, or coordinate its use with other agencies, the project schedule could be delayed. Smith believes that there is a 90 percent chance that the Lynn site could involve minor delays (level 1 on the scale) and a 10 percent chance that delays could be moderate. At the Quincy site, she judges that the probability that delays would be minor is 80 percent, while the probability that they would be moderate is 20 percent. Because the Spectacle Island site involves both permitting problems and competing uses, she assigns a probability of 50 percent that delays will be moderate and a probability of 50 percent that delays will be major.

Finally, Smith rates each site on its performance on the last attribute, construction costs. She studies the technical reports to determine whether the sites have any of the nine special conditions that could raise construction costs. Construction at the Deer Island site would require blasting, moderate soil cleanup, moderate water cleanup, and dewatering. Because all construction materials, personnel and equipment would have to be barged to the site, Deer Island also demands unique or scarce resources (the barges).

Construction at the Lynn site would require blasting and dewatering. Transportation improvements would have to be made--a new pier built if access was to be by barge, new roads built if access would be by truck. The project would require large amounts of clay to cap a landfill currently on the site. Because many construction projects are planned for the Boston area in the next ten years, clay will be a scarce resource. The soil at the Lynn site is contaminated, and will require at least a moderate cleanup, and perhaps an extensive one. Finally, sewer services might have to be built at the site if the MWRA is not able to hook up to the Lynn sewage treatment plant. This plant is currently being upgraded for secondary treatment, and there is some uncertainty whether it will have the capacity to handle sewage from the sludge treatment plant.

The Quincy site is heavily polluted with hazardous waste, and will require extensive soil cleanup and moderate water cleanup. Unique resources--personnel trained in handling hazardous waste--will be required for this project. In addition, construction at the site will require dewatering.

Spectacle Island has many of the special conditions that raise costs because it is an undeveloped island. The MWRA must build piers so that barges can bring the sludge back and forth. All site utilities must be constructed on the island. Extensive dewatering will be required. The island is contaminated, and will require moderate soil and water cleanups. Construction on the island will also demand unique or scarce resources--barges to transport personnel, equipment and materials; clay to cap the trash landfills on the site; and a disposal site for material that is dredged to build piers.

Construction at the Stoughton site will require blasting and dewatering. The MWRA must regrade an access road before its trucks can safely use it. The site may be contaminated, and could require moderate soil and water cleanups. It is not clear whether the MWRA will be able to hook up to the local sewer lines. The MWRA must regrade a road and alter bridges near the Walpole site before construction can begin there. In addition, it is uncertain whether the agency will be able to use local sewers. At the Wilmington site, blasting and dewatering must be performed before construction, and a bridge built across wetland areas. The local sewer situation is also unclear here.

Smith summarizes the information about costs in a table (Table 2-13). She also includes probability judgments for those sites where the number of special conditions is uncertain.

Assessing Preferences

Now that Smith has expected value for the impacts at each site, she must find a common unit by which to compare them. Decision analysis uses utility measures--measures of the strength of preference or desirability of various impact levels. A separate utility function is assessed for each

TABLE 2-13
SPECIAL CONDITIONS THAT COULD RAISE CONSTRUCTION COSTS--BY SITE

* Probability
** Uncertainty

Deer Island 5
- Blasting
- Moderate soil cleanup
- Moderate water cleanup
- Dewatering
- Unique or scarce resources

Lynn 6 (.6)* 7 (.3) 8 (.1)
- Blasting
- Moderate soil cleanup
- Extensive soil cleanup**
- Moderate water cleanup
- Dewatering
- Transportation improvements
- Unique or scarce resources
- Site utilities**

Quincy 5
- Moderate soil cleanup
- Extensive soil cleanup
- Moderate water cleanup
- Dewatering
- Unique or scarce resources

Spectacle Island 6
- Moderate soil cleanup
- Moderate water cleanup
- Dewatering
- Transportation improvements
- Unique or scarce resources
- Site utilities

Stoughton 3 (.5) 4 (.2) 5 (.2) 6 (.1)
- Blasting
- Moderate soil cleanup**
- Moderate water cleanup**
- Dewatering
- Transportation improvements
- Site utilities**

Walpole 1 (.7) 2 (.3)
- Transportation improvements
- Site utilities**

Wilmington 3 (.7) 4 (.3)
- Blasting
- Dewatering
- Transportation improvements
- Site utilities**

attribute. Smith assesses her utility function for the first attribute--transportation access--as follows: first, she defines the extreme values that impacts can have. The worst transportation access impact is at level 3 of the constructed scale. The best impact is no impact--level 0 of the scale. She sets her utility for the worst impact at 0 and at 1 for the best impact. Next, she constructs a series of "gambles"--hypothetical lotteries that can help her judge her preferences. In the first gamble, she asks herself, "What impact level of this attribute would I find exactly as desirable as a lottery that gives me a 50 percent chance that impacts will be at their worst and a 50 percent chance that impacts will be at their best?" After much deliberation, she decides that impacts at level 2 would render her "indifferent" to the lottery. In the second gamble, she now asks, "What impact level would I find exactly as desirable as a lottery that gives me a 50 percent chance that impacts will be at level 2 and a 50 percent chance that impacts will be at their best?" She determines that impacts at level 1 would make her indifferent to the lottery. Finally, she asks herself, "What impact level would I find exactly as desirable as a lottery that gives me a 50 percent chance that impacts will be at level 2 and a 50 percent chance that impacts will be at their worst?" She decides that impacts that fall a little more than halfway between levels 2 and 3 would make her indifferent to this lottery.

Smith now has five points that she can graph to create a utility function. Her points are shown in Figure 2-5. She draws a curve through the points, and adjusts it so that the values between the points reflect her preferences. Smith repeats this procedure for each attribute. Her final

FIGURE 2-5
SMITH'S FIVE-POINT ASSESSMENT OF PREFERENCES FOR ATTRIBUTE X_1:
TRANSPORTATION ACCESS

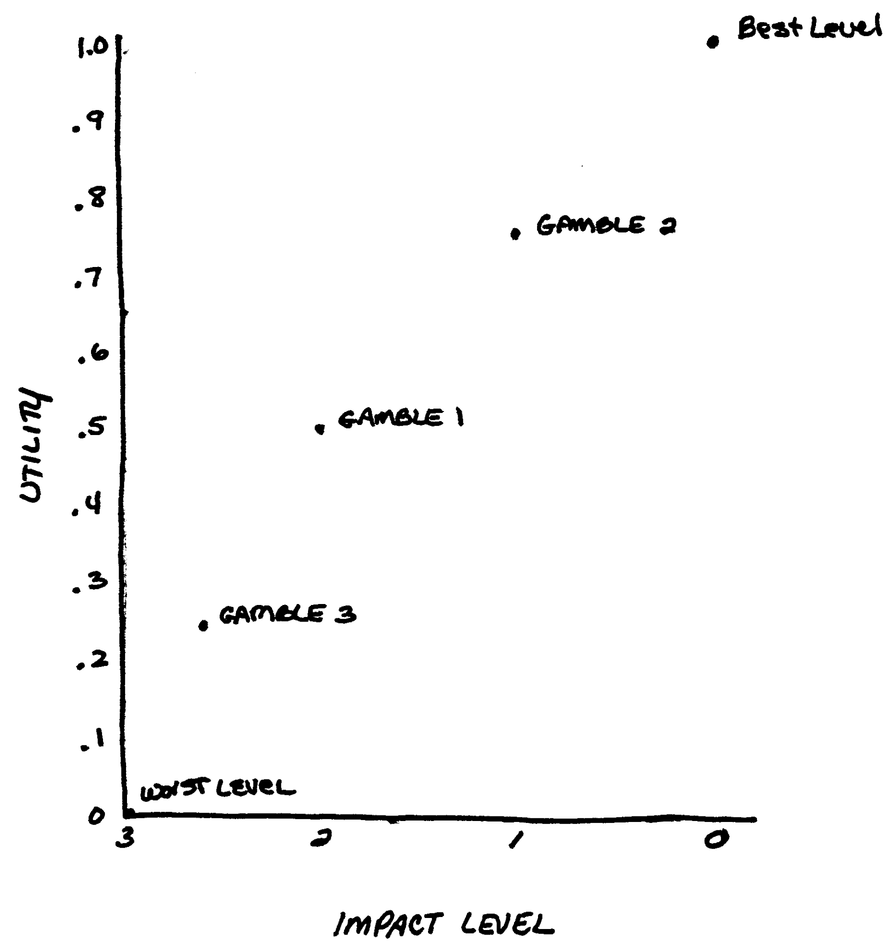
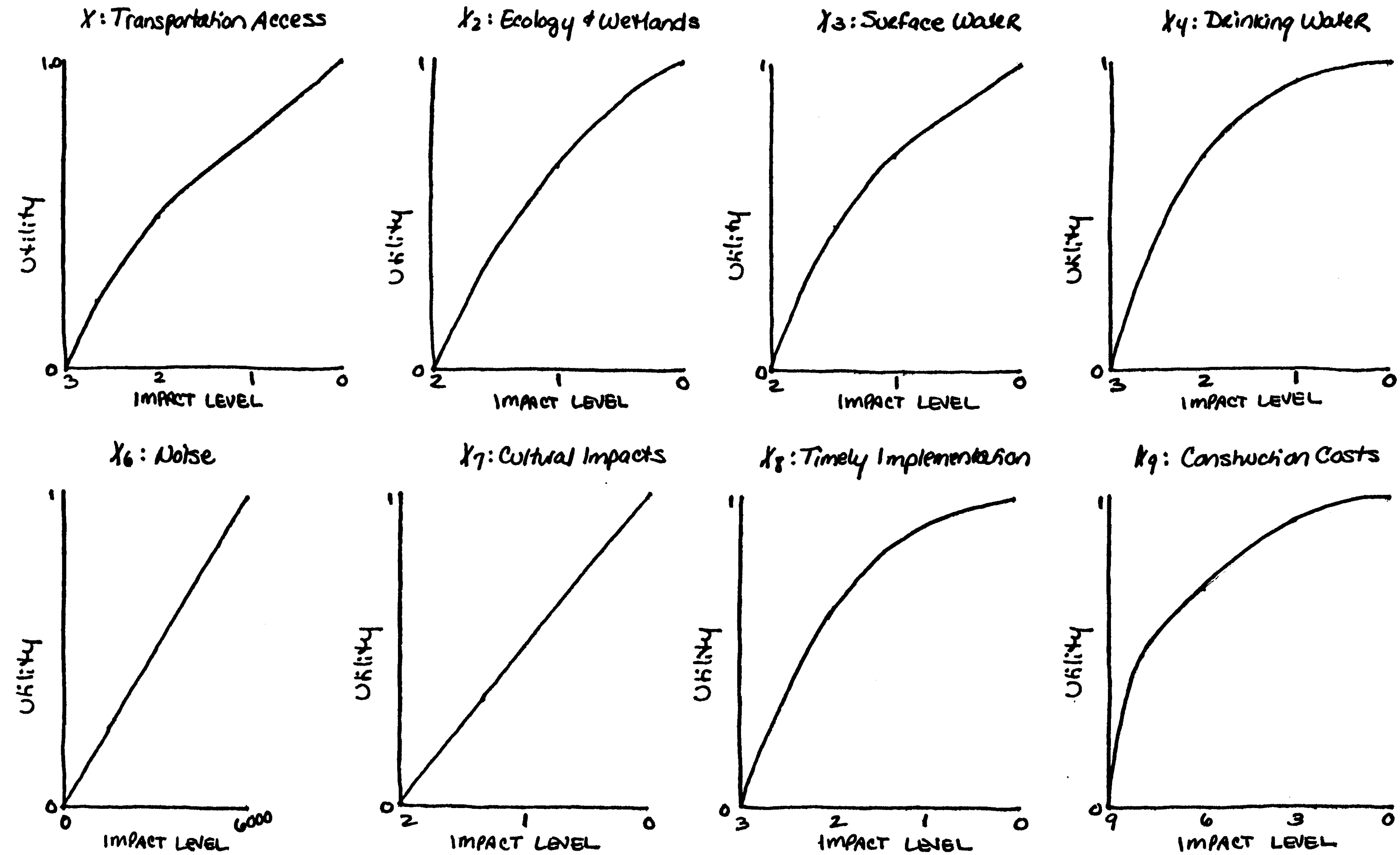


FIGURE 2-6
SMITH'S UTILITY ASSESSMENTS FOR ALL ATTRIBUTES

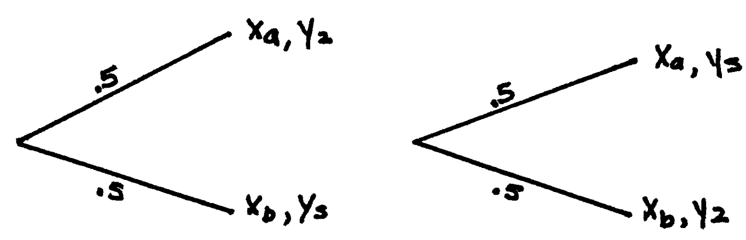


utility assessments are displayed in Figure 2-6.[5] The shapes of the curves reveal Smith's attitudes for risk on each attribute. She is "risk-averse" on the transportation access, ecology and wetlands, surface water, drinking water, timely implementation and construction cost attributes. Her utilities show that she is unwilling to take risks on these attributes--if given a choice between a lottery offering a 50 percent chance that impacts will be at their best and a 50 percent chance that they will be at their worst and a certain impact, Smith prefers the certainty, not the gamble. She is "risk-neutral" on the noise and cultural resources attributes, meaning she is indifferent between a gamble and a certainty. Smith does not need to assess a utility function for the air quality attribute. If odors will reach sensitive receptors or interaction sources exist near the site, the utility is 0. If these conditions are not present at the site, the utility is 1.

Next, Smith calculates an expected utility for each attribute by multiplying the probability of occurrence of each impact level by the utility for that level. The resulting expected utilities for each level within an

----

5. In order to simplify her models, Smith makes an assumption of additive utility independence among the attributes. Under this condition, a decision maker would be indifferent to the following lotteries:



The decision maker's preference between levels of attribute X is not related to the level of attribute Y. If the attributes are additive utility independent, Smith can simply add the weighted expected utilities for all attributes to obtain a measure for each site. Smith assumes additive utility independence for all of the models she uses.

attribute are added together to produce an expected utility for that attribute. These are displayed in Table 2-14.

Making Tradeoffs among Objectives

Smith has expected utility assessments for each site over nine attributes. Before she can combine this data into final utility rankings for each site, however, she must weight the attributes. She is not equally concerned about all of the attributes. To find which are more important than others, she asks herself, "If all the attributes are at their worst levels, which one would I want to bring to its best level?" She decides that attribute 8, timely implementation, is the most important. She continues this line of questioning and comes up with the following ranking of attributes:

Timely implementation
Construction costs
Drinking water
Air quality
Noise
Transportation access
Surface water
Ecology
Cultural resources

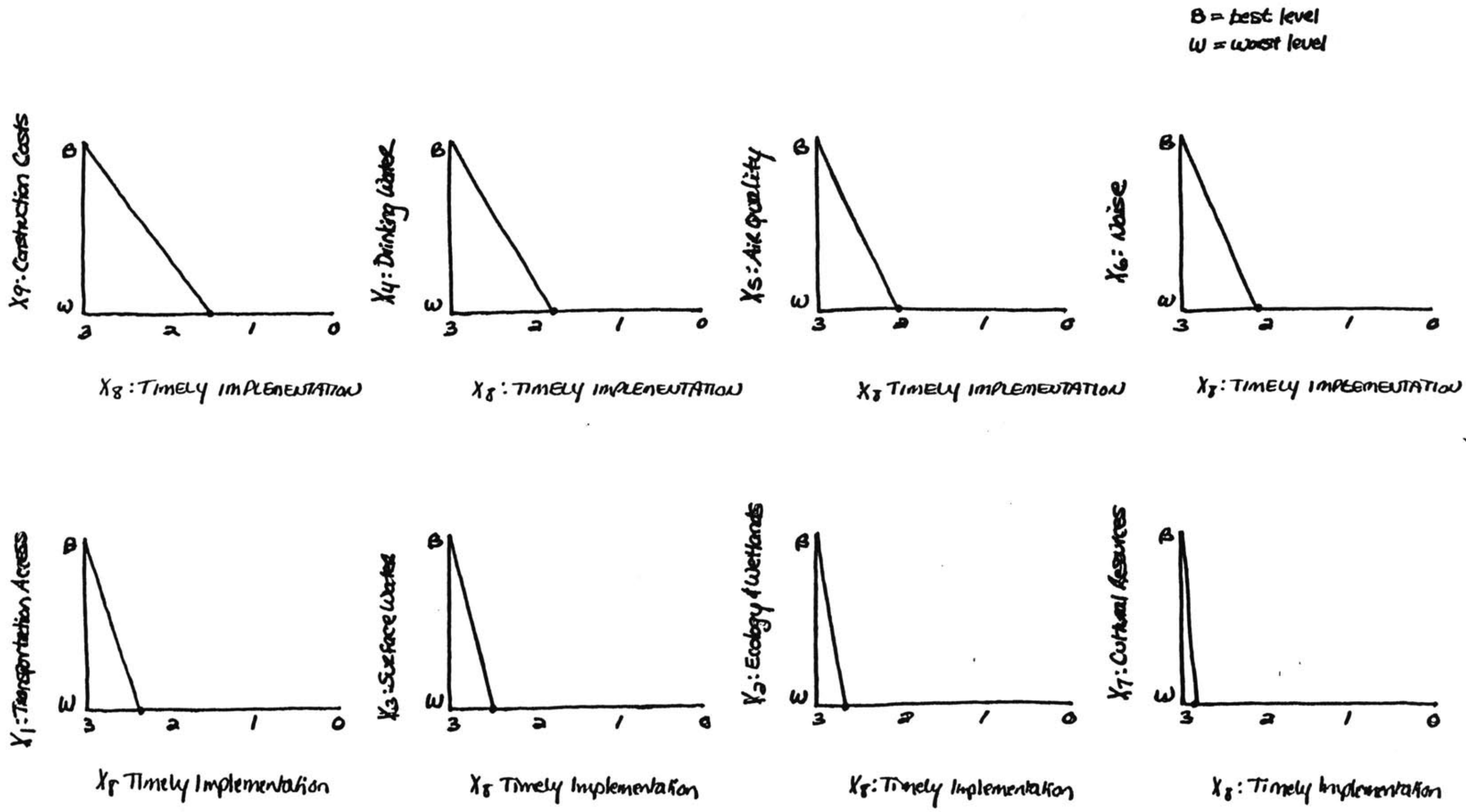
She then assesses what tradeoffs she would make against the highest ranking attribute to bring the other attributes to their best levels. Figure 2-7 shows Smith's value tradeoffs. The first graph illustrates the tradeoff she would make between the most heavily weighted attribute, timely implementation, and the second most heavily weighted attribute, construction costs. The graph shows that Smith is willing to incur an increase in delays from between minor and moderate to major in order to move construction costs from their worst to their best level. On the other hand, the last graph

TABLE 2-14
EXPECTED UTILITIES FOR ALL ATTRIBUTES

ATTRIBUTE	DEER ISLAND	LYNN	QUINCY	SPECTACLE ISLAND	STOUGHTON	WALPOLE	WILMINGTON
X_1: Transportation Access	1	0	.5	1	.75	0	.65
X_2: Ecology & Wetlands	.204	.84	.868	.136	.34	.676	.204
X_3: Surface Water	.07	.85	.85	.07	.35	.85	.66
X_4: Drinking Water	.993 * .986 **	.916 * .895 **	.993 * .986 **	.993 * .986 **	.36 * .36 **	.916 * .895 **	.916 * .895 **
X_5: Air Quality	1 * 0 **	0 * 0 **	0 * 1 **	1 * 1 **	0 * 1 **	0 * 1 **	0 * 1 **
X_6: Noise	.83	.34	.09	.68	.09	.09	.18
X_7: Cultural Impacts	.75	1	.75	0	.5	0	.15
X_8: Timely Implementation	1	.874	.848	.32	1	1	1
X_9: Construction Costs	.81	.668	.81	.72	.87	.971	.859

* Composting
** Incineration

FIGURE 2-7
SMITH'S VALUE TRADEOFFS FOR ALL ATTRIBUTES



shows that she is willing to incur only very minor additional delays in order to move cultural impacts from their worst to their best.

Results and Conclusions

Smith uses these tradeoff judgments to calculate a weight for each attribute. She then calculates a utility score for each site by multiplying the expected utility of each attribute by the attribute weight, and adding up the weighted utilities for all nine attributes. These values are then entered into the decision tree, and an expected utility for each site is calculated. Figure 2-8 shows the final results. Deer Island has the highest utility score, followed by Quincy, Wilmington, Walpole and Spectacle Island. The range of scores is displayed in Figure 2-9.

Before Smith determines what she has learned from this model, she performs sensitivity analysis to see whether changing some of her assumptions and judgments change the results of the model. She had originally assumed that there was a 50/50 chance that either technology would have to be used. She changes the tree model to see if certainty about either technology would change her decision about a site. The result, shown in Table 2-15, shows that if composting is the certain technology, Deer Island and Quincy remain the top two choices, but Spectacle Island and Lynn move to third and fourth place, respectively, above Wilmington and Walpole. If incineration is the certain technology, Deer Island, Quincy and Wilmington are still the top three sites, but Quincy is now first, Wilmington second, and Deer Island third. Walpole remains in fourth place.

Smith remembers that she was very unsure about the air quality impact of a composting facility at several sites because, due to lack of

FIGURE 2-8
DECISION TREE SHOWING RESULTS OF THE TECHNICAL MODEL

```
                      DEER ISLAND____  C COMPOSTING_____
                      |  .7404         C|(.5) .7964
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .6843
                      |
                      |
                      |LYNN__________  C COMPOSTING_____
                      |  .5957         C|(.5) .5971
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .5943
                      |
                      |
                      |QUINCY________  C COMPOSTING_____
                      |  .6965         C|(.5) .6414
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .7516
                      |
                      |
SITING DECISION_     D|SPECTACLE ISLAND C COMPOSTING_____
  .7404              D|  .606          C|(.5) .6064
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .6055
                      |
                      |
                      |STOUGHTON_____  C COMPOSTING_____
                      |  .5786         C|(.5) .523
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .6341
                      |
                      |
                      |WALPOLE_______  C COMPOSTING_____
                      |  .6273         C|(.5) .5731
                      |                 |
                      |                 |INCINERATION___
                      |                  (.5) .6814
                      |
                      |
                      |WILMINGTON_____ C COMPOSTING_____
                         .6453         C|(.5) .5911
                                        |
                                        |INCINERATION___
                                         (.5) .6995
```

FIGURE 2-9

TECHNICAL MODEL RESULTS

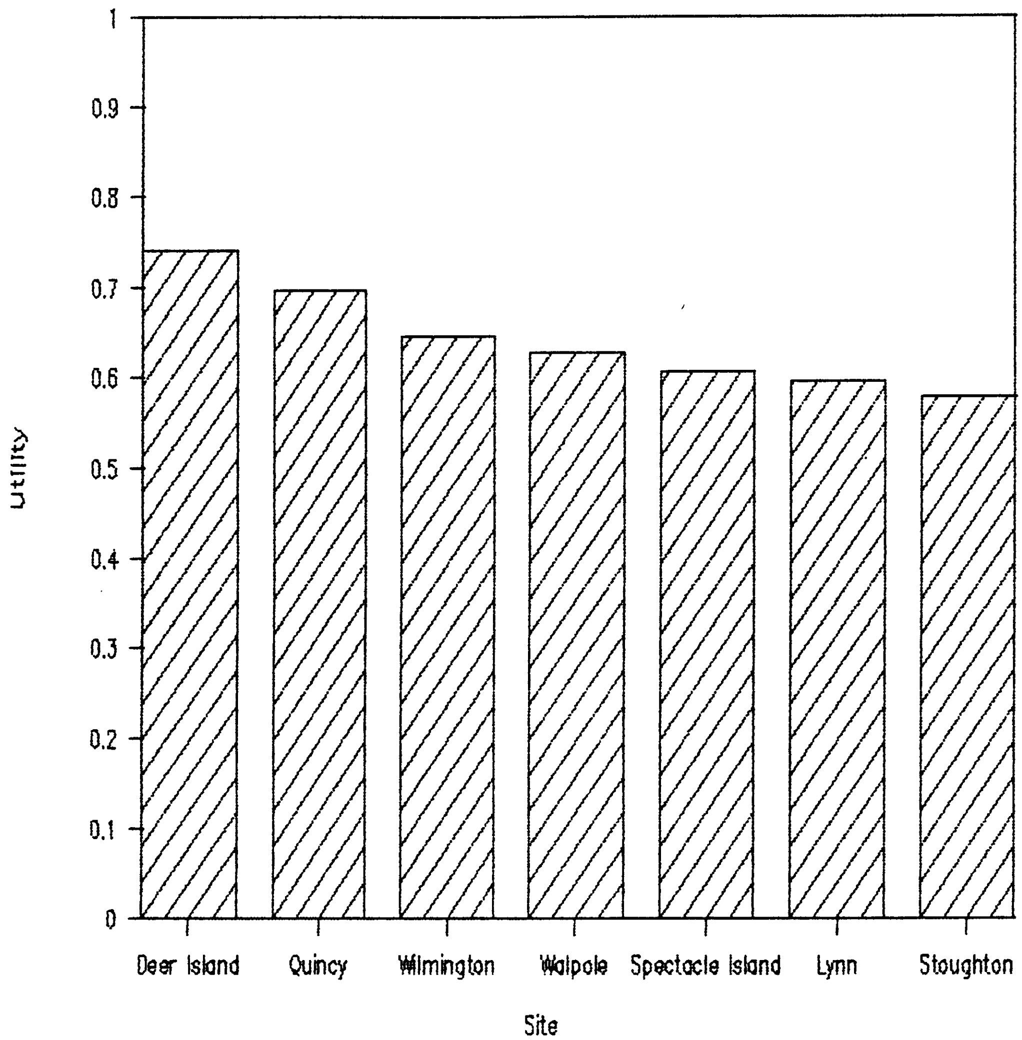


TABLE 2-15
SENSITIVITY ANALYSIS OF TECHNOLOGY OUTCOME

Model Results at 50 Percent Chance of Either Outcome		Model Results at 100 Percent Chance of Composting		Model Results at 100 Percent Chance of Incineration	
Deer Island	.7404	Deer Island	.7964	Quincy	.7516
Quincy	.6965	Quincy	.6414	Wilmington	.6453
Wilmington	.6453	Spectacle Island	.6064	Deer Island	.6843
Walpole	.6273	Lynn	.5971	Walpole	.6814
Spectacle Island	.6060	Wilmington	.5911	Stoughton	.6341
Lynn	.5957	Walpole	.5731	Spectacle Island	.6055
Stoughton	.5786	Stoughton	.5230	Lynn	.5943

information, she had to estimate the distance that odors would travel. When she changes the impact assessments for these sites, both Lynn and Stoughton move up in the rankings, Lynn to third place behind Quincy, Stoughton to fifth place behind Wilmington. Smith decides that it might be worthwhile to get more information about the odor impacts before she eliminates Lynn and Stoughton from further consideration.

Smith also remembers that there was some uncertainty as to whether interaction sources would be built near the Quincy site. When she changes the value associated with incineration at Quincy, Quincy drops to third place in the final rankings behind Wilmington. Smith is also interested in the uncertainties surrounding Spectacle Island on the attribute of timely implementation. When she runs the model again assuming that there will be no delays, Spectacle Island moves to third place behind Deer Island and Quincy and above Wilmington and Walpole.

Smith is surprised by some of the technical model's results. She had expected the Lynn and Spectacle Island sites to have higher rankings. After all, the Lynn site is located in an area already used for industry; and many members of the legislature, press and environmental community have been pushing Spectacle Island as the perfect site. When she examines the model structure carefully, she finds that her three most heavily weighted attributes, timely implementation, costs and drinking water, account for 45 percent of a site's final score because of the tradeoffs she made. The Lynn site had high costs and the possibility of delay. Both costs and delay were related to the presence of hazardous waste on the site. Spectacle Island scored well on air quality, noise, transportation access, and drinking water attributes, but poorly on timely implementation and costs. Deer Island, on the other hand, ranked first because although constructions costs were high, no delays were expected and no impact on drinking water was likely. Deer Island also scored highly on other heavily weighted attributes such as air quality, noise, and transportation access. These high scores were enough to allow Deer Island to overcome its low rating on the construction cost attribute.

What has Smith learned from this first cut at the sludge facility siting problem? First, she sees that timely implementation and costs are extremely important to her. She is not willing to change the weights of these attributes even though they appear to "run" the model. She has also learned that her decision, if made on technical grounds, is not really affected by the outcome of the technology uncertainty. True, Spectacle Island dominates Wilmington if composting is the technology, but the utilities are not all that different between the two sites (.6064 for Spectacle Island and .5911 for Wilmington). Resolving the uncertainties around transportation access at the Wilmington site in favor of the commercial/industrial access road alternative would be more than enough to allow Wilmington to dominate Spectacle Island in the ranking (Wilmington's new score would be .6300 in this case). Based on the technical model, she tentatively decides to eliminate Walpole and Spectacle Island from further study, to obtain more information on the odor impacts at Lynn and Stoughton, and to retain Deer Island, Quincy, and Wilmington for further consideration.

THE POLITICAL MODEL

Despite the extensive analysis she put into the technical model, Smith is not satisfied with the results. She realizes that technical considerations are only one dimension of the sludge facility siting problem. She decides to take another cut at formulating the problem, this time as a political problem.

In the political model, the processing technology is not considered as important as in the technical model. Smith believes that political considerations will not be related to technology, but instead to the fact that any type of facility will be placed on a certain site. She defines her new decision problem using a simple decision tree, shown in Figure 3-1.

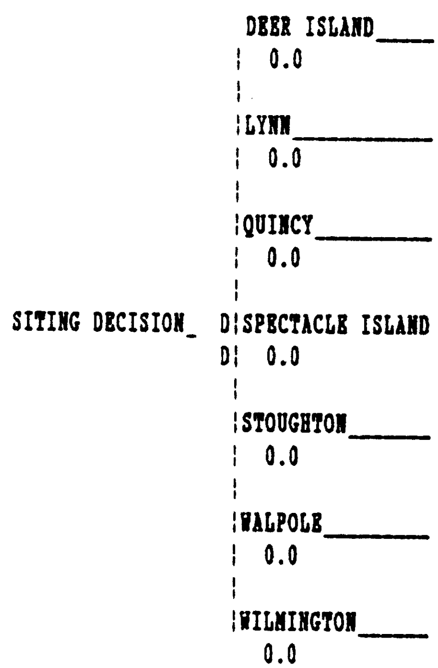
Structuring Objectives for the Decision

Next, Smith turns her attention to defining objectives for the siting decision. What are her political objectives? She decides that her primary objective is to build a sludge treatment facility as quickly as possible to meet the court-ordered schedule. Other political objectives, such as using her political "capital" wisely and advancing her own career, are related to the major objective of timely implementation. She decides to build her political model around this one objective.

Defining Attributes and Performance Measures

Smith sees five considerations that could delay project implementation. First, she could choose a site that has a powerful political "sponsor"--someone who represents the potential host community in the state

FIGURE 3-1
DECISION TREE STRUCTURE FOR THE POLITICAL MODEL



legislature, and has a lot of political clout; or a powerful politician who is interested in protecting the site from a sludge facility for some other reason. Second, she could choose a site in a community where abutters could easily organize to sue, put pressure on politicians, or protest the siting choice. Third, she could choose a site that public sentiment believes should not be chosen--for example, she could choose a site in a community that already hosts many regional facilities. Public outcry could delay the siting. Fourth, she could choose a site that has been proposed for a competing public use. If she had to play a lot of political games with other agency heads or politicians to get control of the site, project implementation could be delayed. Finally, she could choose a site that must be approved by the legislature. Under the MWRA's enabling legislation, the agency must go to the legislature to get eminent domain authority to take privately owned land. If the agency chooses a site that it already controls, or is already controlled by the state, legislative approval would not be necessary.

Smith decides to use these five considerations as attributes to measure each site's performance on her major objective, timely implementation. What kind of scale should she use to measure these attributes? Obviously, no natural scales to measure political power or the possibility of protest exist. She decides to build five similar constructed scales, each with two levels corresponding to presence of the condition or absence of the condition. Because uncertainties surround some of the attributes, these scales will be continuous, not discrete--a site's performance on an attribute could fall between the two levels. The five scales are described in Table 3-1.

TABLE 3-1
CONSTRUCTED SCALES FOR POLITICAL MODEL ATTRIBUTES

X_1: POLITICAL SPONSOR

Impact Level	Political Situation
0	No sponsor, or sponsor will not use power to stop choice of site
1	Sponsor will use power to stop choice of site

X_2: POWER OF ABUTTERS

Impact Level	Political Situation
0	Abutters unable to organize to delay
1	Abutters able to organize and obtain resources to delay implementation

X_3: PUBLIC SENTIMENT

Impact Level	Political Situation
0	No general public sentiment against using this site for a facility
1	General public sentiment against using this site could delay implementation

X_4: COMPETING PUBLIC USE

Impact Level	Political Situation
0	No competing public use for the site
1	Competing public use could delay implementation

X_5: LEGISLATIVE APPROVAL

Impact Level	Political Situation
0	Legislative approval not needed to acquire site
1	Gaining legislative approval could delay implementation

Assessing Impacts and Probabilities

Smith is now ready to assess how each site will perform on each attribute. Deer Island does not have a politically powerful sponsor. However, Smith judges that abutters to the site are able to organize to delay. The people of Winthrop have long protested the presence of Logan Airport, a prison, and the primary and secondary sewage treatment plants near their community. Community groups are entrenched, powerful, and well-funded. Smith believes that there is a 90 percent probability that Deer Island's abutters would be able to delay implementation. Because Winthrop already experiences the impacts of other regional facilities, Smith believes that general public sentiment might be opposed to siting sludge treatment facilities on Deer Island. She assesses a 50 percent probability that public sentiment against the site could delay implementation. There is no competing public use for the site. Finally, legislative approval is not needed, since the MWRA already owns Deer Island.

The site in Lynn does not have a politically powerful sponsor who could delay implementation. Abutters are unorganized, because Lynn does not host any regional burdens, and the people have little experience with organizing. Smith judges the probability that abutters could delay implementation to be 20 percent. It is likely that general public sentiment would oppose siting the sludge facility in Lynn, however, because Lynn is not part of the MWRA service district. Smith believes that there is strong public concern that wastes should be kept within the boundaries of the region that produces them. She judges that there is a 70 percent probability that public sentiment could delay implementation. There is no competing use for the Lynn site. Legislative approval would be needed to acquire this site, since it is privately owned.

The Quincy site does not have a politically powerful sponsor. Abutters are judged able to organize and delay, however, because the MWRA has already purchased the Quincy site for a transfer and staging facility, and has sited an interim sludge treatment facility there. The people of Quincy opposed these projects, and they are organized, well-funded and angry. Smith believes there is a 70 percent chance that abutters could delay implementation of construction of a sludge treatment facility on the Quincy site. Although abutters might be opposed to the facility, Smith does not believe that there is general public sentiment against the site. There is no competing use for the site, and legislative approval is not needed because the MWRA already owns the site.

Spectacle Island is sponsored by a very powerful politician. The president of the State Senate has announced his support for developing the island into a harbor park. Smith believes that there is a 80 percent chance that he will use his power to delay implementation if she should choose Spectacle Island as the site of the sludge treatment facility. Because the site is an island, there are no real "abutters" to the site; for purposes of her analysis, Smith assumes that the people living in the harbor areas of the city of Boston are abutters to Spectacle Island. She believes that there is a 10 percent chance that these people could organize and delay implementation. No public sentiment against using the site is expected; in fact, there is much public support for choosing Spectacle Island. There is a competing public use for the site, however. The state's Secretary of Transportation has proposed using the island as a disposal site for fill from the Central Artery reconstruction project. Smith judges that the probability that the Secretary could delay implementation of the sludge facility construction if she chooses Spectacle Island to be 90 percent. Legislative approval is necessary to buy portions of this site from the city of Boston.

The three inland sites, Stoughton, Walpole and Wilmington, all have the same political characteristics. None of them are sponsored by politically powerful figures. The abutters in these communities are not judged easily able to organize and delay the project schedule. Smith believes that the probability of delay from abutters' opposition is 20 percent. There is no public sentiment against siting sludge treatment facilities in any of these communities. No competing uses exist for these sites, and legislative approval is required for all three, since they are privately owned. Smith summarizes her impact and probability assessments for all of the sites in Table 3-2.

Assessing Preferences

Next, Smith assesses her preferences for levels of each attribute. Her utility functions are shown in Figure 3-2. Smith is risk-averse on the attributes of politically powerful sponsor, abutters' opposition, and competing public uses. Her utility functions show that she is risk-prone (preferring a gamble to a certainty) on the public sentiment and legislative approval attributes.

Making Tradeoffs among Objectives

Smith now considers how to weight the five attributes. Which is more important--avoiding a battle with a politically powerful sponsor, or avoiding the need for legislative approval? She believes that tangling with

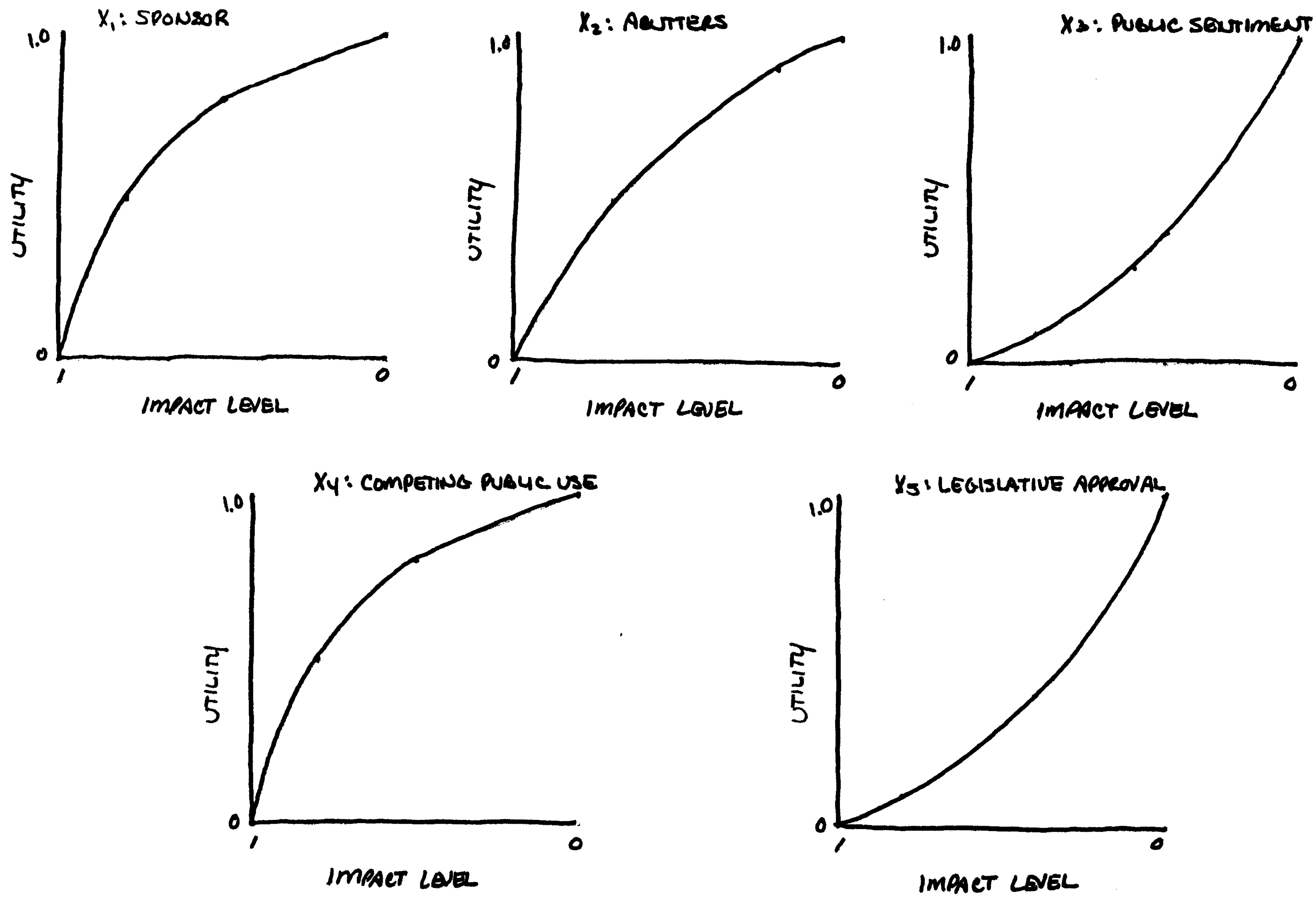
TABLE 3-2

IMPACT AND PROBABILITY ASSESSMENTS FOR THE POLITICAL MODEL

ATTRIBUTE	DEER ISLAND	LYNN	QUINCY	SPECTACLE ISLAND	STOUGHTON	WALPOLE	WILMINGTON
X_1: SPONSOR	0 (1.0)	0 (1.0)	0 (1.0)	0 (.2) 1 (.8)	0 (1.0)	0 (1.0)	0 (1.0)
X_2: ABUTTERS	0 (.1) 1 (.9)	0 (.8) 1 (.2)	0 (.3) 1 (.7)	0 (.9) 1 (.1)	0 (.8) 1 (.2)	0 (.8) 1 (.2)	0 (.8) 1 (.2)
X_3: PUBLIC SENTIMENT	0 (.5) 1 (.5)	0 (.3) 1 (.7)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
X_4: COMPETING PUBLIC USE	0 (1.0)	0 (1.0)	0 (1.0)	0 (.1) 1 (.9)	0 (1.0)	0 (1.0)	0 (1.0)
X_5: LEGISLATIVE APPROVAL	0 (1.0)	1 (1.0)	0 (1.0)	1 (1.0)	1 (1.0)	1 (1.0)	1 (1.0)

Note: Figures outside parentheses are impact levels; figures inside parentheses are probabilities.

FIGURE 3-2
SMITH'S UTILITY ASSESSMENTS FOR ALL ATTRIBUTES



a powerful political sponsor could cause a great deal of delay, so she weights this attribute most heavily. Next, she believes that abutters' opposition can cause serious delays, so she will weight that attribute second most heavily. Of the remaining three attributes, she judges competing public uses to be most important; of the last two attributes, legislative approval and public sentiment, she judges that she would prefer to bring legislative approval to its best level. Smith then makes the value tradeoffs shown in Figure 3-3. The graphs show that she is willing to incur quite a bit of delay from a sponsor in order to eliminate opposition from abutters and competing public uses. She is less willing to take on a powerful political figure, however, to better the legislative approval and public sentiment attributes.

Results and Conclusions

Smith now feeds the impact, probability and utility assessments and the value tradeoff data into a multiattribute utility function. The results are as follows:

Site	Utility
Stoughton	.9496
Walpole	.9496
Wilmington	.9496
Quincy	.8211
Lynn	.7390
Deer Island	.7307
Spectacle Island	.3863

The three inland sites share first place. Spectacle Island, the site with the most political complications, ranks last. The range of results is illustrated in Figure 3-4.

Smith is uncertain about some of the assumptions she made in evaluating the sites. Suppose a past history of being able to organize is not a good indicator of whether a community will organize against a sludge

FIGURE 3-3
SMITH'S VALUE TRADEOFFS FOR ALL ATTRIBUTES

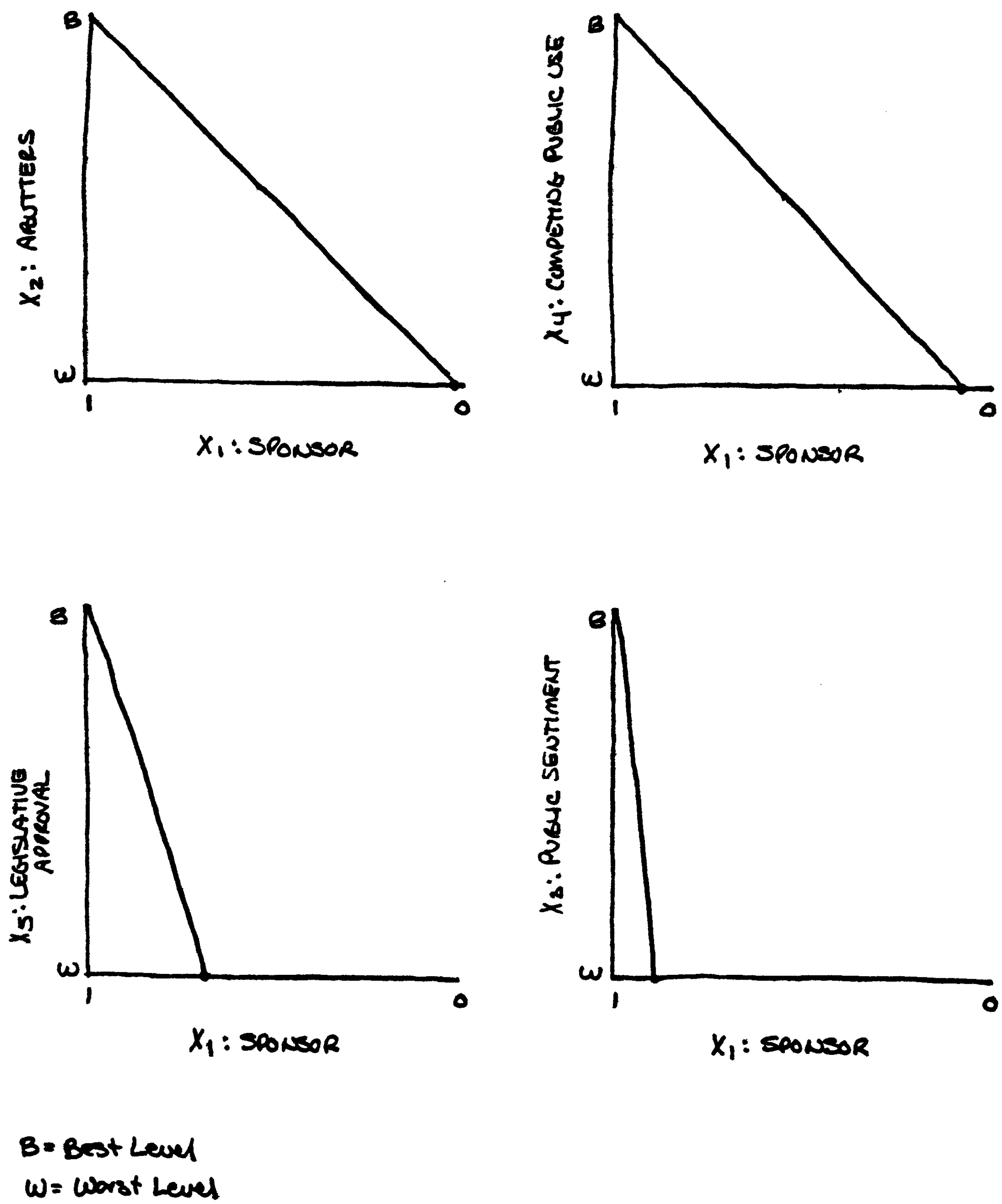
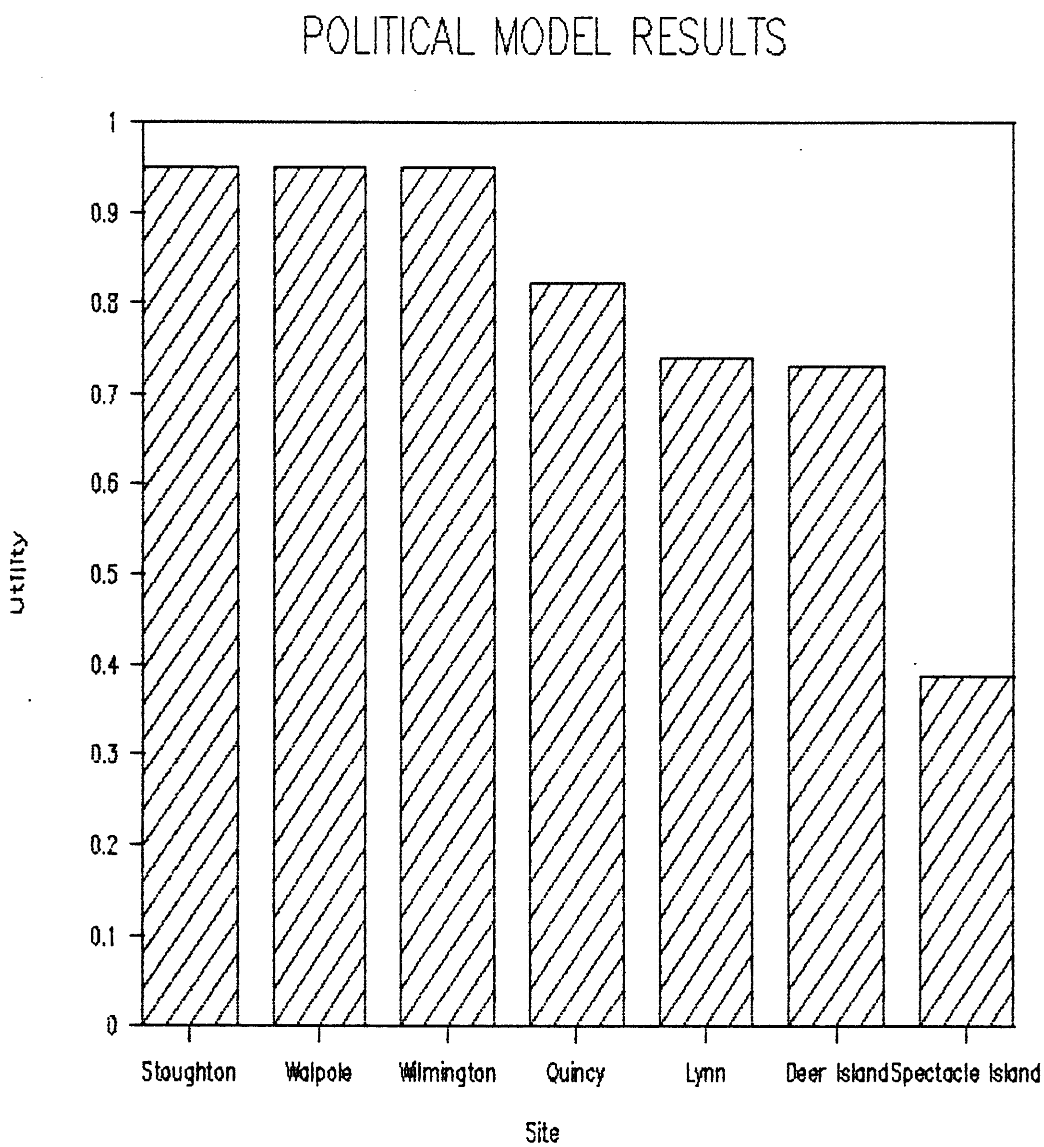


FIGURE 3-4


POLITICAL MODEL RESULTS
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Utility
Stoughton
Walpole
Wilmington
Quincy
Lynn
Deer Island
Spectacle Island
Site

facility? She recalculates the model, this time assuming that there is a 90 percent probability that abutters in each community will delay project construction. She obtains the following results:

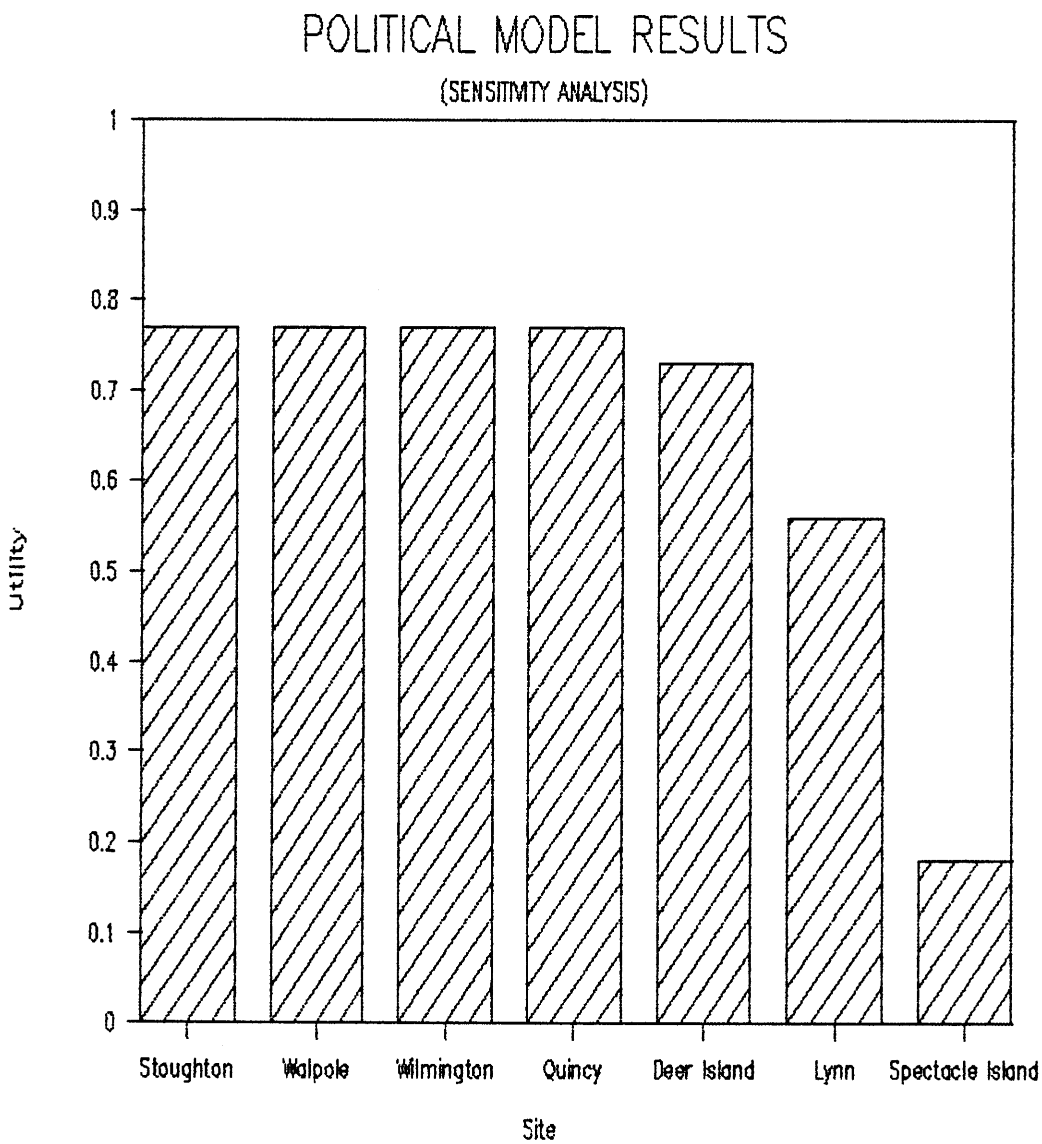
Site	Utility
Stoughton	.7697
Walpole	.7697
Wilmington	.7697
Quincy	.7697
Deer Island	.7307
Lynn	.5591
Spectacle Island	.1807

This time, Quincy joins the inland sites at the top of the ranking. Spectacle Island remains at the bottom of the list. The range of results is shown in Figure 3-5.

Smith next tries to see if any changes in her probability assessments can move the Spectacle Island site up in the list. She assumes a "best case" scenario-- the site's sponsor decides not to use his power to delay project implementation, and the Secretary of Transportation finds another site for his fill. There is a 10 percent probability that abutters will delay the project. Under this scenario, the total utility for Spectacle Island becomes .8193, and it moves above Lynn and Deer Island the ranking. If only one of the two most heavily weighted attributes changes, however, Spectacle Island remains at the bottom of the list. If the sponsor declines to use his power to block implementation, but the competing use remains, the site's total utility is .5683. If the sponsor will delay implementation, but the competing use disappears, the score is .5593.

What has Smith learned from building this model? First, her choice of three sites for further study is not really sensitive to her judgments about whether abutters will delay implementation of the project. If she

FIGURE 3-5


POLITICAL MODEL RESULTS
(SENSITIVITY ANALYSIS)
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Stoughton
Walpole
Wilmington
Quincy
Deer Island
Lynn
Spectacle Island
Site

downplays the probability that abutters will delay, she should choose Stoughton, Walpole and Wilmington for further study. If she judges that abutters at all sites can delay implementation, her choice remains the same, but she can add Quincy to the list.

Second, Smith has learned that she should not expend political capital and energy to negotiate with the Senate President or the Secretary of Transportation over Spectacle Island. Even in a "best case" scenario, with the president agreeing to drop his opposition to the site and the Secretary considering another site for fill, four sites have higher utilities than Spectacle Island.

THE NEGOTIATION MODEL

Smith has learned a lot about her problem from the technical and political models, but she does not feel that these models have dealt with the problem comprehensively. The models have not really treated the sludge facility's potential impacts on people, and Smith believes that concern over these impacts are what the "not in my backyard" syndrome is all about. She finds the negotiation theories of facility siting attractive, and decides to build a model based on the views and inputs of the different social groups--"stakeholders"--interested in the project.

There are several ways Smith can go about using stakeholder group inputs in her model. First, she can act as a "Supra-Decision Maker" (Keeney and Raiffa, 1976). Under this theory, a single decision maker incorporates or reflects the probability judgments and preferences of the various stakeholder into his or her own beliefs. For example, the decision maker could have an attribute in his or her personal model called "satisfy the preferences of group X", and could measure a site's performance in satisfying these preferences. Second, Smith could build a totally negotiated model--she could sit down with stakeholders and negotiate until the group reached consensual definitions of objectives, attributes, performance measures, probabilities, preferences, and value tradeoffs for the model. (Von Winterfeldt and Rios, 1980). Finally, Smith could negotiate a consensual objectives hierarchy with stakeholder groups. (Edwards and Von Winterfeldt, 1987). She could then use the information about each group's objectives to establish better lines of communication with the stakeholders; to decide where to seek more information about impacts; and to possibly modify the design of the facility. (Keeney, 1988).

Smith is intrigued by the second strategy--building a consensual model--but she does not think she has the time to engage in detailed negotiations with stakeholder groups. Also, because she is just trying to learn about the nature of the problem from this modeling exercise, she does not want to become involved in a process that could require her to make commitments to a strategy. If she negotiated model-building with stakeholder groups, she might have to make promises and commit to a negotiation and compensation strategy before she has determined the nature of the problem.

She decides to use the last technique, building a common objectives hierarchy. She will identify stakeholder groups, and hold informal conversations with them about the sludge facility siting problem. She will then try to identify their major objectives, and incorporate these into a shared objectives hierarchy. After that, she will use the information gleaned from her discussions to design a model based on a hypothetical negotiation, in which she tries to guess how each group would measure performance on each objective, how it would assess the probabilities of impacts, what its preferences for impact levels would be, and what tradeoffs it would make among objectives. She will then build a model and produce a ranking of sites for each group. She can see if the results show any agreement on particular sites. Although the models will be hypothetical, based on her guesses about how stakeholders think and what they value, she believes that the exercise will be useful in highlighting sources of agreement and disagreement. If she eventually decides to use a negotiation strategy, she can engage in further discussions with the stakeholder groups to verify or change her inputs to the model.

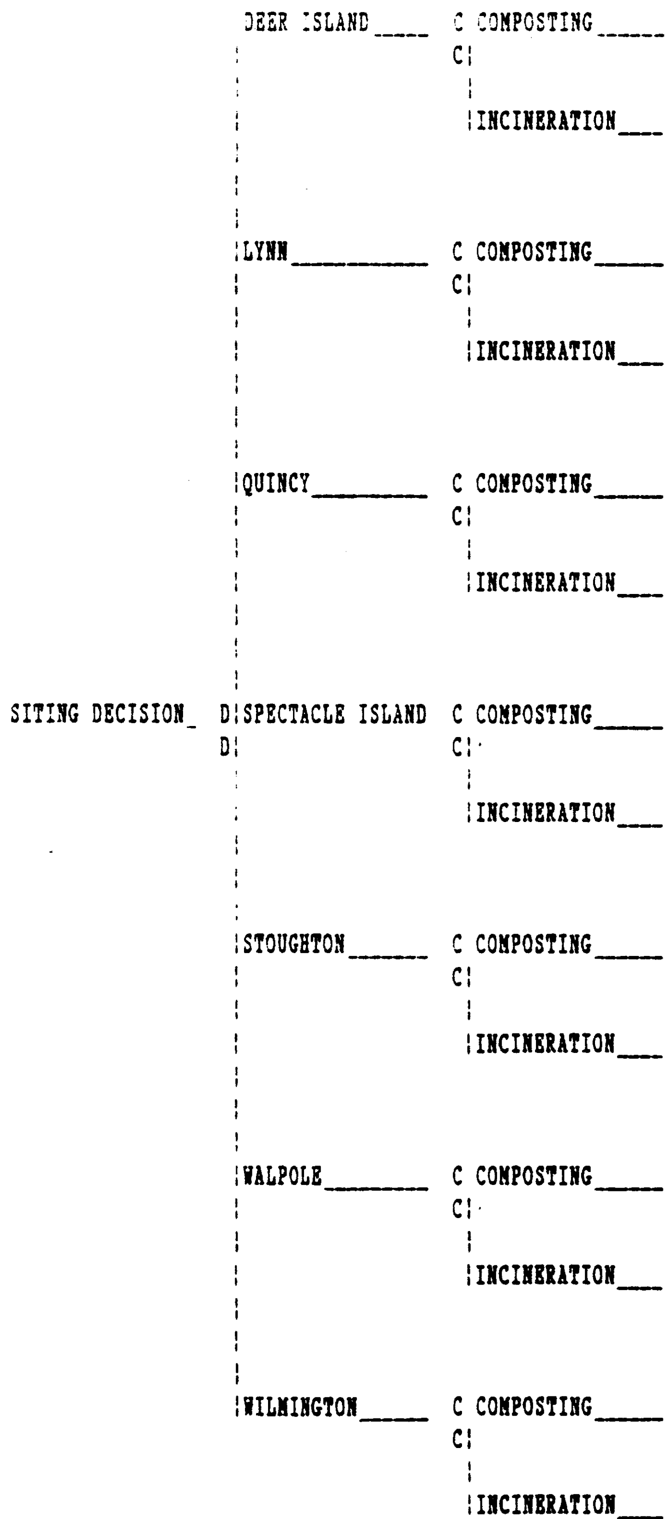
Smith believes that the technology used at the sludge facility will be very important to the stakeholder groups. She constructs a decision tree (Figure 4-1) to represent the problem.

Identifying Stakeholder Groups

First, Smith tried to identify the groups that are affected by the sludge facility siting decision. The most obvious group are the people who live near each candidate sites--the abutters. Smith has a problem--who should she talk to as a representative of these groups? In some communities, notably Winthrop and Quincy, neighborhood groups have already been formed to protest other facilities. However, in many instances, abutters are not organized into a formal group. The MWRA has held several hearings in each community, and developed mailing lists of people who have attended these meetings. In addition, the agency has received many letters from people in the community. Smith uses this information to pick a group of five people (those who have attended and spoken at the most meetings, and who have written the most letters) she judges to be leaders of each neighborhood.

The second most obvious group of stakeholders are the local officials representing each town--mayors, members of boards of selectmen, planning board members, etc. Smith believes that this group may have slightly different interests than abutters. While abutters are most concerned with the immediate physical impacts of the facility, local officials will also be concerned about how a facility would impact the town as a whole--physically, fiscally, and socioeconomically. Smith assembles a group

FIGURE 4-1
DECISION TREE STRUCTURE FOR THE NEGOTIATION MODEL



consisting of the mayor, chairman of the board of selectmen or city council, and chairman of the planning board from each town to represent local officials.

Next, Smith decides to include environmentalists among the stakeholder groups. She believes that there are two types of environmental groups--groups whose primary interest is the cleanup of Boston Harbor, and groups who are more interested in impacts on local environments. She therefore includes two environmental stakeholder groups--harbor environmental groups and local environmental groups. The harbor group consists of representatives of statewide environmental organizations such as the Massachusetts Audubon Society, the Conservation Law Foundation, and Save the Harbor, Save the Bay--all who are interested in Boston Harbor. The local group consists of representatives of smaller groups whose chief concern is local air and water pollution, damage to wetlands and local ecology (whether or not of statewide importance), and impacts on archaeological and historical resources. Smith also includes state and federal environmental regulators as stakeholders in the sludge facility siting decision.

Finally, Smith identifies the MWRA itself and its ratepayers as two separate stakeholder groups. The MWRA has an interest in siting a facility that is technically reliable and environmentally sound. The ratepayers, who will have to pay for the entire harbor cleanup project, have an interest in keeping sludge facility construction costs low. Smith decides to act as the representative of the MWRA; and to use members of the agency's advisory board, made up of representatives of every city and town in the district, as representatives of the ratepayers.

Structuring a Common Objectives Hierarchy

After identifying each stakeholder group and its representatives, Smith holds a series of informal conversations with each group. In these conversations, she tries to understand what objectives each group has for the siting decision, how they would measure performance on each of these objectives, and generally, what their preferences and tradeoffs would be. She does not try to get precise assessments in these conversations; rather, she tries to get a general idea of each groups feelings and beliefs about the siting problem.

First, Smith lists the MWRA's objectives for the siting problem. She believes that the agency is interested in transportation reliability, transportation safety, timely implementation, construction costs, and operating costs. The ratepayers are primarily interested in keeping construction and operating costs low. From her conversations with environmental groups interested in the harbor, she judges that they are concerned with timely implementation of the harbor cleanup, protecting marine ecology and wetlands, and minimizing impacts of marine water resources. Environmental groups more interested in local issues, however, care about protecting local ecology and wetlands, minimizing damage to local surface and ground water resources, preventing air pollution, and avoiding damage to local archaeological and historic resources.

While reviewing her conversations with abutters and local officials from each of the seven communities, Smith discovers that the seven groups of abutters have similar interests, and that the seven groups of local officials have similar interests. In order to simplify her model, she decides to aggregate these 14 separate groups into two groups, abutters and local officials. Abutters are most interested in transportation safety, protection of surface and ground water resources (particularly those used for drinking water), air quality, and minimizing noise impacts. They are also interested in any visual impacts the facility might have--how it will look, and whether it will blend into the neighborhood or be an eyesore. Abutters are also concerned about the socioeconomic impacts of the facility--whether local property values will decline, if the facility will fit into the general neighborhood character, and whether the MWRA's use of the site will prevent other uses that could revitalize the community or provide benefits to the neighborhood. Abutters worry about the fiscal impacts a facility would have on the town--whether their property taxes will rise because the town has to improve its fire and police services to accommodate the sludge treatment facility; or whether the town will lose tax revenues if the sludge facility, which as a state facility is exempt from local taxes, takes the place of development which could bring substantial tax revenues to the community. Finally, abutters are interested in equity--that a community that already "hosts" a regional facility, such as a prison, airport, or other type of waste plant, should not have to bear additional burdens. Abutters believe that regional responsibilities should be distributed among the towns and cities in the region.

Local officials, while interested in physical impacts on their constituents, are primarily concerned with the fiscal impacts and socioeconomic impacts of the facility. In addition, they also believe that regional responsibility should be distributed equitably. State and federal environmental regulators are required by the statutes they enforce to ensure that a sludge facility has minimal impacts on ecology and wetland, water resources, air quality, and archaeological and historic resources. They are also interested in ensuring that access routes used by the sludge transfer trucks and barges are as reliable and as safe as possible. Finally, the regulators desire that the sludge facility construction, as a component of the harbor cleanup, be implemented as quickly as possible.

Smith summarizes the varying objectives of the stakeholder groups in a table (see Table 4-1). She next turns her attention to combining these objectives into a joint objectives hierarchy for all seven groups. Since she believes that the MWRA's and regulators' concern with transportation reliability is related to safety, she combines the reliability aspect with safety to create one objective--"maximize transportation safety". Smith has noticed that the harbor and local environmental groups have different concerns relating to ecology and wetlands--the group interested in the harbor is most concerned with harbor ecology and salt marshes, while the local environmentalists are interested in local ecology and inland wetlands. She therefore splits the ecology and wetlands concern into two objectives--"minimize impacts on harbor ecology and wetlands", and "minimize impacts on inland ecology and wetlands. "

The stakeholder groups' concern with water resources divides into several objectives. The groups are concerned both with surface water and with ground water that is used as a drinking water supply. Harbor environmental groups worry about impacts on marine surface water bodies (e.g., Boston Harbor), while local environmental groups are concerned with a facility's impact on inland lakes, rivers, streams and ponds. Smith breaks the water resources objectives into three new objectives--"minimize impacts on harbor surface water", "minimize impacts on inland surface water", and "minimize impacts on drinking water."

TABLE 4-1
OBJECTIVES FOR INDIVIDUAL STAKEHOLDER GROUPS

MWRA

- Transportation Reliability
- Transportation Safety
- Timely Implementation
- Construction Costs
- Operating Costs

Ratepayers

- Operating Costs
- Construction Costs

Harbor Environmental Groups

- Timely Implementation
- Harbor Ecology and Wetlands
- Harbor Surface Water

Local Environmental Groups

- Inland Ecology and Wetlands
- Inland Surface Water
- Drinking Water
- Air Quality
- Cultural Resources

Abutters

- Transportation Safety
- Equitable Distribution of Regional Responsibility
- Water Resources
- Air Quality
- Noise
- Socioeconomic Impacts
- Fiscal Impacts
- Visual Impacts

Local Officials

- Fiscal Impacts
- Socioeconomic Impact
- Equitable Distribution of Regional Responsibility

Regulators

- Transportation Reliability
- Transportation Safety
- Timely Implementation
- Ecology and Wetlands
- Water Resources
- Air Quality
- Cultural Resources

Smith also adds the other concerns of the stakeholder groups--air quality, noise, visual impacts, damage to archaeological and historical resources, socioeconomic impacts, fiscal impacts, equity, and timely implementation--to the joint objectives hierarchy. Finally, she includes "minimizing construction costs", but eliminates operating costs because as she concluded in designing the technical model, these costs are not site-specific. The final objectives hierarchy is shown in Figure 4-2.

Defining Attributes and Performance Measures

Next, Smith uses the information gained from her discussions with the stakeholder groups to design constructed scales and performance measures for each attribute. (Her final list of objectives and performance measures is displayed in Table 4-2.) The abutter groups had outlined four major conditions they felt entered into a site's transportation safety score: the accident rate of the transportation mode (e.g., barge, truck); the general accident rate along the access route; the type of land use around the access route (e.g., commercial, residential, industrial); and whether any physical or road geometry problems exist that would contribute to unsafe conditions. Smith has no information about accident rates along the routes, so she decides to incorporate only the other three considerations into a constructed scale for transportation safety. The scale is shown in Table 4-3.

Smith uses the constructed scales from the technical model to measure each site's performance on the next two attributes, harbor ecology and wetlands and inland ecology and wetlands. These scales consider a facility's impacts on wetlands, species of special concern, and threatened or endangered species; habitat loss for all on-site species; and impacts on off-site aquatic ecology due to runoff or airborne contaminants. Smith believes

FIGURE 4-2
JOINT OBJECTIVES HIERARCHY FOR SEVEN STAKEHOLDER GROUPS

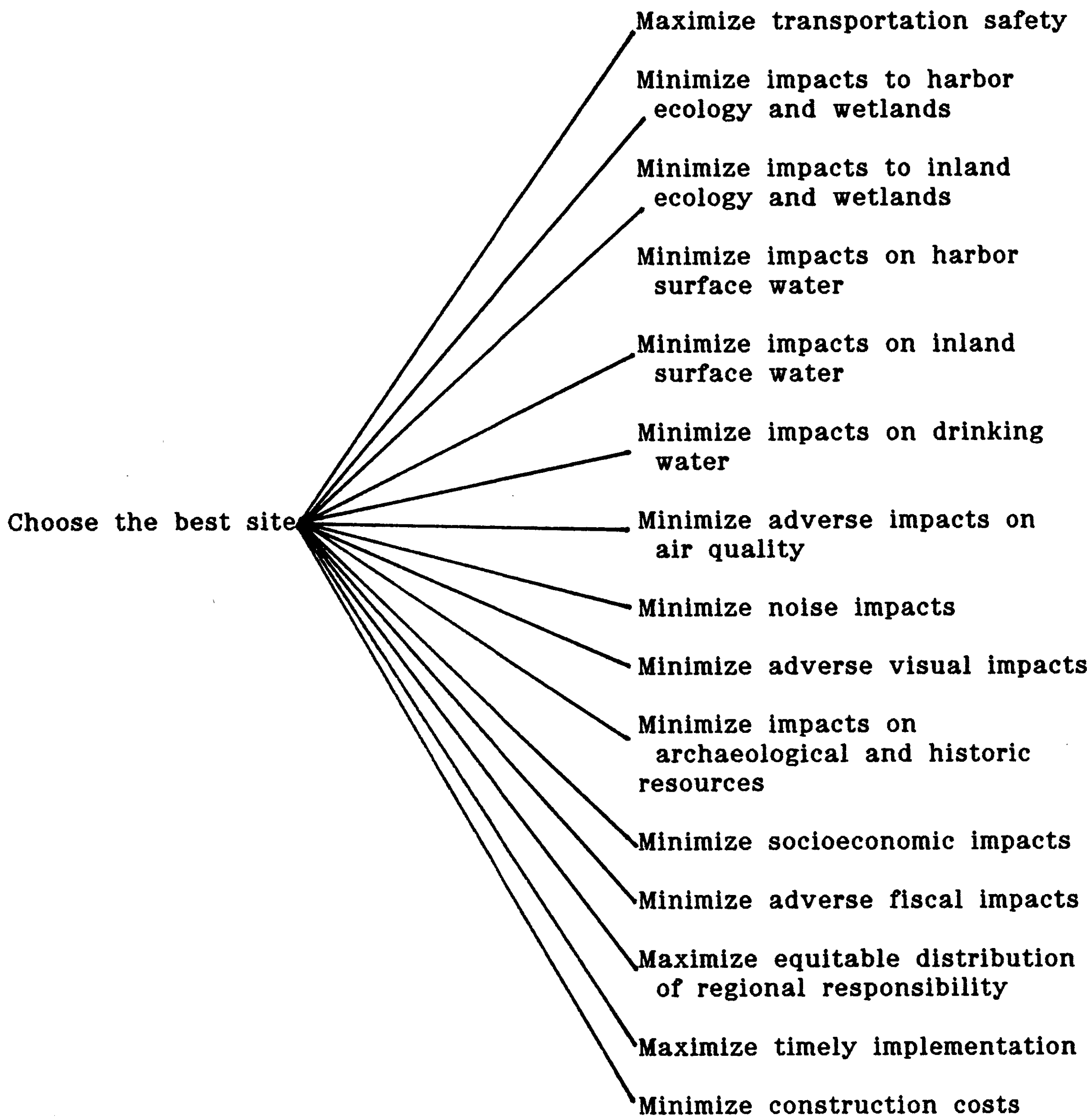


TABLE 4-2
ATTRIBUTES AND PERFORMANCE MEASURES FOR THE SITING DECISION

Objective	Performance Measure
1. Maximize transportation safety	X_1: Constructed scale
2. Minimize adverse impacts on harbor ecological systems	X_2: Constructed scale
3. Minimize adverse impacts on inland ecological systems	X_3: Constructed scale
4. Minimize adverse impacts on harbor surface water bodies	X_4: Constructed scale
5. Minimize adverse impacts on inland surface water bodies	X_5: Constructed scale
6. Minimize adverse impacts on drinking water supplies	X_6: Constructed scale
7. Minimize adverse air quality impacts	X_7: Presence of interaction sources (incineration) Will odors reach sensitive receptors (composting)
8. Minimize noise impacts	X_8: Distance to sensitive receptors (in feet)
9. Minimize visual impacts	X_9: Constructed scale
10. Minimize adverse archaeological, historic or cultural impacts	X_{10}: Constructed scale
11. Minimize socioeconomic impacts	X_{11}: Number of indicators
12. Minimize fiscal impacts	X_{12}: Constructed scale
13. Maximize equitable distribution of regional responsibility	X_{13}: Number of "burdens" already hosted
14. Maximize timely implementation	X_{14}: Number of delay indicators
15. Minimize construction costs	X_{15}: Number of special conditions

TABLE 4-3
CONSTRUCTED SCALE FOR ATTRIBUTE X_1: TRANSPORTATION SAFETY

Impact Level	Accident Potential
0	Little or no accident potential
1	Moderate accident potential
2	High accident potential

these scales encompass the concerns of environmental groups. The scales are located in Tables 4-4 and 4-5.

Smith also decides to use the constructed scales from the technical model to measure harbor and inland surface water impacts. These scales rate a facility's potential for contaminating surface water bodies as low, moderate or high on a particular site. Since the impacts for composting and incineration are different (a compost facility can contaminate water bodies by runoff, an incinerator by deposition of airborne contaminants), there are separate scales for each technology. (Tables 4-6, 4-7, 4-8, 4-9). Smith also uses the technical model's constructed scales for drinking water impacts. These scales rate a facility's potential for contaminating ground water drinking water supplies as non-existent, low, moderate, or high. Once again, impacts differ by technology, so separate scales exist for composting and incineration. (Tables 4-10, 4-11).

The technical model's measurements of air quality and noise will also be used in this model. Air quality for a composting facility is measured by determining whether odors reach sensitive receptors. For incineration, air quality impacts are measured by deciding if there are other facilities nearby whose emissions could interact with the sludge treatment facility's emissions and degrade air quality. Noise impacts are measured by the distance from the facility to the nearest sensitive noise receptor.

Smith must design a new scale to measure visual impacts. The abutter groups have told her that they are concerned that a facility not be an eyesore--that it blend into the neighborhood, or be buffered well so that residents do not notice it. She designs a first cut at a scale that is based on whether the facility will be located near residential neighborhoods, how

TABLE 4-4
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_2: HARBOR ECOLOGY AND WETLANDS

Impact Level	Impacts in the Affected Area
0	No or minor alteration of wetlands; no damage to species of plants or wildlife that are of special concern[1], threatened[2] or endangered[2]; no loss of habitat to any on-site species, or habitat loss that is easily replaceable off-site[3]; no damage to off-site aquatic ecology due to runoff or airborne contaminants
1	Moderate alteration of wetlands; damage to species of plants or wildlife that are of special concern; habitat loss that is moderately replaceable off-site; impacts on off-site aquatic ecology of local importance due to runoff or airborne contaminants
2	Heavy alteration of wetlands; damage to species of plants or wildlife that are threatened or endangered; habitat loss that has limited replaceability off-site; impacts on off-site aquatic ecology of regional importance due to runoff or airborne contaminants

[1] As listed by the Massachusetts Division of Fisheries and Wildlife
[2] As listed by the United States Fish and Wildlife Service
[3] This criterion does not mean that the agency should rebuild habitats off-site; rather, it refers to the ease with which migrating species can find replacement habitats off-site

TABLE 4-5
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_3: INLAND ECOLOGY AND WETLANDS

Impact Level	Impacts in the Affected Area
0	No or minor alteration of wetlands; no damage to species of plants or wildlife that are of special concern[1], threatened[2] or endangered[2]; no loss of habitat to any on-site species, or habitat loss that is easily replaceable off-site[3]; no damage to off-site aquatic ecology due to runoff or airborne contaminants
1	Moderate alteration of wetlands; damage to species of plants or wildlife that are of special concern; habitat loss that is moderately replaceable off-site; impacts on off-site aquatic ecology of local importance due to runoff or airborne contaminants
2	Heavy alteration of wetlands; damage to species of plants or wildlife that are threatened or endangered; habitat loss that has limited replaceability off-site; impacts on off-site aquatic ecology of regional importance due to runoff or airborne contaminants

[1] As listed by the Massachusetts Division of Fisheries and Wildlife
[2] As listed by the United States Fish and Wildlife Service
[3] This criterion does not mean that the agency should rebuild habitats off-site; rather, it refers to the ease with which migrating species can find replacement habitats off-site

TABLE 4-6
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_4: COMPOSTING FACILITY IMPACTS ON HARBOR SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for harbor water contamination due to stormwater runoff
1	Moderate potential for harbor water contamination due to stormwater runoff
2	High potential for harbor water contamination due to stormwater runoff

TABLE 4-7
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_4: INCINERATION FACILITY IMPACTS ON HARBOR SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for harbor water contamination due to deposition of airborne contaminants
1	Moderate potential for harbor water contamination due to deposition of airborne contaminants
2	High potential for harbor water contamination due to deposition of airborne contaminants

TABLE 4-8
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_5: COMPOSTING FACILITY IMPACTS ON INLAND SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for surface water contamination due to stormwater runoff
1	Moderate potential for surface water contamination due to stormwater runoff
2	High potential for surface water contamination due to stormwater runoff

TABLE 4-9
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_5: INCINERATION FACILITY IMPACTS ON INLAND SURFACE WATER

Impact Level	Impacts in the Affected Area
0	No or low potential for surface water contamination due to deposition of airborne contaminants
1	Moderate potential for surface water contamination due to deposition of airborne contaminants
2	High potential for surface water contamination due to deposition of airborne contaminants

TABLE 4-10
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_6: COMPOSTING FACILITY IMPACTS ON DRINKING WATER SUPPLY

Impact Level	Impacts in Affected Area
0	No potential for water supply contamination due to facility runoff
1	Low potential for water supply contamination due to facility runoff
2	Moderate potential for water supply contamination due to facility runoff
3	High potential for water supply contamination due to facility runoff

TABLE 4-11
CONSTRUCTED SCALE FOR PERFORMANCE MEASURE X_6: INCINERATOR FACILITY IMPACTS ON DRINKING WATER SUPPLY

Impact Level	Impacts in Affected Area
0	No potential for deposition of airborne contaminants on aquifer recharge areas
1	Low potential for deposition of airborne contaminants on aquifer recharge areas
2	Moderate potential for deposition of airborne contaminants on aquifer recharge areas
3	High potential for deposition of airborne contaminants on aquifer recharge areas

far from the facility the nearest residences are located, and whether buffering is possible. She then examines this scale to see if it would satisfy the interests of the other stakeholder groups. She believes that the harbor environmental groups will not accept the scale because of its emphasis on residential impacts. Members of these groups are concerned that a sludge treatment facility might ruin harbor views. Smith therefore redesigns her scale to rank visual impacts as minor, moderate, or major. (Table 4-12). This scale is much more general than her first cut scale, and rankings will be dependent on a group's highly subjective view of what minor, moderate or major visual impacts are. She decides that if the results show that visual impacts are very important to the stakeholder groups, she will try to negotiate a more detailed scale to measure these impacts before deciding on a site for the facility.

In her constructed scale for archaeological and historic impacts in the technical model, Smith proposed to measure only those archaeological and historic resources located on each site. Local environmental groups have expressed a concern that a facility could impact historic resources near the site, as well as those on the site. Smith decides to use the same scale, but to include nearby historic resources in the impact assessments for each site. The scale measures a site's archaeological and historic sensitivity as low, moderate or high. The scale is found in Table 4-13.

The abutter groups had very strong opinions about how socioeconomic impacts should be measured. First, they believed that any constructed scale of socioeconomic impacts should include the possible decline of property values near the facility and along transportation routes. Second, the scale should measure whether the MWRA's use of the site will preclude

TABLE 4-12
CONSTRUCTED SCALE FOR ATTRIBUTE X_9: VISUAL IMPACTS

Impact Level	Impacts in Affected Area
0	No or minor visual impacts
1	Moderate visual impacts
2	Major visual impacts

TABLE 4-13
CONSTRUCTED SCALE FOR ATTRIBUTE X_{10}: ARCHAEOLOGICAL AND HISTORIC IMPACTS

Impact Level	Sensitivity at Site
0	Low archaeological and historic sensitivity
1	Moderate archaeological and historic sensitivity
2	High archaeological and historic sensitivity

TABLE 4-14
CONSTRUCTED SCALE FOR ATTRIBUTE X_{12}: FISCAL IMPACTS

Impact Level	Impacts Predicted
0	No negative fiscal impacts
1	Low fiscal impacts
2	Moderate fiscal impacts
3	Heavy fiscal impacts

other projects that could revitalize a community or provide benefits to a neighborhood. Third, the scale should measure whether a sludge facility is consistent with neighborhood character. Fourth, the facility's impact on a community's open space and recreational areas should be included. Will the MWRA be building the facility on land that was once a park, or used by neighborhood children as playing fields? Fifth, the scale should measure the impacts that could occur if construction and permanent workers at the facility migrate into the community. Will the community have to build more schools, and increase the level of other services such as police and fire protection? Finally, the abutters want any socioeconomic scale to measure the "stigma" that could be attached to a community if a sludge facility is located there--a reputation as the region's "sludge dump", etc.

Smith assumes that any construction and permanent workers migrating from outside the greater Boston area will not congregate in the facility's host community, but will settle in many towns in the area. She therefore eliminate inmigrant impacts from the scale. She decides to include the other five criteria in the scale. She will measure a site's performance on the socioeconomic objective by counting how many socioeconomic conditions could result from a sludge facility being located in the town. The five conditions are:

Property values in the vicinity of the site will drop.

The MWRA's use of the site will affect future revitalization efforts.

The MWRA's plans are inconsistent with neighborhood character.

Locating the facility on this site will cause the community to lose open space.

Locating the facility on this site will cause the community to be viewed by others as a "dump site".

Smith decides to measure the next attribute, fiscal impacts, by calculating the revenues localities will lose in taxes if the site is used by the MWRA. The MWRA, a state agency, is exempt from local property taxes. Although the agency will probably pay the host community payments in lieu of taxes, Smith decides to ignore that possibility in this model, so that she can determine which communities would suffer the greatest amount of lost revenues. The revenues can be lost because a state agency takes over a site where property taxes are currently being paid, or because the state takes over a site for which revenue-generating projects, such as condominium of industrial parks, have been proposed. Because Smith has no information about local tax rates and revenues, she decides to construct a scale that ranks negative fiscal impacts of the facility as non-existent, low, moderate, or heavy. The scale is found in Table 4-14.

Measuring the next attribute, equitable distribution of regional responsibility, requires some negotiation between abutters, local officials and the MWRA. In public meetings held before Smith assumed her position at the agency, the MWRA asked communities to list the regional facilities they hosted that people considered "burdens". The resulting list contained waste disposal facilities, prisons, airports, power stations, and public transportation stations. Smith does not consider public transportation stations, which benefit people living nearby, to be regional "burdens". She therefore eliminates these from her list of facilities already hosted by each community. A site's performance on the equity attribute will be measured by the number of burdens a town or city already hosts.

Environmental groups and regulators have identified four possible causes of delay in timely implementation of the project. These are:

Delay caused by the need to clean up hazardous waste on a site before permits can be issued.

Delay caused by political opposition to the site from state legislators and other politicians.

Delay caused by the necessity to negotiate or coordinate with other agencies proposing to use a site.

Delay caused by public protest, in the form of litigation or civil disobedience.

A site's performance on this attribute will be measured by the number of possible causes of delay at each site.

In her discussions with abutters, Smith has discovered that they are not concerned with timely implementation at all. In fact, Smith believes that abutters value sites where delay will occur more highly than other sites. Since most abutters do not want a facility in their "backyard", they value anything that could delay or prevent implementation of a siting decision. Because abutters' interests on the timely implementation attribute are in opposition to those of other groups, Smith decides to eliminate the attribute from her model for abutters.

The final attribute, minimizing construction costs, is measured with the same scale as in the technical model. The scale measures the number of special circumstances at each site that could cause additional costs. (See Table 2-9 in Chapter II).

Assessing Impacts and Probabilities

Next, Smith makes educated guesses based on her discussions with members of the stakeholder groups to assess each site's performance on each attribute.[6] All seven groups judge the transportation safety impacts of a sludge facility on Deer Island to be minimal. Sludge will be transported to and from Deer Island by barge, and on routes that will not interfere with recreational boating. Sludge could be brought to the Lynn site either by barge or by truck. The MWRA, ratepayers, both environmental groups, and regulators believe that the sludge will be transported by truck, and that transportation safety impacts will be moderate. The access road to the Lynn site is a commercial/industrial strip with some awkward turns, a few pedestrian crossings, and signalized intersections. Local officials and abutters believe there is an even chance that sludge will be transported by barge. If this situation occurs, these groups predict a high accident potential at the Lynn site, since the barges will have to go through Lynn Harbor, an area congested with recreational boats in the summer.

At the Quincy site, sludge will arrive by barge and leave by truck, rail or barge. The MWRA, ratepayers, environmental groups, and regulators judge that transportation safety impacts at this site will be minor. Local officials and abutters believe there is some possibility that impacts will be moderate, because there is a lot of boat traffic in the Fore River and because nearby streets are congested. All groups judge impacts at Spectacle Island to be minimal, since sludge will arrive at and leave the island by

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6. The text discusses general differences and similarities among the impact assessments and probability judgments of the various groups; the detailed assessments and probabilities are found in the accompanying tables.

barge on routes that will not interfere with recreational boating and other harbor traffic. The MWRA, ratepayers, environmental groups and regulators believe that impacts at the Stoughton site will likely be minimal, because the access route is a commercial road with no physical or geometry problems. Local officials and abutters, however, believe there is a 50 percent chance that impacts will be moderate, because sensitive land uses around the route--a small park, school bus routes--would increase the probability of accidents.

The MWRA, ratepayers, environmental groups,and regulators judge that there is a 60 percent probability that there will be a high potential for accidents at the Walpole site. The site is located in the midst of residential areas, and the access roads were not designed for truck use. There are also a lot of sensitive uses along the access route--several schools, a library, and recreational areas. Local officials and abutters agree that impacts will be severe, but they do not see any uncertainties around the assessment--they believe that the probability of high accident potential is 100 percent. Two options exists for access to the Wilmington site. The MWRA prefers to use Ballardvale Road, a commercial/industrial strip. However, if the town of Wilmington decides to renovate Ballardvale Road, the sludge trucks will have to detour through a residential area during construction. The MWRA, ratepayers, environmental groups and regulators believe there is 40 percent chance that impacts will be moderate (if the residential road must be used), and a 60 percent chance that impacts will be minimal (the agency can use Ballardvale Road without interruption). All of the groups' impact and probability assessments for the transportation safety attribute are detailed in Table 4-15.

TABLE 4-15

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_1: TRANSPORTATION SAFETY

SITE	MWRA	RATEPAYERS	HARBOR ENV	LOCAL ENV	ABUTTERS	LOCAL OFFICIALS	REGULATORS
DEER ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
LYNN	1 (.9) 2 (.1)	1 (.9) 2 (.1)	1 (.9) 2 (.1)	1 (.9) 2 (.1)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.9) 2 (.1)
QUINCY	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.7) 1 (.3)	0 (.7) 1 (.3)	0 (.9) 1 (.1)
SPECTACLE ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
STOUGHTON	0 (.8) 1 (.2)	0 (.8) 1 (.2)	0 (.8) 1 (.2)	0 (.8) 1 (.2)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.8) 1 (.2)
WALPOLE	1 (.4) 2 (.6)	1 (.4) 2 (.6)	1 (.4) 2 (.6)	1 (.4) 2 (.6)	1 (0) 2 (1.0)	1 (0) 2 (1.0)	1 (.4) 2 (.6)
WILMINGTON	0 (.6) 1 (.4)	0 (.6) 1 (.4)	0 (.6) 1 (.4)	0 (.6) 1 (.4)	0 (.3) 1 (.7)	0 (.3) 1 (.7)	0 (.6) 1 (.4)

NOTE: figures outside parentheses are impact level assessments; figures inside parentheses are probability assessments

Next, Smith measures performance on the second attribute, harbor ecology and wetlands. All of the stakeholder groups believe that there is a greater chance that impacts on harbor ecology and wetlands from a sludge facility on Deer Island will be severe than moderate. The reason for this is that there is limited replaceability for the habitats that will be destroyed by construction of the facility. Both environmental groups and regulators judge the probability that impacts will be severe to be slightly more than that judged by the MWRA, ratepayers, local officials, and abutters. At the Lynn site, construction of a facility could alter 10 acres of wetlands. The MWRA, ratepayers, local officials and abutters judge that there is a 50 percent chance that impacts on harbor ecology will be moderate, rather than minimal, at this site. Environmental groups and regulators believe the probability that impacts will be moderate, not minimal, is 70 percent.

At the Quincy site, the MWRA, ratepayers , local officials and abutters believe that impacts will probably be minimal, with a 10 percent chance that they could be severe. Environmental groups and regulators believe there is a 30 percent chance that impacts could be severe. On Spectacle Island, the limited replaceability of habitats and the possible contamination of lobster trapping grounds leads the MWRA, ratepayers, local officials and abutters to judge that there is an 80 percent chance that impacts will be severe. Environmental groups and regulators assess that probability at 90 percent. No impacts to harbor ecology and wetlands are expected at the Stoughton, Walpole and Wilmington sites, because these sites are not located on the coast. The impact and probability assessments of all seven groups are located in Table 4-16.

TABLE 4-16

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_2: HARBOR ECOLOGY AND WETLANDS

SITE	MWRA	RATEPAYERS	HARBOR ENV	LOCAL ENV	ABUTTERS	LOCAL OFFICIALS	REGULATORS
DEER ISLAND	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.1) 2 (.9)
LYNN	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.3) 1 (.7)	0 (.3) 1 (.7)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.2) 1 (.7)
QUINCY	0 (.8) 1 (.1) 2 (.1)	0 (.8) 1 (.1) 2 (.1)	0 (.5) 1 (.2) 2 (.3)	0 (.5) 1 (.2) 2 (.3)	0 (.8) 1 (.1) 2 (.1)	0 (.8) 1 (.1) 2 (.1)	0 (.5) 1 (.2) 2 (.3)
SPECTACLE ISLAND	1 (.2) 2 (.8)	1 (.2) 2 (.8)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.2) 2 (.8)	1 (.2) 2 (.8)	1 (.1) 2 (.9)
STOUGHTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WALPOLE	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WILMINGTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)

No impacts are expected at the Deer Island, Lynn, Quincy, and Spectacle Island sites for the third attribute, inland ecology and wetlands. At the Stoughton site, the MWRA, ratepayers, local officials, abutters, and harbor environmental groups judge that the probability that impacts could be severe due to the possible alteration of more than 20 acres of wetlands is 50 percent. Local environmental groups and regulators believe this probability to be 70 percent. The MWRA, ratepayers, abutters, local officials and harbor environmental groups assess a 10 percent chance that impacts will be severe at the Walpole site, due to contamination of the Neponset River. Local environmental groups and regulators believe that a probability of 40 percent is more accurate. In Wilmington, local environmental groups and regulators believe that limited replaceability of habitats justifies a 90 percent probability that impacts will be severe, while the other stakeholder groups believe the probability is 70 percent. Detailed impact and probability assessments for this attribute are found in Table 4-17.

All seven stakeholder groups agree that there is a high potential for stormwater runoff from a composting pile or airborne contaminants from an incinerator on Deer Island or Spectacle Island to contaminate harbor surface water. The groups also agree that there is a 50 percent probability of moderate contamination of harbor surface water at the Lynn and Quincy sites. Because the Stoughton, Walpole and Wilmington sites are located inland, there will be no impact on harbor surface water from a facility at these sites. The impact and probability assessments are in Tables 4-18 and 4-19.

No impacts on inland surface water are expected from facilities located at the Deer Island, Lynn, Quincy and Spectacle Island sites. The

TABLE 4-17

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_3: INLAND ECOLOGY AND WETLANDS

SITE	MWRA	Ratepayers	Harbor Env	Local Env	Abutters	Local Officials	Regulators
DEER ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
LYNN	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
QUINCY	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
SPECTACLE ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
STOUGHTON	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.3) 2 (.7)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.3) 2 (.7)
WALPOLE	0 (.2) 1 (.7) 2 (.1)	0 (.2) 1 (.7) 2 (.1)	0 (.2) 1 (.7) 2 (.1)	0 (.1) 1 (.5) 2 (.4)	0 (.2) 1 (.7) 2 (.1)	0 (.2) 1 (.7) 2 (.1)	0 (.1) 1 (.5) 2 (.4)
WILMINGTON	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.1) 2 (.9)	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.1) 2 (.9)

TABLE 4-18

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_4: COMPOSTING FACILITY IMPACTS ON HARBOR SURFACE WATER

SITE	MWRA	Ratepayers	Harbor Env.	Local Env.	Abutters	Local Officials	Regulators
DEER ISLAND	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)
LYNN	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
QUINCY	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
SPECTACLE ISLAND	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)
STOUGHTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WALPOLE	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WILMINGTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)

TABLE 4-19

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_4: INCINERATOR FACILITY IMPACTS ON HARBOR SURFACE WATER

SITE	MWRA	Ratepayers	Harbor Env.	Local Env.	Abutters	Local Officials	Regulators
DEER ISLAND	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)
LYNN	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
QUINCY	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
SPECTACLE ISLAND	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.1) 2 (.9)
STOUGHTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WALPOLE	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
WILMINGTON	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)

stakeholder groups agree that the probability that impacts would be severe at the Stoughton site is 50 percent, and that they would be moderate at the Walpole site, 50 percent. Moderate impacts are also predicted for the Wilmington site. The impact and probability assessments are located in Tables 4-20 and 4-21.

The groups disagree about the potential for drinking water supply contamination due to runoff from a composting pile at several sites. They agree that there is a 90 percent chance that there will be no water supply contamination from a composting facility at Deer Island, Quincy or Spectacle Island. The MWRA, ratepayers, and harbor environmental groups assess the probability that a moderate potential for contamination exists at the Lynn site at 10 percent, while abutters, local environmental groups, regulators and local officials believe this probability to be 30 percent. At the Stoughton site, the MWRA, ratepayers and harbor environmental groups assess a 50 percent probability that impacts will be high; while abutters, local environmental groups, regulators and local officials assess this probability at 80 percent. At both the Walpole and Wilmington sites, the MWRA, ratepayers and harbor environmental groups believe the probability of moderate impact is 10 percent, while abutters, local environmental groups, regulators and local officials judge it to be higher, at 30 percent. The impact and probability assessments are detailed in Table 4-22.

Abutters, local environmental groups, regulators and local officials judge the potential for deposition of airborne contaminants from a sludge incinerator on aquifer recharge areas to be more probable than do the MWRA, ratepayers and harbor environmental groups. The former groups believe

TABLE 4-20

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_5: COMPOSTING FACILITY IMPACTS ON INLAND SURFACE WATER

SITE	MWRA	Ratepayers	Harbor Env.	Local Env.	Abutters	Local Officials	Regulators
DEER ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
LYNN	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
QUINCY	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
SPECTACLE ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
STOUGHTON	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)
WALPOLE	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
WILMINGTON	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)

TABLE 4-21

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_5: INCINERATOR FACILITY IMPACTS ON INLAND SURFACE WATER

SITE	MWRA	Ratepayers	Harbor Env.	Local Env.	Abutters	Local Officials	Regulators
DEER ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
LYNN	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
QUINCY	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
SPECTACLE ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
STOUGHTON	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)
WALPOLE	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
WILMINGTON	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)

TABLE 4-22

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_6: COMPOSTING FACILITY IMPACTS ON DRINKING WATER

SITE	MWRA	Ratepayers	Harbor Env	Local Env.	Abutters	Local officials	Regulators
DEER ISLAND	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)
LYNN	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)
QUINCY	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)
SPECTACLE ISLAND	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)	0 (.9) 1 (.1)
STOUGHTON	2 (.5) 3 (.5)	2 (.5) 3 (.5)	2 (.5) 3 (.5)	2 (.2) 3 (.8)	2 (.2) 3 (.8)	2 (.2) 3 (.8)	2 (.2) 3 (.8)
WALPOLE	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)
WILMINGTON	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.8) 2 (.1)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)	0 (.1) 1 (.6) 2 (.3)

airborne particulates can travel farther, thus impacting larger areas. The impact and probability assessments are found in Table 4-23.

None of the groups disagree with the MWRA's judgments about how far odors will travel from a composting facility and whether there are other facilities whose emissions might interact with those from a sludge incinerator and degrade air quality. The groups agree that odors will reach sensitive receptors at the Lynn, Quincy, Stoughton, Walpole and Wilmington sites, and that there is uncertainty around the estimates at the Lynn and Stoughton sites. (The odor distance calculations are shown in Table 4-24). Interaction sources are present at the Deer Island and Lynn sites, and might be present at the Quincy site sometime in the future. The parties also agree with the MWRA's noise impact assessments (Table 4-25).

The stakeholder groups assess the visual impacts of the facility separately for each technology. At the Deer Island site, the immediate surrounding land use is the MWRA's sewage treatment plant. The MWRA, ratepayers, regulators and local officials believe that a composting facility will have no or minor visual impacts at Deer Island. These groups judge that a medium to tall incinerator stack would have moderate visual impacts. Environmental groups and abutters, on the other hand, believe that a composting facility will have moderate impacts, and that an incinerator would have a major visual impact.

The Lynn site is currently used for industrial purposes--the neighborhood includes truck parking for a dairy plant, and the city of Lynn's sewage treatment plant and sludge landfill. The MWRA, ratepayers, regulators and local officials judge that a composting facility will have little or no visual impacts at the Lynn site, and that an incinerator would have

TABLE 4-23

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_6: INCINERATOR FACILITY IMPACTS ON DRINKING WATER

SITE	MWRA	Ratepayers	Harbor Env.	Local Env	Abutters	Local Officials	Regulators
DEER ISLAND	0 (.8)	0 (.8)	0 (.8)	0 (.6)	0 (.6)	0 (.6)	0 (.6)
	1 (.2)	1 (.2)	1 (.2)	1 (.4)	1 (.4)	1 (.4)	1 (.4)
LYNN	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)
	1 (.7)	1 (.7)	1 (.7)	1 (.5)	1 (.5)	1 (.5)	1 (.5)
	2 (.2)	2 (.2)	2 (.2)	2 (.4)	2 (.4)	2 (.4)	2 (.4)
QUINCY	0 (.8)	0 (.8)	0 (.8)	0 (.6)	0 (.6)	0 (.6)	0 (.6)
	1 (.2)	1 (.2)	1 (.2)	1 (.4)	1 (.4)	1 (.4)	1 (.4)
SPECTACLE ISLAND	0 (.8)	0 (.8)	0 (.8)	0 (.6)	0 (.6)	0 (.6)	0 (.6)
	1 (.2)	1 (.2)	1 (.2)	1 (.4)	1 (.4)	1 (.4)	1 (.4)
STOUGHTON	2 (.5)	2 (.5)	2 (.5)	2 (.2)	2 (.2)	2 (.2)	2 (.2)
	3 (.5)	3 (.5)	3 (.5)	3 (.8)	3 (.8)	3 (.8)	3 (.8)
WALPOLE	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)	0 (.1)
	1 (.7)	1 (.7)	1 (.7)	1 (.5)	1 (.5)	1 (.5)	1 (.5)
	2 (.2)	2 (.2)	2 (.2)	2 (.4)	2 (.4)	2 (.4)	2 (.4)
WILMINGTON	1 (.1)	1 (.1)	1 (.1)	1 (.1)	1 (.1)	1 (.1)	1 (.1)
	2 (.7)	2 (.7)	2 (.7)	2 (.5)	2 (.5)	2 (.5)	2 (.5)
	3 (.2)	3 (.2)	3 (.2)	3 (.4)	3 (.4)	3 (.4)	3 (.4)

TABLE 4-24
CALCULATION OF ODOR IMPACTS

Site	Distance Odors Will Travel	Distance to Nearest Sensitive Receptor	Odors Will Impact Sensitive Receptor
Deer Island	734--2217*	5280	No
Lynn	734--2217*	2000	Yes**
Quincy	656--984	500	Yes
Spectacle Island	1640	4000	No
Stoughton	656--984	800	Yes**
Walpole	734--2217*	500	Yes
Wilmington	2624	1000	Yes

* Estimate based on mean distance at other sites plus or minus one standard deviation
** Uncertain because of range

TABLE 4-25
DISTANCE FROM SITE TO SENSITIVE NOISE RECEPTORS

Site	Distance to Sensitive Receptors (in feet)
Deer Island	5280
Lynn	2000
Quincy	500
Spectacle Island	4000
Stoughton	800
Walpole	500
Wilmington	1000

moderate impacts. The environmental groups and abutters believe that the composting facility would have moderate impact, and that an incinerator would have major visual impacts.

The Quincy site is a former shipyard that still contains numerous dry docks and cranes. Proposals have been made to build a hazardous waste incinerator to the south of the site, and to reopen an electrical power plant directly across the river. The MWRA, ratepayers, regulators, and local officials believe that both the composting facility and the incinerator would have no visual impacts at the Quincy site. Environmental groups and abutters believe that both facilities would have moderate visual impacts.

A 90-foot high draft chimney from an abandoned grease extraction plant remains on Spectacle Island. The MWRA, ratepayers, regulators and local officials believe that a composting facility would have no visual impact on views of Boston Harbor, while an incinerator might have moderate impacts. Environmental groups and abutters (people who live near the Harbor) believe that a composting facility would have moderate impacts, and an incinerator would have major visual impacts.

The Stoughton site is located near an industrial park and several sand and gravel operations. No residences are directly next to the site, but instead are located around the wider industrial area. The MWRA, ratepayers, regulators, local officials and harbor environmental groups judge that a composting facility at Stoughton would have no visual impacts, and that an incinerator would have moderate impacts. Local environmental groups and abutters, however, judge that the composting facility would have moderate impacts, and that the incinerator would have major visual impacts.

The Walpole site is located on the former Bird family estate. Tree cover on the site would provide a partial visual buffer between the facility and residences nearby. The MWRA, ratepayers, regulators, local officials and harbor environmental groups believe that a composting facility would have moderate visual impacts on the neighborhood, and that an incinerator would have major impacts. Local environmental groups and abutters believe that both the composting facility and incinerator would have major impacts on the area.

The Wilmington site is surrounded by single family residences, an office park, and light industrial and commercial businesses. The MWRA, ratepayers, regulators, local officials and harbor environmental groups judge that a composting facility would have moderate visual impacts, and that an incinerator would have major impacts. Local environmental groups and abutters believe that both facilities would have major visual impacts on the neighborhood. The impact assessments for all of the groups are summarized in Tables 4-26 and 4-27.

Next, Smith guesses at impact and probability assessments for archaeological and historic resources. The MWRA, ratepayers, local officials, regulators and abutters all believe that the Deer Island has a 50 percent chance of having a moderate archaeological and historic sensitivity,and a 50 percent chance of having low archaeological and historic sensitivity. Both environmental groups believe that the probability of moderate sensitivity is 60 percent, while the probability of low sensitivity at Deer Island is 40 percent. At the Lynn site, all stakeholder groups agree that archaeological and historic sensitivity is low, because the site is on filled ground. The MWRA, ratepayers, local officials, regulators and abutters believe that there

TABLE 4-26

IMPACT ASSESSMENTS FOR ATTRIBUTE X_9: VISUAL IMPACTS OF A COMPOSTING FACILITY

SITE	MWRA	RATEPAYERS	HARBOR ENV	LOCAL ENV	ABUTTERS	LOCAL OFFICIALS	REGULATORS
DEER ISLAND	0	0	1	1	1	0	0
LYNN	0	0	1	1	1	0	0
QUINCY	0	0	1	1	1	0	0
SPECTACLE ISLAND	0	0	1	1	1	0	0
STOUGHTON	0	0	0	1	1	0	0
WALPOLE	1	1	1	2	2	1	1
WILMINGTON	1	1	1	2	2	1	1

TABLE 4-27

IMPACT ASSESSMENTS FOR ATTRIBUTE X_9: VISUAL IMPACTS OF AN INCINERATOR FACILITY

SITE	MWRA	Ratepayers	HARBOR ENV	LOCAL ENV	ABUTTERS	LOCAL OFFICIALS	Regulators
DEER ISLAND	1	1	2	2	2	1	1
LYNN	1	1	2	2	2	1	1
QUINCY	0	0	1	1	1	0	0
SPECTACLE ISLAND	1	1	2	2	2	1	1
STOUGHTON	1	1	1	2	2	1	1
WALPOLE	2	2	2	2	2	2	2
WILMINGTON	2	2	2	2	2	2	2

is a 50 percent chance that the Quincy site will have moderate archaeological and historic sensitivity. Environmental groups believe that probability to be 60 percent. An archaeological site has already been discovered on Spectacle Island. The MWRA, ratepayers, local officials, regulators and abutters believe that there is a 50 percent probability that the entire site has high archaeological and historic sensitivity. Environmental groups believe that probability to be 70 percent. At the Stoughton site, environmental groups believe there is a 50 percent chance that the sludge facility will have high impacts on the Mary Baker Eddy homestead located one-half mile from the site. The rest of the stakeholder groups believe that probability to be 10 percent. The Walpole site is located in an area of extremely high archaeological sensitivity and the site contains a mansion eligible for the National Register of Historic Places. All of the groups agree that the site has high archaeological and historic sensitivity. The Wilmington site is surrounded by a core area of prehistoric activity. Environmental groups believe that the probability that the site has high archaeological and historic sensitivity is 90 percent, while the MWRA, ratepayers, local officials, regulators and abutters believe the probability is 70 percent. The impact and probability assessments are contained in Table 4-28.

Socioeconomic impacts are measured by the number of indicators of impact at each site. These indicators are: whether property values will decline; whether the MWRA's use of the site precludes revitalization efforts; whether the MWRA's use of the site is consistent with neighborhood character; and whether the community will lose open space. Deer Island is reserved for the MWRA's sewage treatment plant. Property values around the site will not decline if a sludge treatment facility is built there--it is

TABLE 4-28

IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE K_{10} : ARCHAEOLOGICAL AND HISTORIC RESOURCES

SITE	MWRA	Ratepayers	Harbor Env	Local Env	Abutters	Local officials	Regulators
DEER ISLAND	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.4) 1 (.6)	0 (.4) 1 (.6)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
LYNN	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
QUINCY	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.4) 1 (.6)	0 (.4) 1 (.6)	0 (.5) 1 (.5)	0 (.5) 1 (.5)	0 (.5) 1 (.5)
SPECTACLE ISLAND	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.5) 2 (.5)
STOUGHTON	1 (.9) 2 (.1)	1 (.9) 2 (.1)	1 (.5) 2 (.5)	1 (.5) 2 (.5)	1 (.9) 2 (.1)	1 (.9) 2 (.1)	1 (.9) 2 (.1)
WALPOLE	2 (1.0)	2 (1.0)	2 (1.0)	2 (1.0)	2 (1.0)	2 (1.0)	2 (1.0)
WILMINGTON	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.1) 2 (.9)	1 (.1) 2 (.9)	1 (.3) 2 (.7)	1 (.3) 2 (.7)	1 (.3) 2 (.7)

assumed that property values would have dropped a long time ago, when the primary sewage treatment plant was built. The MWRA's plans for the site are consistent with neighborhood character, and the community will not lose any open space if a sludge facility is built on Deer Island. Since Deer Island is already the site of the sewage treatment plant, no stigma should attach to the community.

All of the stakeholder groups agree that none of the socioeconomic indicators are present at Deer Island.

No residences border the Lynn site, so property values are not expected to drop. The area in which the site is located is already used for the city of Lynn's sewage treatment plant and sludge landfill, so the MWRA's sludge facility would be consistent with neighborhood character. The community would not lose open space if a sludge facility was built on the site. The MWRA's use of the site would conflict with the city's plans to revitalize the Lynn Harbor waterfront, however. Several developers have proposed to build shopping, hotel and condominiums near the site, and to develop a harborfront park area. The city's reputation could suffer if a sludge treatment facility was built on the site. The seven stakeholder groups all agree that two socioeconomic indicators are present at the Lynn site.

No revitalization projects are planned by the city of Quincy for the Fore River Shipyard. The shipyard is being used by the MWRA for interim sludge treatment and as staging areas for the construction of the secondary treatment plant on Deer Island, so a sludge facility would not be inconsistent with neighborhood character. The city would not lose open space if a sludge facility was built at the shipyard. The stakeholder groups are uncertain whether a sludge facility would result in declining property values near the site. The MWRA, ratepayers, harbor environmentalists, local environmentalists, and regulators argue that property values around the shipyard declined years ago, and that no further decline would result from the sludge facility. They judge that the probability that property values would decline is about 50 percent. Abutters and local officials, however, believe that the probability of declining property values is 70 percent. They also believe that Quincy would suffer from a "stigma" is the sludge treatment plant were sited there. The other groups, arguing that Quincy is already the site of the MWRA's staging area and the interim sludge treatment plant, believe that no stigma would attach to Quincy.

No residences are located around Spectacle Island, so there would be no decline in property values if a sludge facility were built on the island. The island has been used as a dump for years, so a sludge facility would be consistent with "neighborhood character", and the City of Boston would not lose open space if facility were built. There have been proposals to revitalize Spectacle Island and make it into a harbor park. The MWRA's use of the island for a sludge facility would block these efforts. All of the groups believe there is a 70 percent probability that the MWRA's use of Spectacle Island would preclude revitalization efforts. No stigma is expected to attach to the City of Boston if a sludge facility were built on the island.

Some single family residences are located near the Stoughton site, and it is expected that their owners could experience a decline in property value. Much of the site is currently forested, so the town would lose open space if the MWRA built a sludge facility there. The rest of the site is used for gravel and asphalt plants, so a sludge facility would be consistent with the neighborhood character. No revitalization plans have been proposed for the area. Stoughton could gain a reputation as the region's "sludge dump" if the facility were located there. All of the stakeholder groups agree that three socioeconomic indicators are present at the Stoughton site.

The Walpole site is located in a residential area, so the MWRA's use of it for a sludge facility would be inconsistent with neighborhood character. The community could suffer from stigma. Homeowners could expect a decline in property values. Most of the site is currently open space, and part of the site has been identified in the town's open space master plan as a candidate for purchase as conservation land. A plan has been proposed to change the zoning in the area so that cluster housing could be built on the site. All of the groups agree that five socioeconomic indicators are present at the Walpole site.

Some residences are located near the Wilmington site, and homeowners could experience a decline in property values. A residential subdivision is being developed at the eastern end of the site, so the MWRA's use of the site for a sludge facility would be inconsistent with neighborhood character. The town could suffer from the stigma of being the region's "sludge dump". The site is currently forested, so the town would lose open space if a sludge facility was built. No revitalization projects have been proposed for the area. The stakeholder groups agree that four socioeconomic indicators are present at the Wilmington site. The indicators at each site and probability assessments for all of the groups are found in Table 4-29.

Next, Smith measures each site's performance on the fiscal impact attribute. This attribute is measured by whether localities will lose no, low, moderate or large amounts of revenues because a state agency would be

TABLE 4-29
SOCIOECONOMIC INDICATORS AT EACH SITE

<u>Deer Island</u> 0

<u>Lynn</u> 2

Conflict with revitalization efforts
Stigma

<u>Quincy</u>

Abutters and local officials: 1 (.3)* 2 (.7)
All other groups: 0 (.5) 1 (.5)

Property value decline**
Stigma***

<u>Spectacle Island</u> All groups: 0 (.3) 1 (.7)

Conflict with revitalization efforts**

<u>Stoughton</u> 3

Property value decline
Loss of open space
Stigma

<u>Walpole</u> 5

Property value decline
Conflict with revitalization efforts
Inconsistent with neighborhood character
Loss of open space
Stigma

<u>Wilmington</u> 4

Property value decline
Inconsistent with neighborhood character
Loss of open space
Stigma

*Probability
**Uncertainty
***Disagreement

occupying the site. The Deer Island site is already owned by the MWRA. No fiscal impacts are expected at this site by any of the seven stakeholder groups. The Lynn site is privately owned, and three companies pay taxes on it. Several uses have been proposed for the site, including marine-based industrial projects, and some spillover effect from a large mixed use residential and hotel project directly to the south of the site. The MWRA, environmental groups, ratepayers, regulators and abutters all believe that the probability that no development occurs on the site, and that the city of Lynn loses only the current taxes paid, will be 60 percent. In that case, the fiscal impacts of the sludge treatment facility would be low. Local officials believe the probability of this scenario to be only 40 percent. They judge the probability that mixed use development could spill over to the site, resulting in large tax revenues to the city, to be 50 percent. If the MWRA used the site for a sludge facility, the fiscal impacts would therefore be very heavy. The other stakeholder groups judge the probability of this scenario to be only 10 percent.

The Quincy site is owned by the MWRA, so all of the groups agree that there will be no fiscal impacts on the city of Quincy if a sludge facility is sited there. Spectacle Island is owned by the city of Boston and the Commonwealth of Massachusetts. No taxes are paid on it now, and none would be paid if the island became a public park. The Stoughton site is privately owned, and several gravel and asphalt companies are paying taxes on the land. Proposed uses for the site include a small commercial project and scattered industrial development. These projects would bring medium-sized revenues to the town. The MWRA, environmental groups, regulators, ratepayers and abutters believe the probability that this development would occur is 20 percent. If the MWRA used the site for a sludge facility, precluding commercial or industrial development, the town would suffer moderate fiscal impacts. Local officials judge the probability of this scenario occurring to be 50 percent.

The Walpole site is also privately owned. The site is industrially zoned, but there are proposals to change the zoning to allow clustered residential development. Local officials believe the probability that the zoning will be changed and the cluster housing developed to be 50 percent. If the MWRA's siting precluded this development, the town would suffer heavy fiscal impacts. The local officials judge that there is a 30 percent probability that the site will be developed as currently zoned. The other stakeholder groups assign a 20 percent probability to the cluster development scenario, and judge that there is a 20 percent probability that industrial development would take place on the site. They believe that the probability that no development would occur on the site is 60 percent.

The Wilmington site is privately owned. No developments have been proposed for the site. However, a residential subdivision has been created at the eastern end of the site. Local officials judge the probability that more subdivisions would be created on the site to be 50 percent. The other stakeholder groups believe this probability to be 20 percent. If residential development was precluded by a sludge facility, the town would suffer moderate fiscal impacts. The impact and probability assessments for each group are summarized in Table 4-30.

The equitable distribution of regional responsibility attribute is measured by the number of regional "burdens" a community already hosts. Deer Island already contains the MWRA's wastewater treatment plant, and a correctional facility. The people of the nearby town of Winthrop also bear

TABLE 4-30
IMPACT AND PROBABILITY ASSESSMENTS FOR ATTRIBUTE X_{12}: FISCAL IMPACTS

SITE	MWRA	RATEPAYERS	HARBOR ENV	LOCAL ENV	ABUTTERS	LOCAL OFFICIALS	REGULATORS
DEER ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
LYNN	1 (.6) 2 (.3) 3 (.1)	1 (.6) 2 (.3) 3 (.1)	1 (.6) 2 (.3) 3 (.1)	1 (.6) 2 (.3) 3 (.1)	1 (.6) 2 (.3) 3 (.1)	1 (.4) 2 (.1) 3 (.5)	1 (.6) 2 (.3) 3 (.1)
QUINCY	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
SPECTACLE ISLAND	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
STOUGHTON	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.5) 2 (.5)	1 (.8) 2 (.2)
WALPOLE	1 (.6) 2 (.2) 3 (.2)	1 (.6) 2 (.2) 3 (.2)	1 (.6) 2 (.2) 3 (.2)	1 (.6) 2 (.2) 3 (.2)	1 (.6) 2 (.2) 3 (.2)	1 (.2) 2 (.3) 3 (.5)	1 (.6) 2 (.2) 3 (.2)
WILMINGTON	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.8) 2 (.2)	1 (.5) 2 (.5)	1 (.8) 2 (.2)

the noise impacts from nearby Logan International Airport. As part of a negotiated agreement with the town of Winthrop over the secondary treatment plant siting, the city of Boston agreed to move the correctional facility before 1991. The MWRA, environmental groups, ratepayers and regulators therefore do not include the correctional facility as a regional burden hosted by Winthrop. Local officials and abutters, however, believe that Winthrop should be credited for having hosted the facility, whether it will be moved or not. They believe that the Deer Island site hosts three regional burdens, while the other groups believes it hosts only two.

Local officials and abutters argue that the city of Lynn hosts a regional burden because it has a sewage treatment plant that is used by the city, and the nearby towns of Saugus and Nahant. The other stakeholder groups believe that this facility is not really "regional", since it benefits the city of Lynn directly, and serves only two other towns. They judge that Lynn does not host any regional burdens.

The city of Quincy is already host to the MWRA's staging areas and interim sludge treatment facility at the Fore River Shipyard. In addition, a hazardous waste incinerator will be built near the border of the city. Other proposals for the areas include the restarting of a large, regional electrical plant across the river from the shipyard, and the construction of a solid waste incinerator in nearby Weymouth. The MWRA, environmental groups, ratepayers and regulators believe there is only a 10 percent chance that these last two facilities will be built, thereby giving Quincy five regional burdens. Local officials and abutters believe that there is a 30 percent probability that these projects will be constructed.

Spectacle Island, Stoughton and Wilmington do not host any regional burdens. The town of Walpole, however, is the site of a state prison. All of the stakeholder groups agree that Walpole hosts one regional burden. A list of burdens hosted by each site and each stakeholder group's probability assessments is found in Table 4-31.

Four considerations make up the measure of a site's performance on the next attribute, timely implementation. They are: delay caused by permitting problems; delay caused by political problems; delay caused by competing public uses; and delay caused by local protest. The six stakeholder groups (not including abutters) judge that only one of these indicators will be present at the Deer Island site. The people of Winthrop feel that they have hosted enough regional facilities, and they are certain to protest a sludge facility. The Lynn site is contaminated with hazardous waste, and will involve permitting delays. In addition, political delays may occur because the site is privately owned, and the MWRA must get legislative approval to take the land by eminent domain. There are thus two delay indicators present at the site. In addition, the stakeholder groups believe that there is a 50 percent chance that local protest could delay construction of the facility.

The Quincy site is contaminated with hazardous waste, and may involve permitting delays. In addition, the people of Quincy are expected to protest the siting decision, because they already host the MWRA's staging facility, its interim sludge treatment plant, and several other regional facilities. At Spectacle Island, permitting delays are expected because of the amount of trash and waste on the site. In addition, political delays might occur because a powerful politician has proposed developing the island into a

TABLE 4-31
NUMBER OF REGIONAL BURDENS HOSTED BY EACH COMMUNITY

<u>Deer Island</u> — Abutters and local officials: 3
All other groups: 2

Sewage treatment plant
Logan Airport
(City of Boston correctional facility)

<u>Lynn</u> — Abutters and local officials: 1
All other groups: 0

(Lynn sewage treatment plant)

<u>Quincy</u> — Abutters and local officials: 3 (.4)* 4 (.3) 5 (.3)
All other groups: 3 (.7) 4 (.2) 5 (.1)

MWRA staging area
Interim sludge facility
Clean Harbors hazardous waste facility
Edgar Power Station**
Weymouth solid waste incinerator**

<u>Spectacle Island</u> 0

<u>Stoughton</u> 0

<u>Walpole</u> 1

Cedar Junction MCI--state prison

<u>Wilmington</u> 0

*Probability
**Uncertainty

harbor park. There might also be a competing use for the island--the state Secretary of Transportation has proposed using Spectacle Island as the dump for fill from a large road construction project in the Boston area. In addition, people who live around the harbor might protest the use of the island for a sludge facility. The stakeholder groups believe the probability that all four delay indicators will be present at the Spectacle Island site to be 10 percent. They judge that there is a 60 percent chance that three indicators will be present at the site.

Political delay could result from the choice of Stoughton as the site of the sludge facility, because the land is privately owned, and legislative approval is required for its acquisition. In addition, the stakeholder groups believe that there is a 50 percent chance that local protest could delay timely implementation of the sludge project. Legislative approval is also required for acquisition of the Walpole site, and people in Walpole are expected to protest the siting decision since they already host a state prison. At the Wilmington site, the need for legislative approval could delay construction of the facility. The stakeholder groups also judge that there is a 50 percent chance that local protest could delay implementation of the project. The delay indicators and probability assessments for all sites are listed in Table 4-32.

Measurement of the final attribute, construction cost, is performed the same as in the technical model. All of the stakeholder groups agree with the MWRA's assessment on this attribute. The cost indicators for each site and the groups' probability assessments are summarized in Table 4-33.

TABLE 4-32
CONDITIONS THREATENING TIMELY IMPLEMENTATION--BY SITE

Deer Island	1
Local protest	
Lynn	2 (.5)* 3 (.5)
Permitting delay	
Political delay	
Local protest**	
Quincy	2
Permitting delay	
Local protest	
Spectacle Island	2 (.3) 3 (.6) 4 (.1)
Permitting delay	
Political delay	
Competing use**	
Local protest	
Stoughton	1 (.5) 2 (.5)
Political delay	
Local protest**	
Walpole	2
Political delay	
Local protest	
Wilmington	1 (.5) 2 (.5)
Political delay	
Local protest**	

*Probability
**Uncertainty

TABLE 4-33
SPECIAL CONDITIONS THAT COULD RAISE CONSTRUCTION COSTS--BY SITE

<u>Deer Island</u> 5
Blasting
Moderate soil cleanup
Moderate water cleanup
Dewatering
Unique or scarce resources

<u>Lynn</u> 6 (.6)* 7 (.3) 8 (.1)
Blasting
Moderate soil cleanup
Extensive soil cleanup**
Moderate water cleanup
Dewatering
Transportation improvements
Unique or scarce resources
Site utilities**

<u>Quincy</u> 5
Moderate soil cleanup
Extensive soil cleanup
Moderate water cleanup
Dewatering
Unique or scarce resources

<u>Spectacle Island</u> 6
Moderate soil cleanup
Moderate water cleanup
Dewatering
Transportation improvements
Unique or scarce resources
Site utilities

<u>Stoughton</u> 3 (.5) 4 (.2) 5 (.2) 6 (.1)
Blasting
Moderate soil cleanup**
Moderate water cleanup**
Dewatering
Transportation improvements
Site utilities**

<u>Walpole</u> 1 (.7) 2 (.3)
Transportation improvements
Site utilities**

<u>Wilmington</u> 3 (.7) 4 (.3)
Blasting
Dewatering
Transportation improvements
Site utilities**

* Probability
** Uncertainty

Assessing Preferences

Smith now turns her attention to assessing preferences for the impact levels of each attribute. She decides to put herself in the position of the representatives of each stakeholder group, and to make guesses about each group's preferences. She uses the five-point assessment method discusses in the technical model chapter. Her "utility guesses" for the attributes are displayed in Figures 4-3 through 4-16. As in the technical model, the utility for a "yes" answer on the air quality attribute is 0, and for a "no" answer, 1.

The utility graphs show the different risk attitudes stakeholder groups have about different attributes. For example, all of the groups are risk-averse on the first attribute, transportation safety (Figure 4-3). However, local officials and abutters are more risk-averse than are the MWRA, ratepayers, both environmental groups and regulators. The MWRA and ratepayers are risk-neutral on the noise attribute (Figure 4-9). Abutters, on the other hand, are very risk-averse. On the equity attribute (Figure 4-14), the MWRA, ratepayers, both environmental groups and regulators are "risk-prone"--they prefer a lottery with equal chances of a best and a worst outcome to a certainty. Abutters and local officials are very risk-averse on this attribute. Environmental groups, abutters and regulators are risk-neutral on the construction cost attribute (Figure 4-16). The MWRA, ratepayers and local officials are all risk-averse on this attribute. [7]

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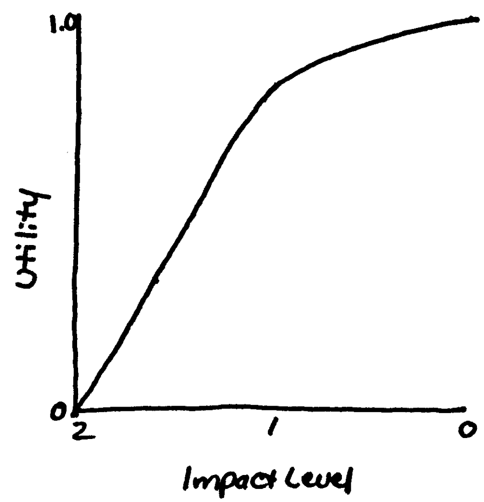
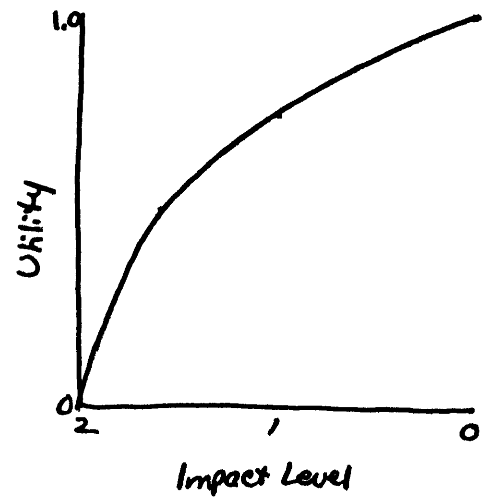
7. Local officials are judged to be risk-averse on construction costs because they must decide how to assess their constituent ratepayers for MWRA rate increases. The MWRA is a wholesale provider of sewer and water services to cities and towns; the local governments are responsible for distributing the wholesale cost among individual homeowners and businesses.

FIGURE 4-3

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_1 : TRANSPORTATION SAFETY



MWRA
Ratepayers
Harbor Environmental Groups
Local Environmental Groups
Regulators



Local Officials
Abutters

FIGURE 4-4

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_2: HARBOR ECOLOGY AND WETLANDS

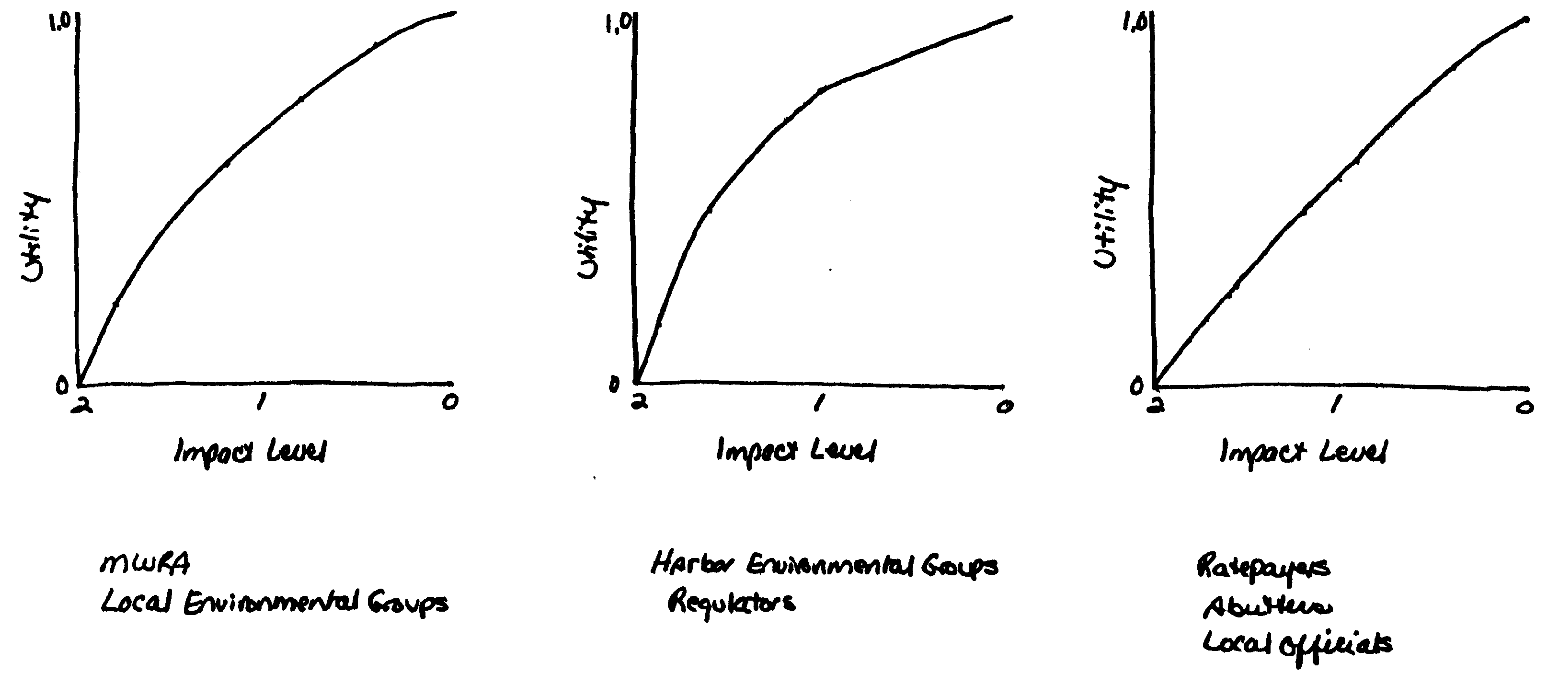
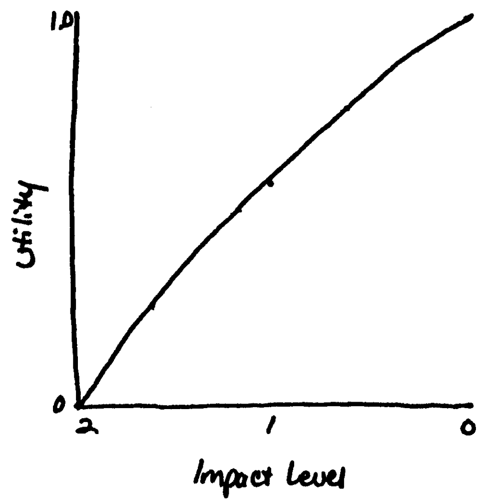
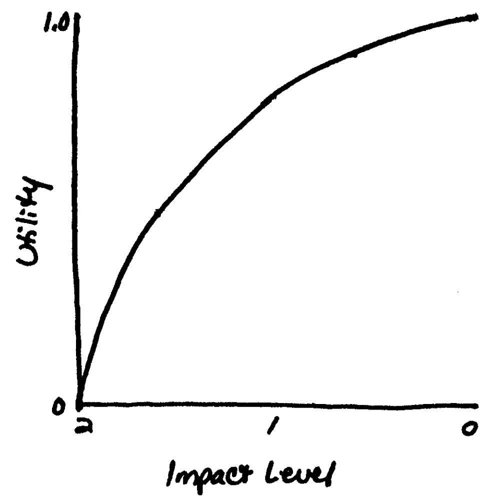


FIGURE 4-5

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_3: INLAND ECOLOGY AND WETLANDS



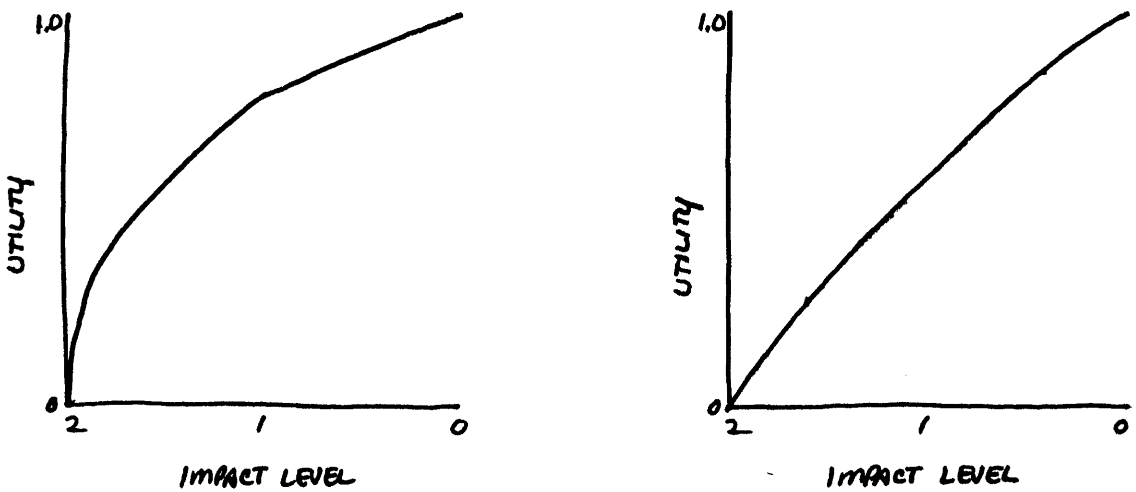
MWRA
Harbor Environmental Groups
Ratepayers
Abutters
Local Officials



Local Environmental Groups
Regulators

FIGURE 4-6

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_4: HARBOR SURFACE WATER

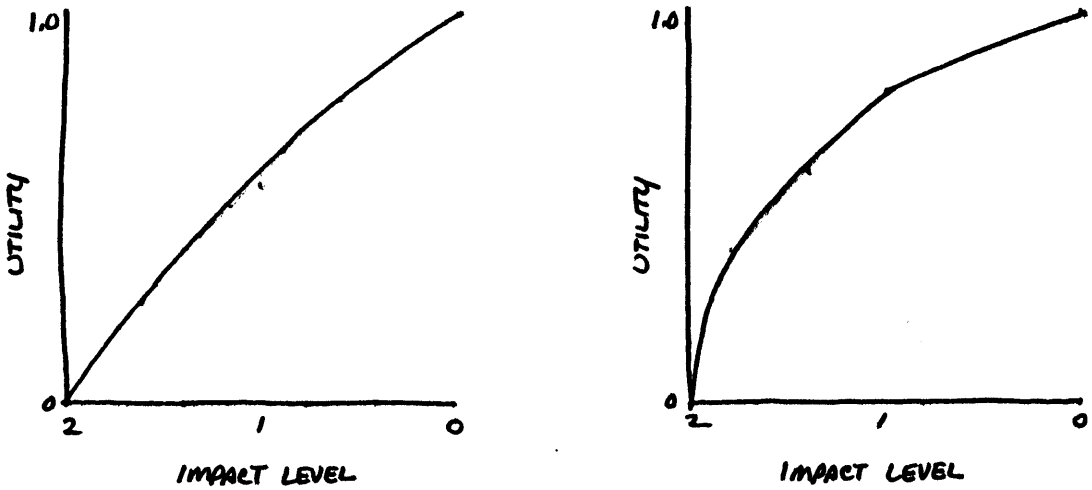


MWRA
Harbor Environmental Groups
Regulators
Ratepayers

Abutters
Local Officials
Local Environmental Groups

FIGURE 4-7

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_5: INLAND SURFACE WATER

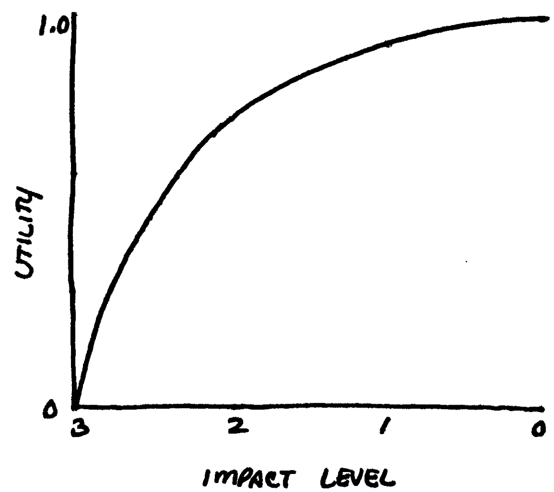


MWRA
Harbor Environmental Groups
Ratepayers
Abutters
Local Officials

Local Environmental Groups
Regulators

FIGURE 4-8

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_6 : DRINKING WATER



ALL GROUPS

FIGURE 4-9

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_8: NOISE

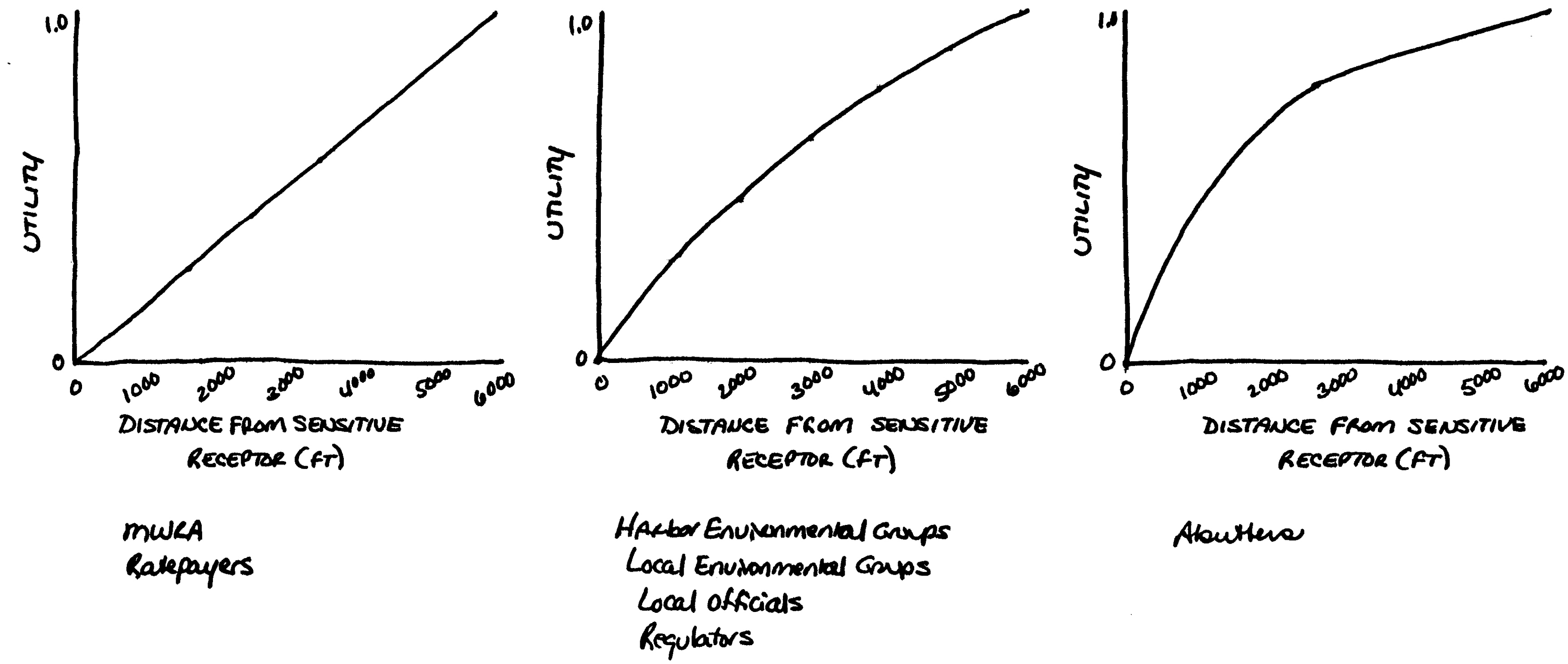


FIGURE 4-10

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_9: VISUAL IMPACTS

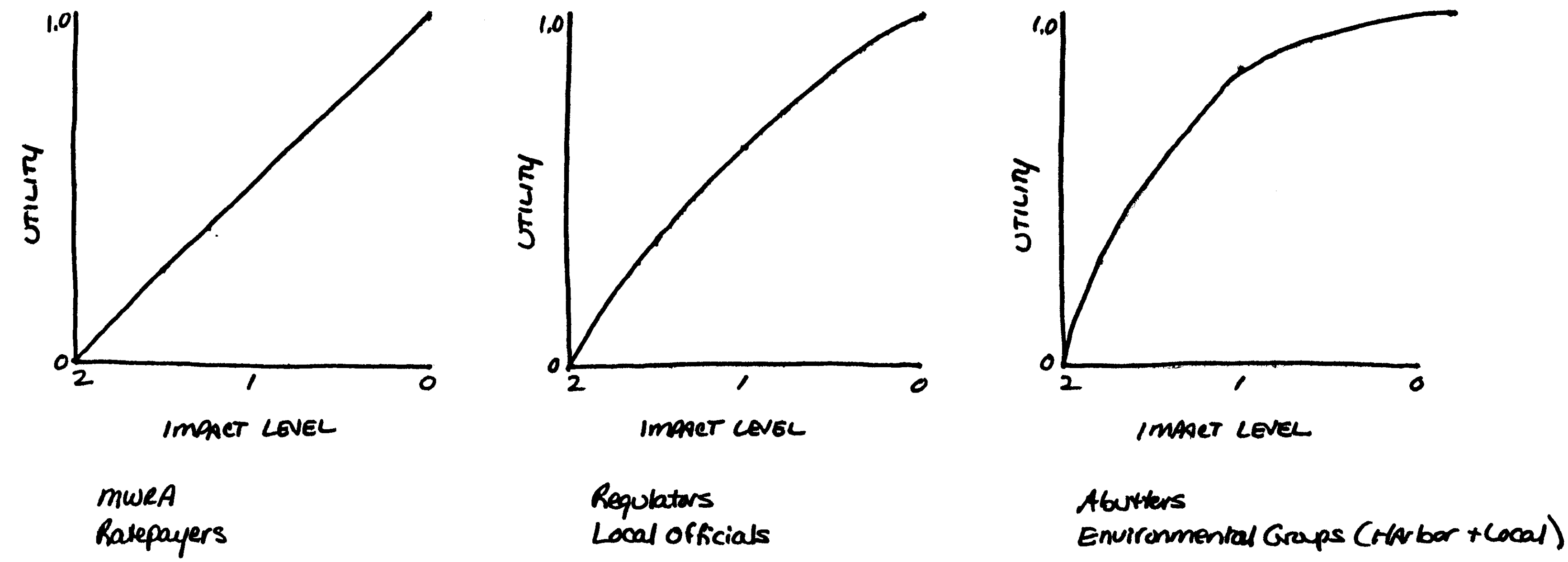


FIGURE 4-11

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_{10}: IMPACTS ON ARCHAEOLOGICAL AND HISTORIC RESOURCES

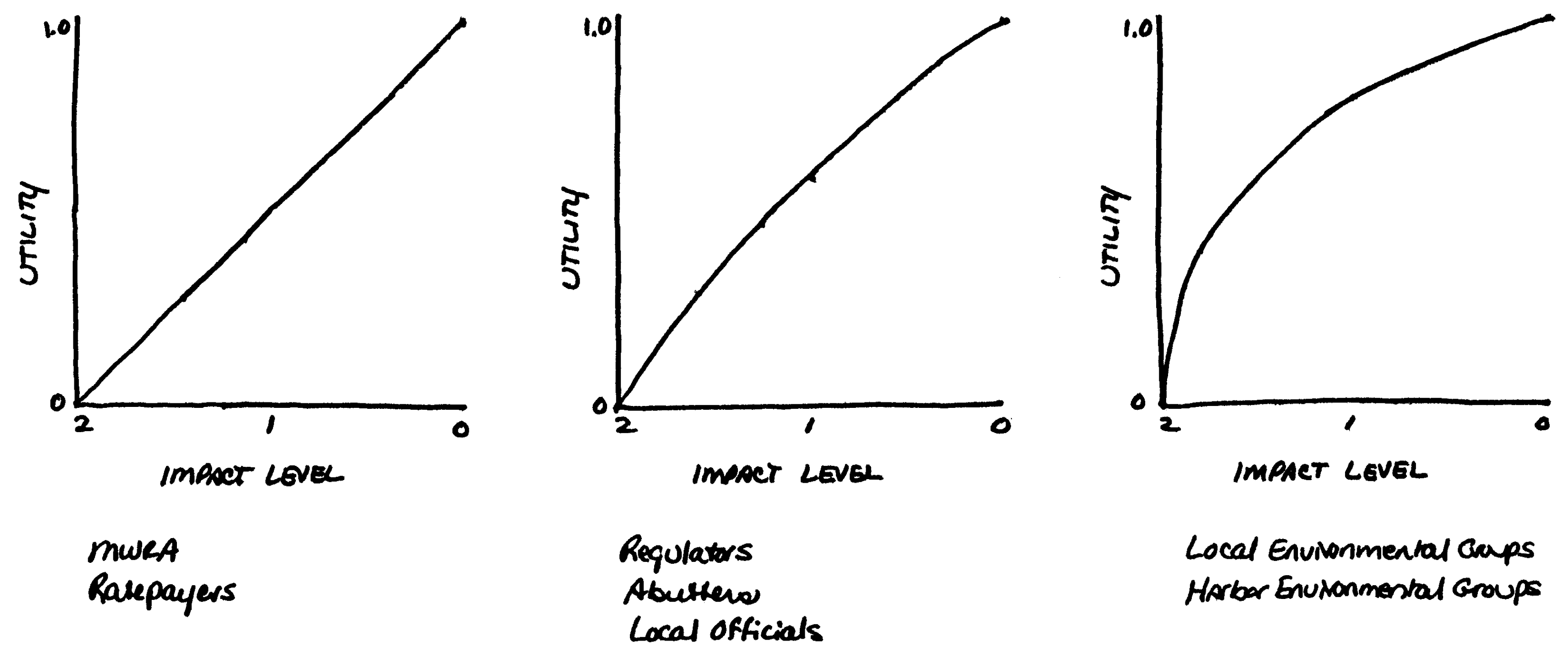
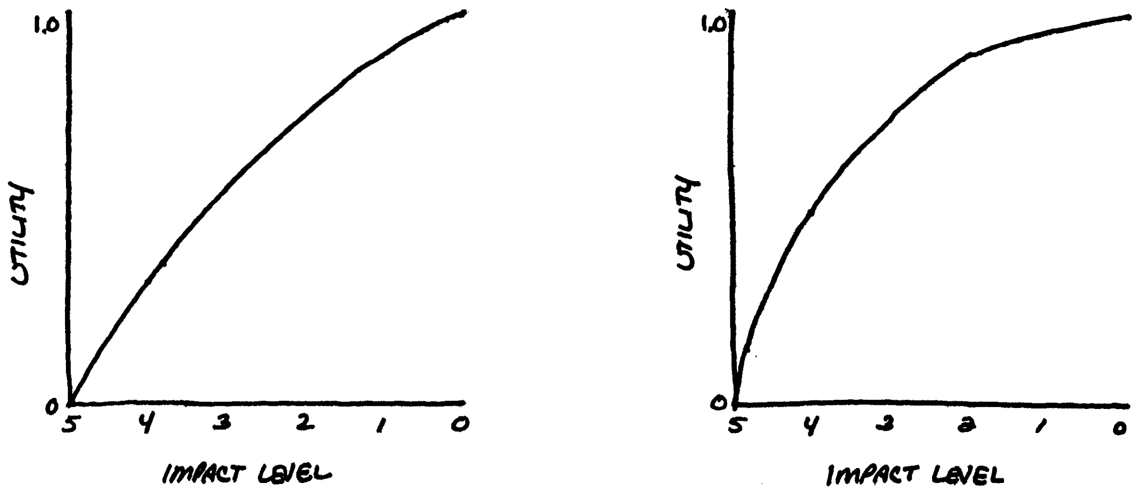


FIGURE 4-12

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_{11}: SOCIOECONOMIC IMPACTS



MWRA
Regulators
Harbor Environmental Groups
Local Environmental Groups
Ratepayers

Abutters
Local Officials

FIGURE 4-13

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_{12}: FISCAL IMPACTS

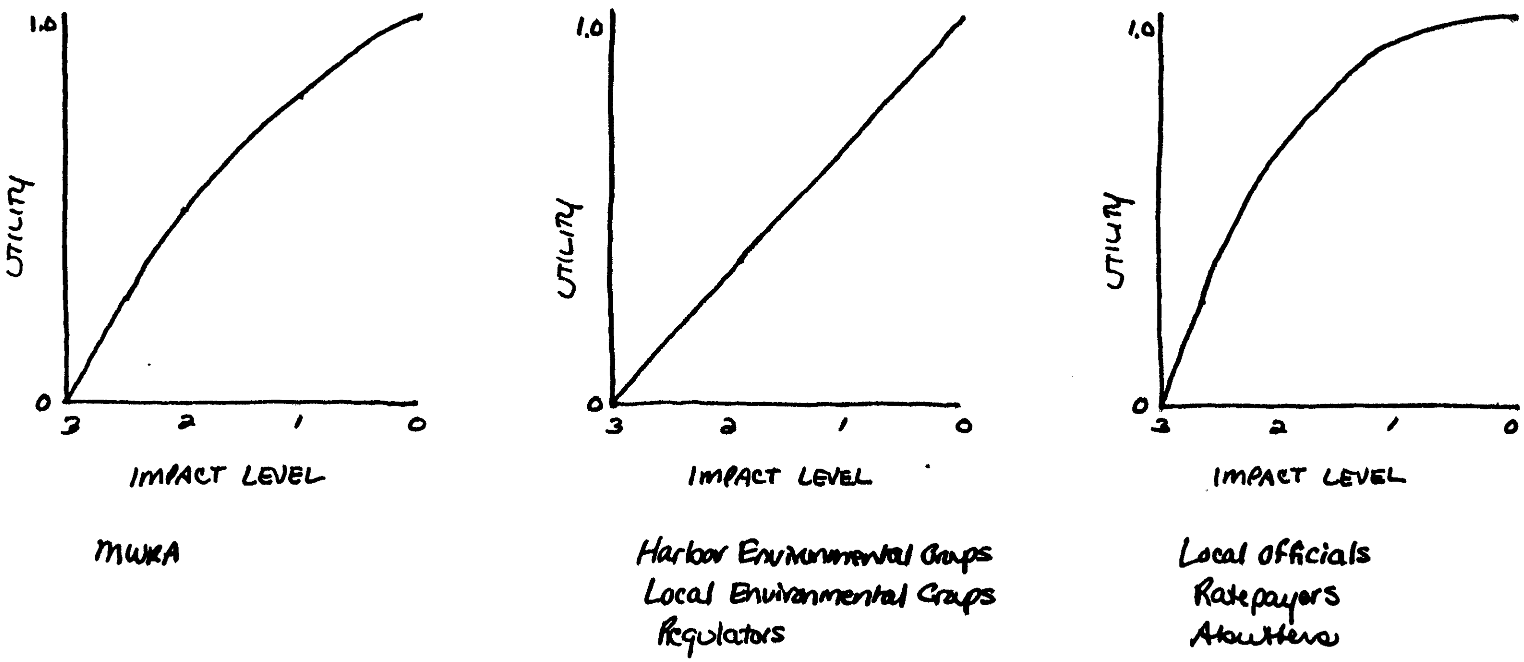
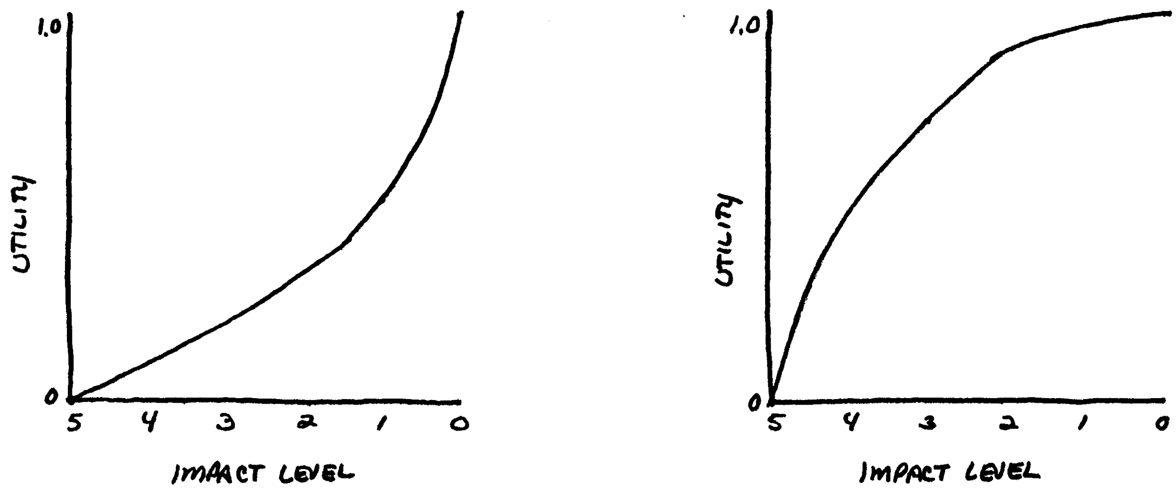


FIGURE 4-14

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_{13}: EQUITABLE DISTRIBUTION OF REGIONAL RESPONSIBILITY

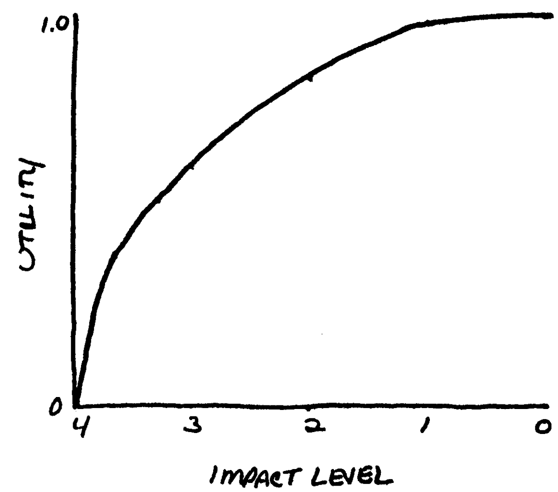


MWRA
Ratepayers
Harbor Environmental Groups
Local Environmental Groups
Regulators

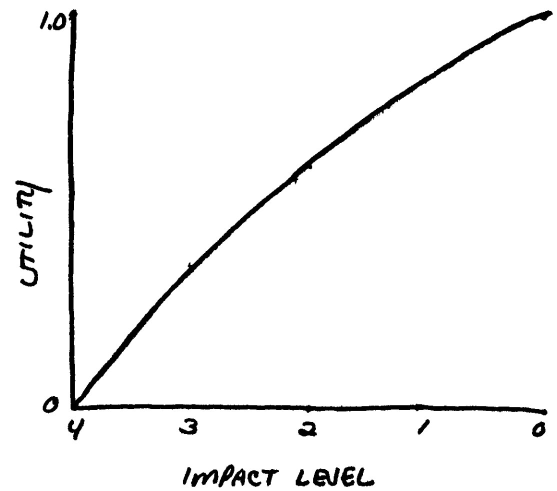
Abutters
Local Officials

FIGURE 4-15

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE X_{14}: TIMELY IMPLEMENTATION



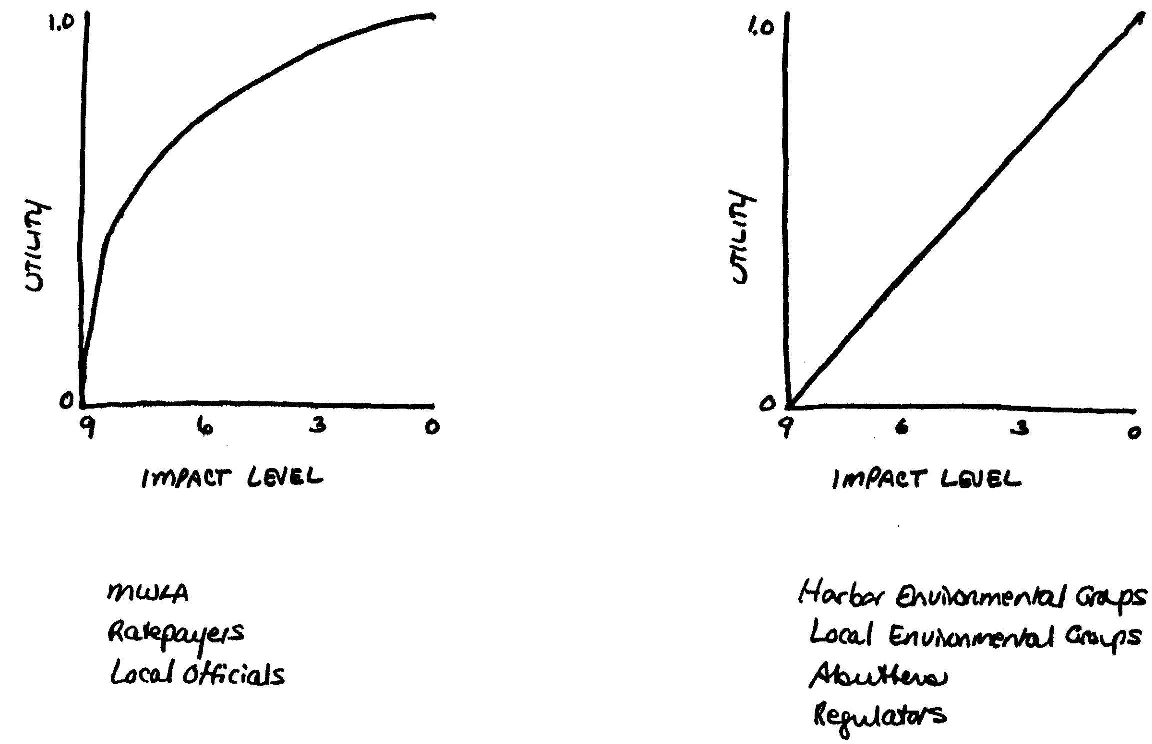
MWRA
Ratepayers
Harbor Environmental Groups
Regulators



Local Environmental Groups
Local Officials

FIGURE 4-16

STAKEHOLDER GROUPS' UTILITIES FOR ATTRIBUTE K_{15} : CONSTRUCTION COSTS



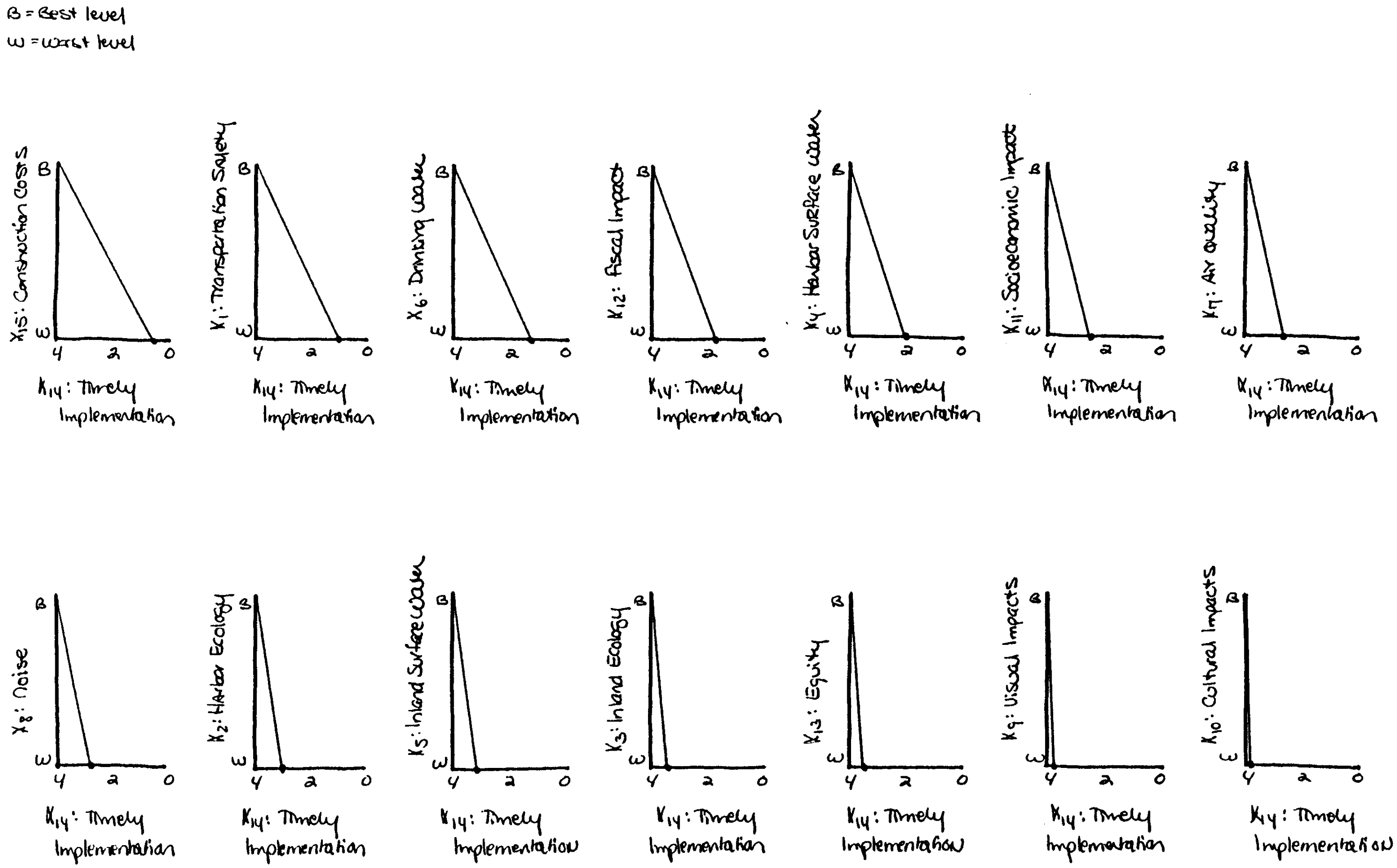
Making Tradeoffs among Objectives

Next, Smith uses the information from her discussions with representatives of stakeholder groups to try to guess how each group would make tradeoffs among objectives and weight each attribute. She uses the method described in Chapter II, asking herself, "If I were a representative of that group, and all attributes were at their worst level, which would I want to bring to its best level?" It is easy for Smith to assess the MWRA's ranking of the attributes--she is the agency's representative in her hypothetical negotiation structure. Smith ranks the attributes as follows:

Timely Implementation
Construction Costs
Transportation Safety
Drinking Water Impacts
Fiscal Impacts
Harbor Surface Water
Socioeconomic Impacts
Air Quality
Noise
Harbor Ecology
Inland Surface Water
Inland Ecology
Equitable Distribution of Regional Responsibility
Visual Impacts
Cultural Resources

It is interesting to note that the MWRA ranks fiscal impacts above impacts on harbor surface water, and ranks socioeconomic impact and noise above harbor ecology. Although the agency has an environmental mission, it is more concerned with the impacts its projects will have on people nearby. The agency ranks equity, visual impacts, and cultural impacts very low, however. As expected, the MWRA ranks timely implementation and construction costs most heavily. The tradeoffs Smith makes using these rankings are illustrated in Figure 4-17.

FIGURE 4-17
MWRA'S VALUE TRADEOFFS FOR ALL ATTRIBUTES

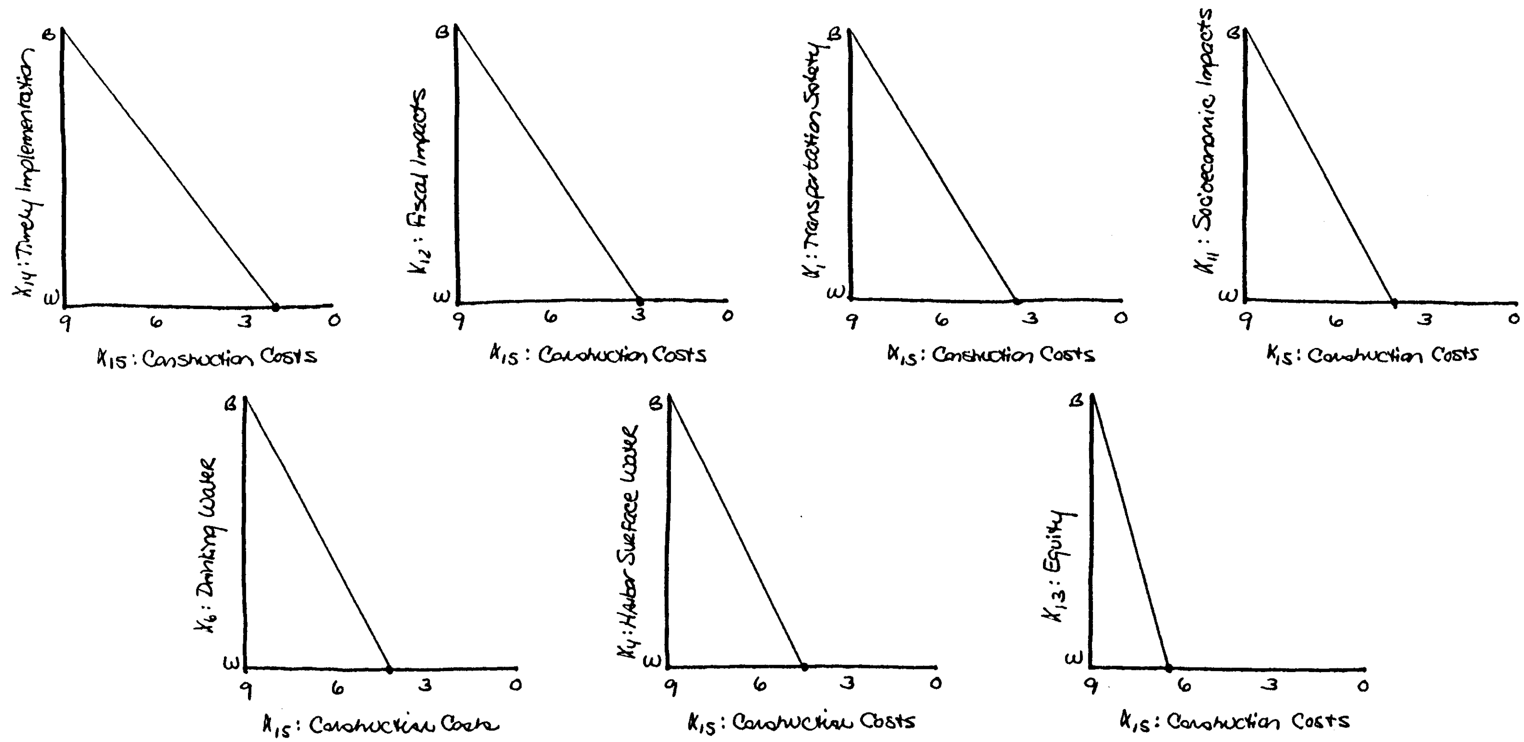


Ratepayers rank construction costs most heavily, followed by timely implementation and fiscal impacts. They place environmental concerns at the middle and bottom of the list. The rankings Smith estimates for the ratepayer group are as follows:

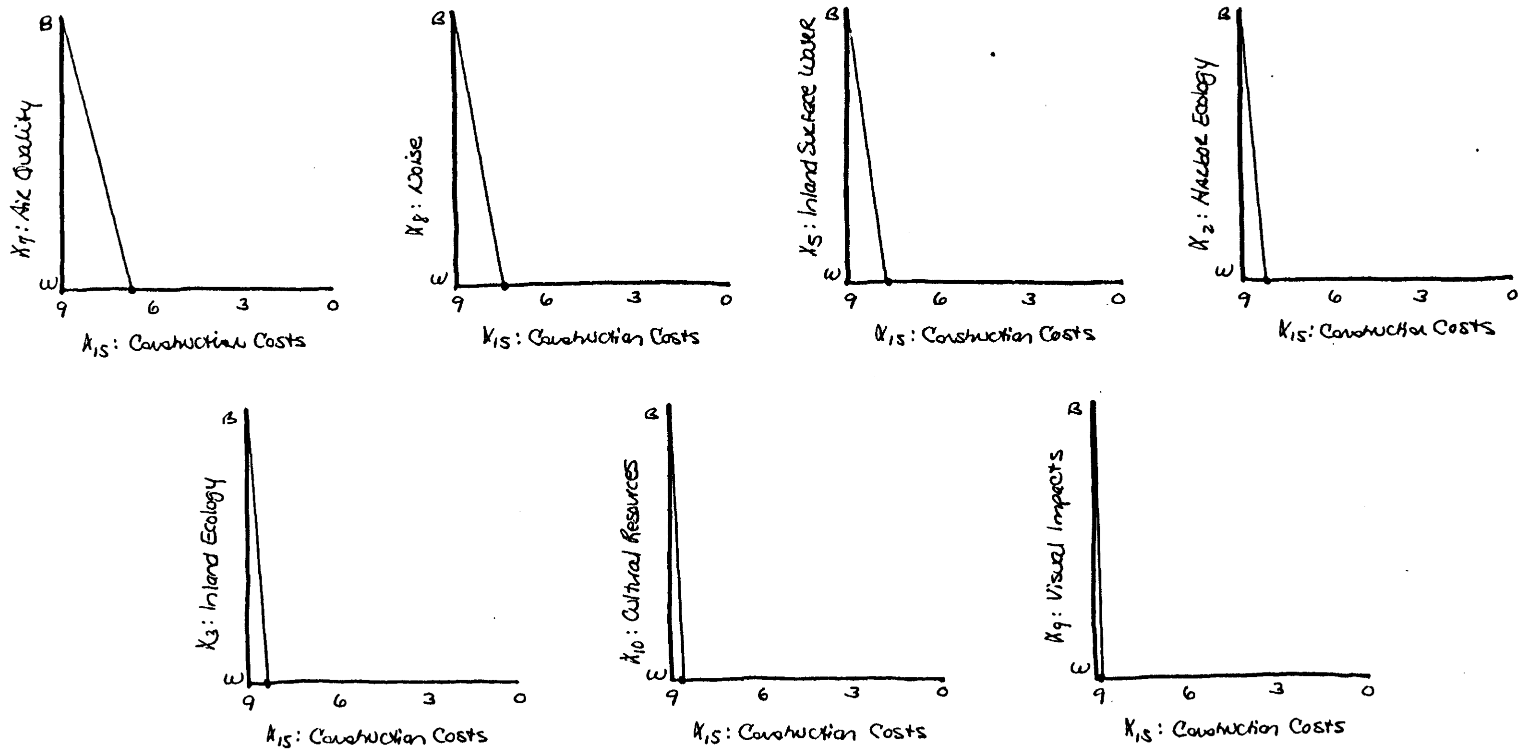
Construction Costs
Timely Implementation
Fiscal Impacts
Transportation Safety
Socioeconomic Impact
Drinking Water
Harbor Surface Water
Equitable Distribution of Regional Responsibility
Air Quality
Noise
Inland Surface Water
Harbor Ecology
Inland Ecology
Cultural Resources
Visual Impacts

It is interesting to note that the seven most heavily weighted attributes all might involve financial cost to the ratepayers. The facility's construction costs obviously will be absorbed by the ratepayers. If the court ordered schedule is violated, the MWRA may have to pay huge fines. Ratepayers expect that they will have to make payments in lieu of taxes to offset any fiscal impacts a sludge facility might have. The transportation safety attribute involves liability issues and costs. The ratepayers are concerned with socioeconomic impacts because they believe they might have to compensate homeowners whose property values decline as a result of the sludge facility. If a facility polluted drinking water supplies, the ratepayers might be held liable for expensive cleanup projects. Finally, if the sludge facility pollutes harbor surface water, the MWRA might be found in violation of the Clean Water Act again, and fined heavily. The tradeoffs Smith makes for ratepayers using these rankings are found in Figure 4-18.

FIGURE 4-18
RATEPAYERS' VALUE TRADEOFFS FOR ALL ATTRIBUTES



(Continued)


B
W
X7: Air Quality
9 6 3 0
X15: Construction Costs
B
W
X8: Noise
9 6 3 0
X15: Construction Costs
B
W
X5: Inland Surface Water
9 6 3 0
X15: Construction Costs
B
W
X2: Harbor Ecology
9 6 3 0
X15: Construction Costs
B
W
X3: Inland Ecology
9 6 3 0
X15: Construction Costs
B
W
X10: Cultural Resources
9 6 3 0
X15: Construction Costs
B
W
X9: Visual Impacts
9 6 3 0
X15: Construction Costs

Harbor environmental groups place timely implementation at the top of the list of attributes. They are concerned that a sludge facility be sited and built quickly, so that sludge will no longer be dumped untreated into Boston Harbor. As expected, these groups are more concerned with environmental attributes, and weight the facility's impacts on neighbors and communities less heavily. The attribute ranking for harbor environmental groups are:

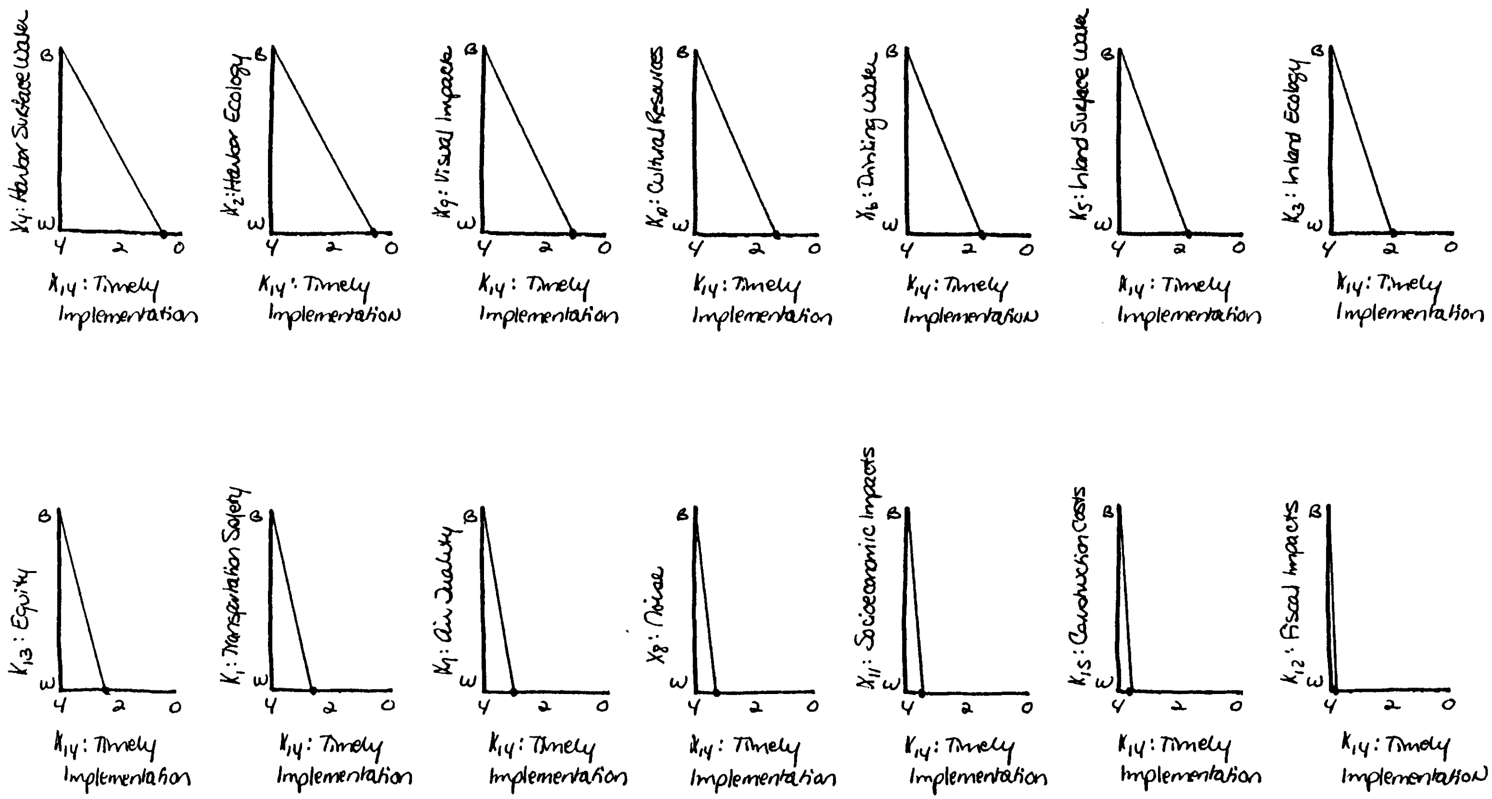
Timely Implementation
Harbor Surface Water
Harbor Ecology
Visual Impacts
Cultural Resources
Drinking Water
Inland Surface Water
Inland Ecology
Equitable Distribution of Regional Responsibility
Transportation Safety
Air Quality
Noise
Socioeconomic Impact
Construction Costs
Fiscal Impact

Smith's estimates of the harbor environmental groups' tradeoffs using these rankings are illustrated in Figure 4-19.

Local environmental groups weight the inland ecology, inland surface water, and drinking water attributes most heavily. Like harbor environmental groups, they rank economic and socioeconomic attributes at the bottom of the list. Local environmental groups are less concerned with timely implementation than are harbor environmental groups; and are more concerned with noise and air quality impacts. Smith's guesses of rankings for the local environmental groups are as follows:

Inland Ecology
Inland Surface Water
Drinking Water
Harbor Ecology

FIGURE 4-19
HARBOR ENVIRONMENTAL GROUPS' VALUE TRADEOFFS FOR ALL ATTRIBUTES



Harbor Surface Water
Cultural Resources
Visual Impacts
Noise
Air Quality
Transportation Safety
Equitable Distribution of Regional
  Responsibility
Timely Implementation
Socioeconomic Impact
Construction Costs
Fiscal Impacts

Value tradeoffs for local environmental groups are displayed in Figure 4-20.

Abutters rank the equitable distribution of regional responsibility most heavily, followed by transportation safety, air quality, noise, and visual impacts. These groups rank environmental concerns, cost and timely implementation low. The rankings for abutters are:

Equitable Distribution of Regional
  Responsibility
Transportation Safety
Air Quality
Noise
Visual Impacts
Socioeconomic Impact
Drinking Water
Cultural Resources
Fiscal Impact
Inland Surface Water
Harbor Surface Water
Inland Ecology
Harbor Ecology
Construction Costs

Smith's estimates of the value tradeoffs abutters would make using these rankings are found in Figure 4-21.

Local officials weight fiscal impact, socioeconomic impact, and equitable distribution of regional responsibility most heavily among the attributes. Environmental concerns and timely implementation are ranked at the bottom of the list. The officials rank construction costs fairly high, however, above air quality, noise and visual impacts. This reflects their

FIGURE 4-20
LOCAL ENVIRONMENTAL GROUPS' VALUE TRADEOFFS FOR ALL ATTRIBUTES

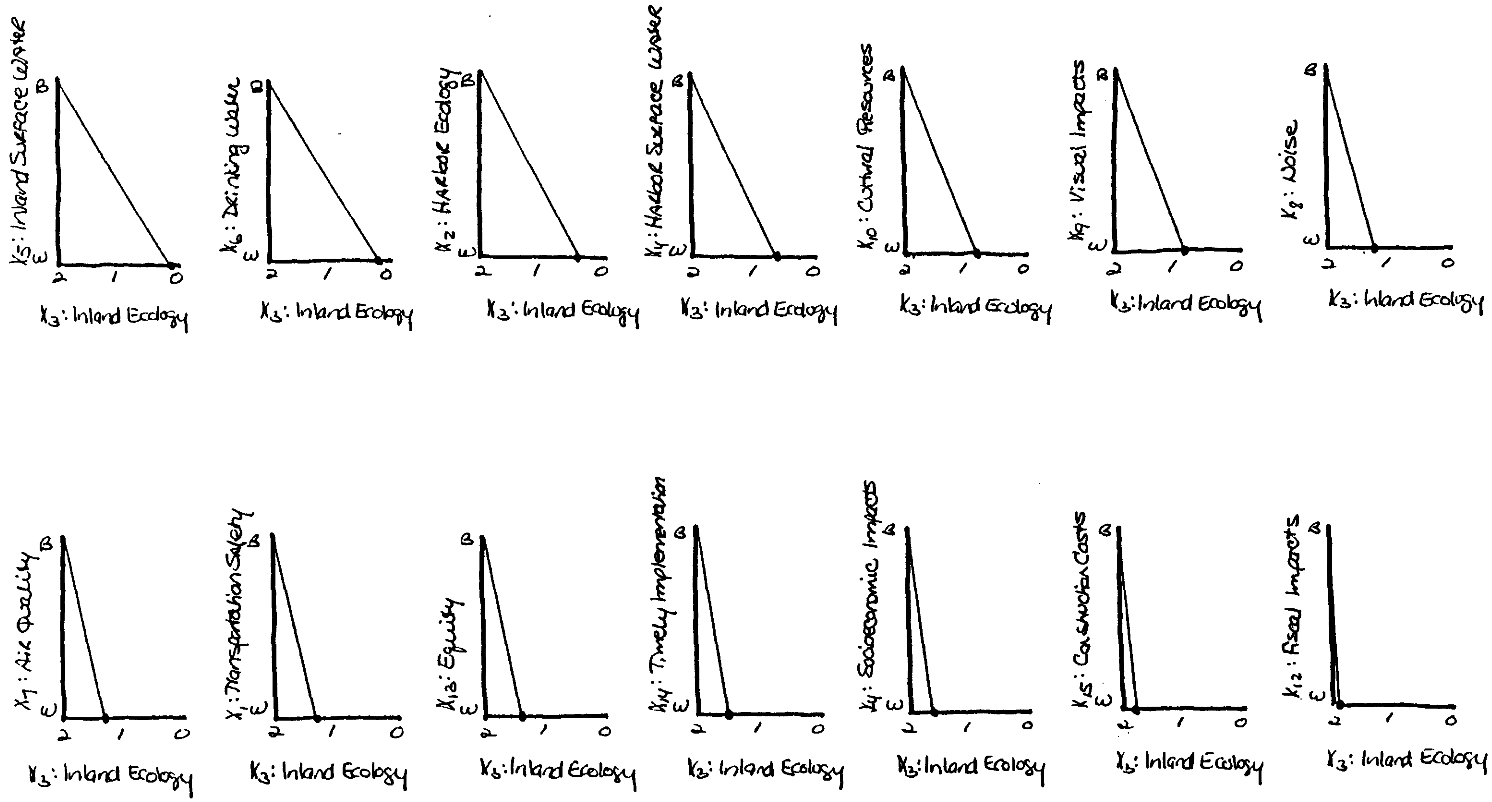
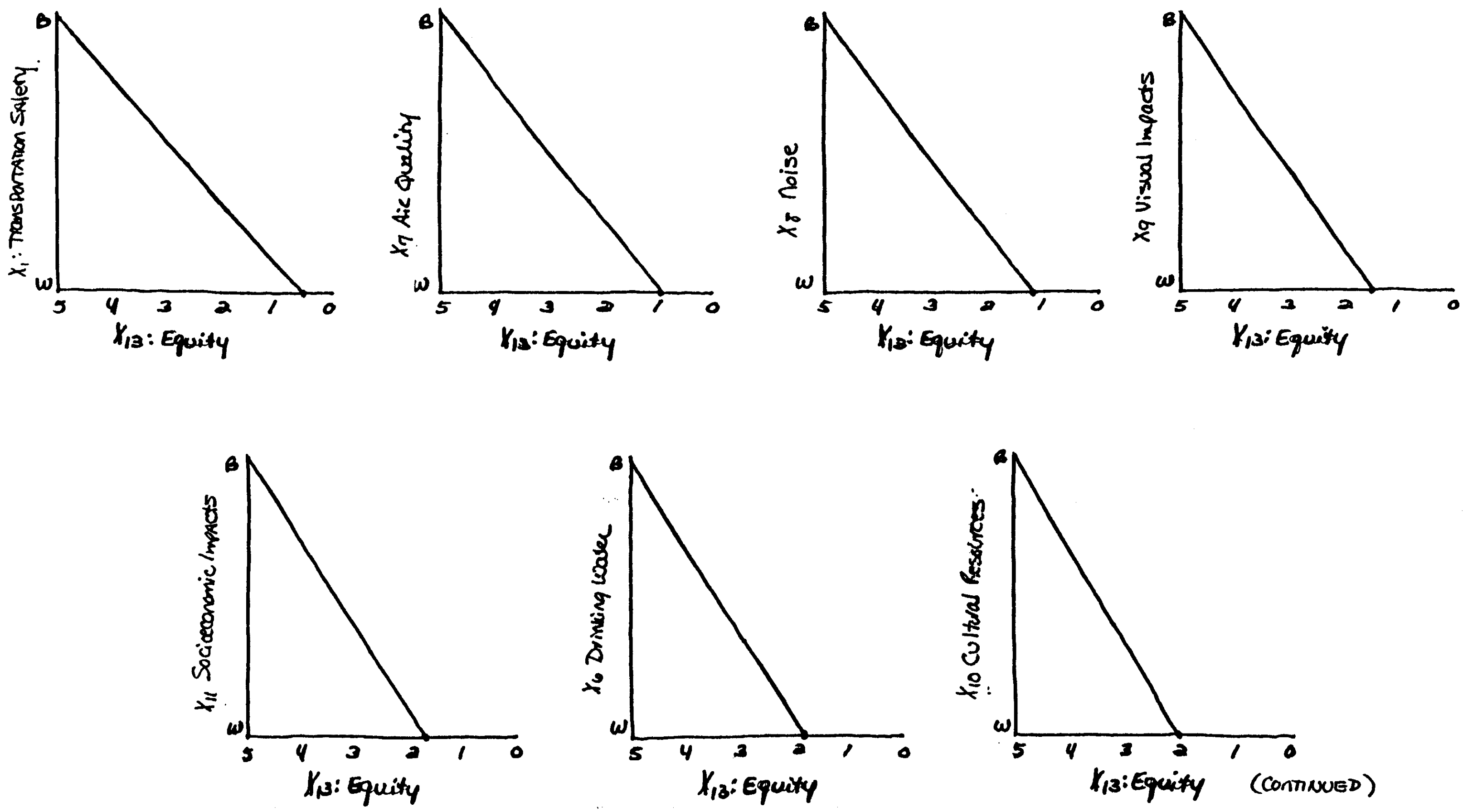
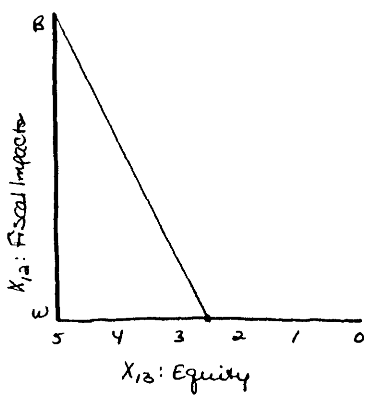
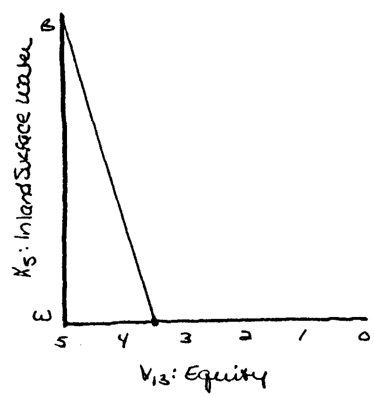


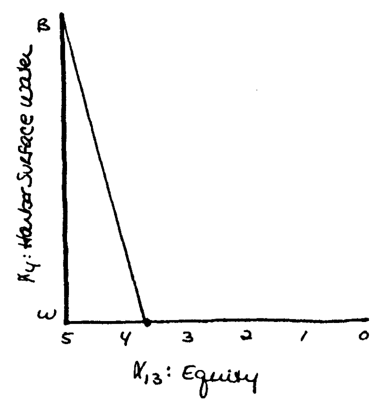
FIGURE 4-21
ABUTTERS' VALUE TRADEOFFS FOR ALL ATTRIBUTES

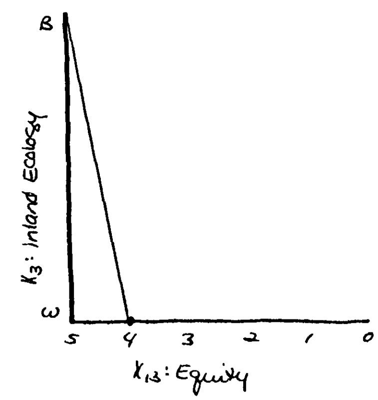


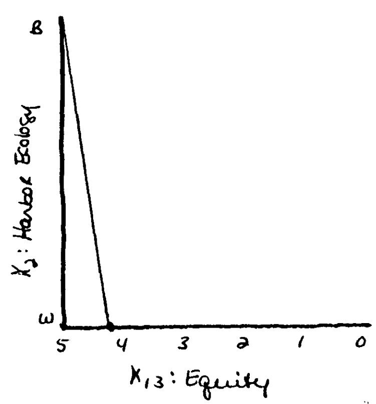
(CONTINUED)

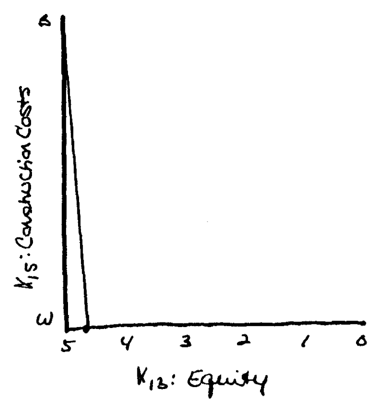

B
X_{12}: Fiscal Impacts
W
5 4 3 2 1 0
X_{13}: Equity


B
X_5: Inland Surface Water
W
5 4 3 2 1 0
X_{13}: Equity


B
X_4: Harbor Surface Water
W
5 4 3 2 1 0
X_{13}: Equity


B
X_3: Inland Ecology
W
5 4 3 2 1 0
X_{13}: Equity


B
X_2: Harbor Ecology
W
5 4 3 2 1 0
X_{13}: Equity


B
X_{15}: Construction Costs
W
5 4 3 2 1 0
X_{13}: Equity

concern about passing rate increases onto their constituents. The complete list for local officials is:

Fiscal Impacts
Socioeconomic Impact
Equitable Distribution of Regional Responsibility
Transportation Safety
Drinking Water
Construction Costs
Air Quality
Noise
Visual Impacts
Cultural Resources
Inland Surface Water
Harbor Surface Water
Inland Ecology
Harbor Ecology
Timely Implementation

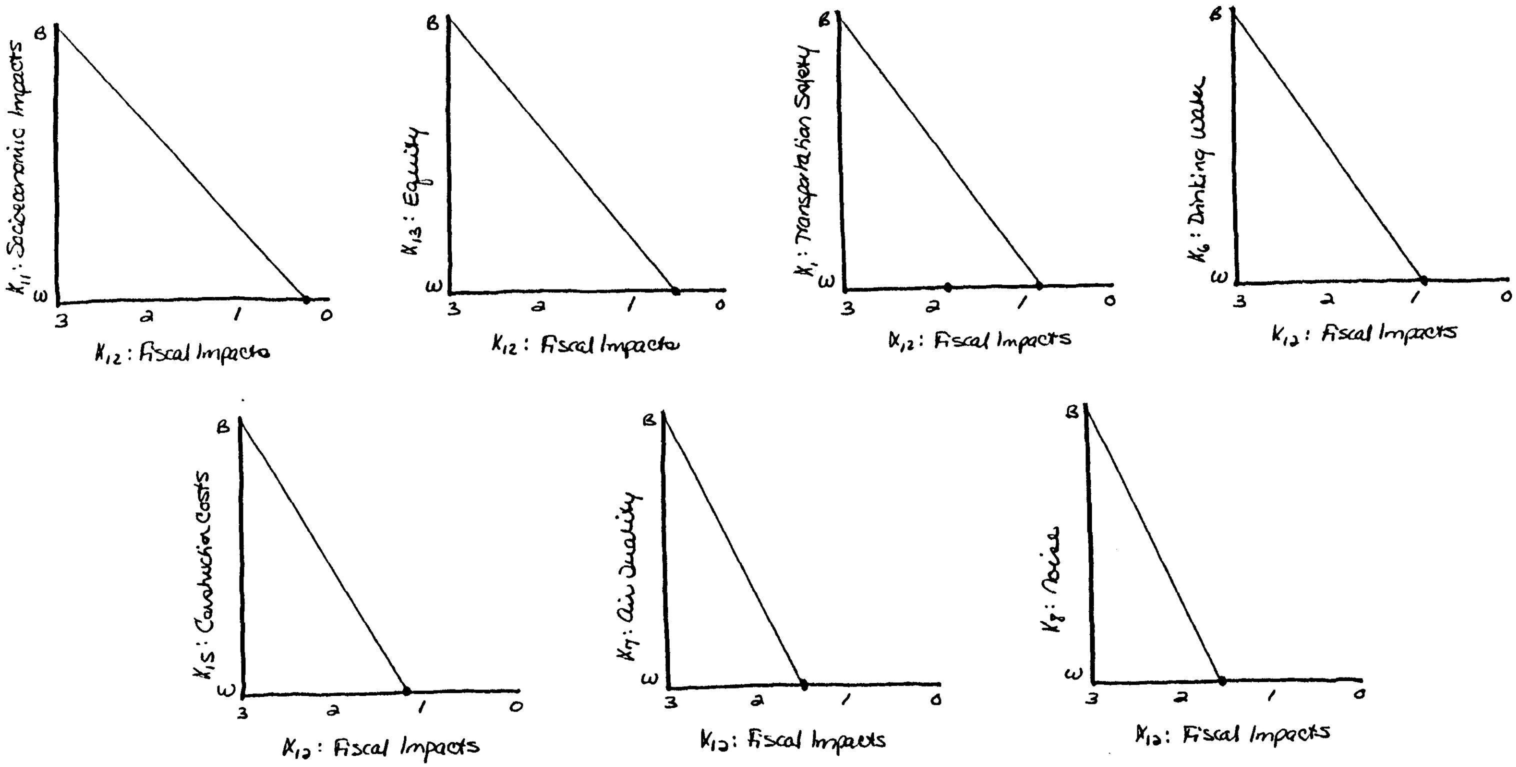
The value tradeoffs for local officials are illustrated in Figure 4-22.

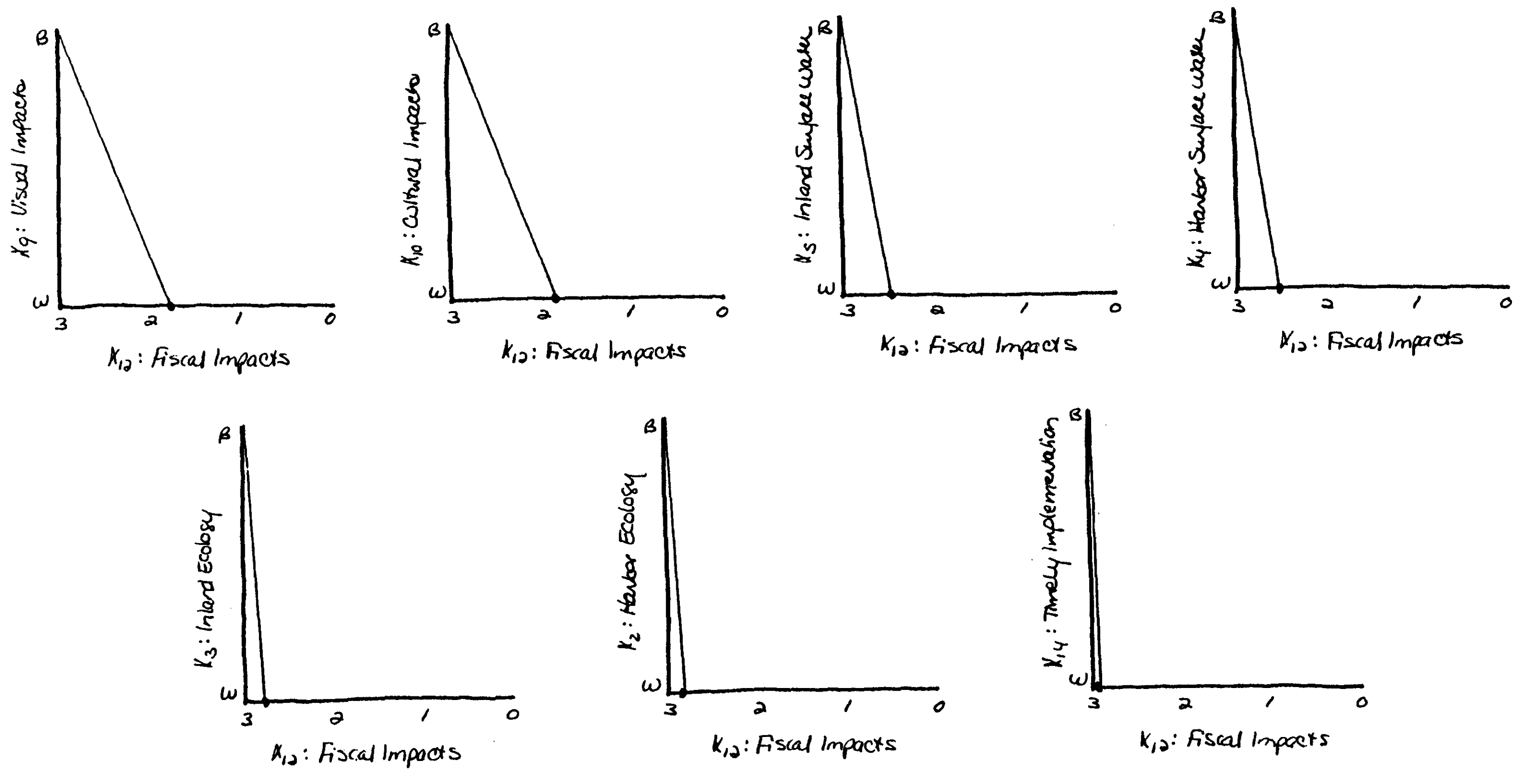
Finally, Smith guesses at ranking for regulators. Regulators weight timely implementation most heavily, followed by the environmental attributes--harbor surface water, drinking water, inland surface water, air quality, and ecology. Regulators rank cost, equitable distribution of regional responsibility, and fiscal impacts low. The exact rankings are:

Timely Implementation
Harbor Surface Water
Drinking Water
Inland Surface Water
Air Quality
Harbor Ecology
Inland Ecology
Cultural Resources
Transportation Safety
Noise
Visual Impacts
Socioeconomic Impact
Construction costs
Equitable Distribution of Regional Responsibility
Fiscal Impacts

The regulators' value tradeoffs are illustrated in Figure 4-23.

FIGURE 4-22
LOCAL OFFICIALS' VALUE TRADEOFFS FOR ALL ATTRIBUTES





X_9: Visual Impacts
X_{10}: Cultural Impacts
X_5: Inland Surface Water
X_4: Harbor Surface Water
X_3: Inland Ecology
X_2: Harbor Ecology
X_{14}: Timely Implementation
X_{12}: Fiscal Impacts
B
W
3
2
1
0

FIGURE 4-23
REGULATORS' VALUE TRADEOFFS FOR ALL ATTRIBUTES

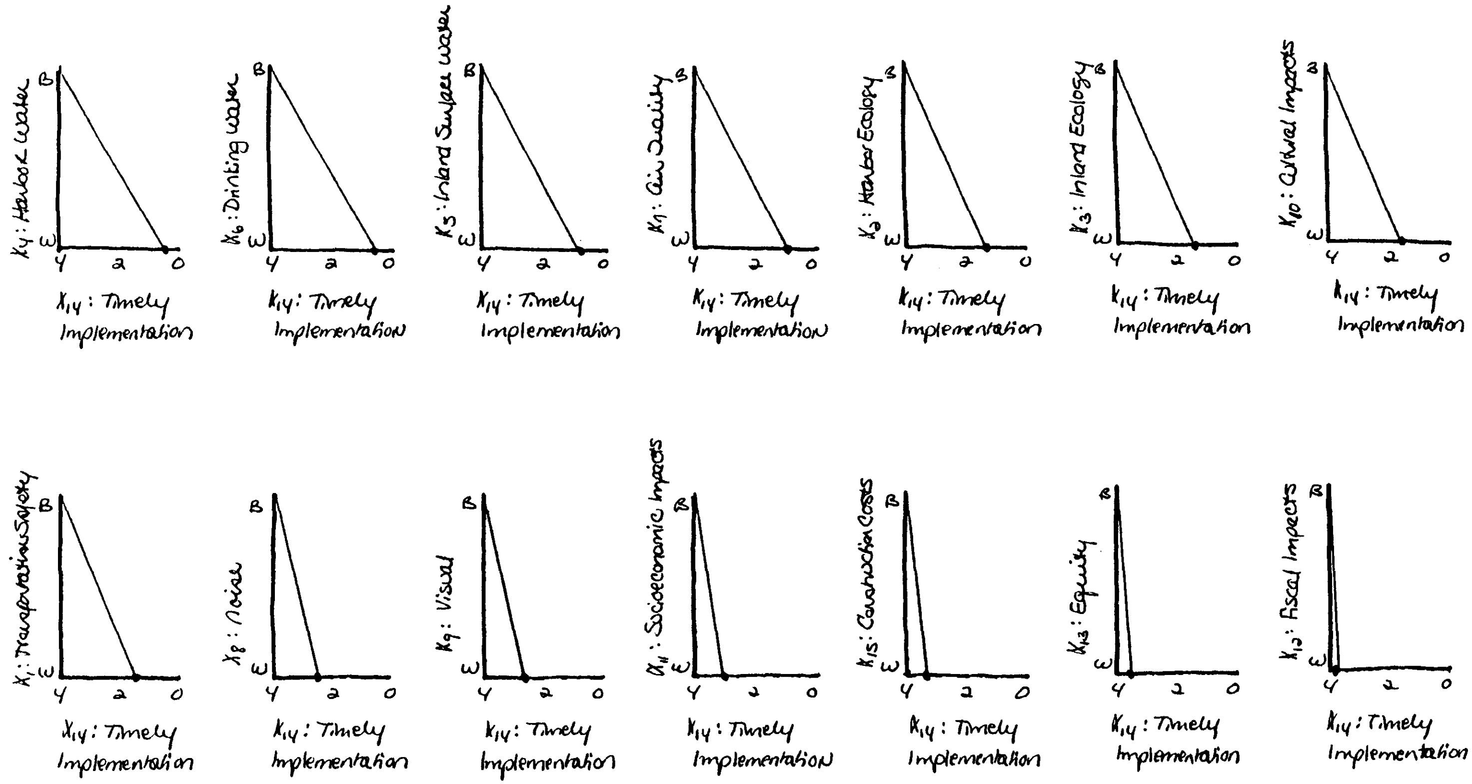


Table 4-34 shows how each stakeholder group ranks each attribute. There is not a lot of agreement between the groups on attribute weights. For example, the MWRA, local environmental groups, and regulators rank the equitable distribution of regional responsibility in the bottom third of their lists, while abutters and local officials rank it in the top third. Local environmental groups weight the inland ecology attribute most heavily, while the MWRA, ratepayers, abutters and local officials rank this attribute at the bottom third of all attributes. Local officials rank fiscal impacts first, while harbor environmental groups, local environmental groups and regulators rank them last. There is some agreement among groups on the timely implementation attribute: the MWRA, harbor environmental groups and regulators all weight this attribute most heavily. Unfortunately, the other four stakeholder groups rank timely implementation very low (local officials rank it last, local environmental groups rank it 12th out of 15).

Results and Conclusions

Smith calculates a utility measure for each site under each possible technology outcome for each stakeholder group and enters the result into individual decision trees for each group. The groups do not agree on the probability that composting will be the technology for the sludge facility. Table 4-35 shows the probability judgments for each group. The final results for each stakeholder group, with sensitivity analysis performed on the technology outcome, are listed in Table 4-36. (Bar graphs showing the results are displayed in Figures 4-24 through 4-30). Smith then compares each stakeholder group's top three choices with those of the other groups. (Table 4-37). She quickly notices that Quincy is in the top three for all of the groups, and that Spectacle Island and Deer Island are in the top three

TABLE 4-34
COMPARISON OF STAKEHOLDER GROUPS' ORDERING OF ATTRIBUTES

	MWRA	Ratepayers	Harbor Env	Local Env	Abutters	Local officials	Regulators
Transportation Safety	3	4	10	10	2	4	9
Harbor Ecology	10	12	3	4	13	14	6
Inland Ecology	12	13	8	1	12	13	7
Harbor Surface Water	6	7	2	5	11	12	2
Inland Surface Water	11	11	7	2	10	11	4
Drinking Water	4	6	6	3	7	5	3
Air Quality	8	9	11	9	3	7	5
Noise	9	10	12	8	4	8	10
Visual Impacts	14	15	4	7	5	9	11
Cultural Resources	15	14	5	6	8	10	8
Socioeconomic Impact	7	5	13	13	6	2	12
Fiscal Impact	5	3	15	15	9	1	15
Equity	13	8	9	11	1	3	14
Timely Implementation	1	2	1	12	--	15	1
Construction Costs	2	1	14	14	14	6	13

TABLE 4-35
STAKEHOLDER GROUPS' PROBABILITY ASSESSMENTS ON TECHNOLOGY OUTCOME

Group	Probability of Composting	Probability of Incineration
MWRA	.5	.5
Ratepayers	.3	.7
Harbor Environmental Groups	.1	.9
Local Environmental Groups	.1	.9
Abutters	.2	.8
Local Officials	.3	.7
Regulators	.4	.6

TABLE 4-36
NEGOTIATION MODEL RESULTS

Technology Choice Uncertain		Composting Certain		Incineration Certain	
MWRA					
Quincy	.8077	Deer Island	.8138	Quincy	.8426
Deer Island	.7692	Quincy	.7727	Spectacle Island	.7513
Spectacle Island	.7606	Spectacle Island	.7699	Deer Island	.7246
Lynn	.7287	Lynn	.7385	Lynn	.7188
Wilmington	.6888	Wilmington	.6634	Wilmington	.7142
Stoughton	.6739	Stoughton	.6476	Stoughton	.7001
Walpole	.6009	Walpole	.5755	Walpole	.6263
RATEPAYERS					
Quincy	.8118	Deer Island	.8059	Quincy	.8317
Spectacle Island	.7592	Spectacle Island	.7752	Spectacle Island	.7524
Lynn	.7447	Quincy	.7655	Lynn	.7376
Deer Island	.7432	Lynn	.7614	Deer Island	.7163
Wilmington	.7031	Wilmington	.6730	Stoughton	.7160
Stoughton	.7027	Stoughton	.6715	Wilmington	.7160
Walpole	.6037	Walpole	.5735	Walpole	.6166
HARBOR ENVIRONMENTAL GROUPS					
Quincy	.7997	Lynn	.7852	Quincy	.8048
Stoughton	.6729	Quincy	.7533	Lynn	.7137
Wilmington	.6451	Deer Island	.7509	Stoughton	.6769
Lynn	.6423	Spectacle Island	.6988	Wilmington	.6431
Deer Island	.6406	Wilmington	.6626	Deer Island	.6283
Spectacle Island	.6353	Stoughton	.6372	Spectacle Island	.6282
Walpole	.5805	Walpole	.5980	Walpole	.5785
LOCAL ENVIRONMENTAL GROUPS					
Quincy	.7782	Deer Island	.7536	Quincy	.7846
Lynn	.6883	Lynn	.7482	Lynn	.6816
Spectacle Island	.6442	Quincy	.7209	Spectacle Island	.6375
Deer Island	.6345	Spectacle Island	.7043	Deer Island	.6213
Wilmington	.6035	Stoughton	.5613	Wilmington	.6099
Stoughton	.5618	Wilmington	.5460	Walpole	.5635
Walpole	.5571	Walpole	.4996	Stoughton	.5619

ABUTTERS

Quincy	.7809	Deer Island	.8269	Quincy	.7978
Spectacle Island	.7381	Spectacle Island	.7959	Spectacle Island	.7236
Deer Island	.7003	Lynn	.7270	Deer Island	.6686
Lynn	.6693	Quincy	.7135	Lynn	.6549
Wilmington	.6298	Stoughton	.5967	Wilmington	.6467
Stoughton	.6091	Wilmington	.5623	Stoughton	.6122
Walpole	.5055	Walpole	.4380	Walpole	.5224

LOCAL OFFICIALS

Spectacle Island	.7952	Deer Island	.8582	Quincy	.8153
Quincy	.7939	Spectacle Island	.8140	Spectacle Island	.7871
Deer Island	.7882	Quincy	.7441	Deer Island	.7582
Lynn	.6823	Lynn	.7011	Stoughton	.6784
Stoughton	.6641	Wilmington	.6419	Lynn	.6743
Wilmington	.6619	Stoughton	.6306	Wilmington	.6704
Walpole	.5111	Walpole	.4911	Walpole	.5196

REGULATORS

Quincy	.7923	Deer Island	.7793	Quincy	.8237
Lynn	.7390	Lynn	.7527	Lynn	.7299
Deer Island	.7174	Quincy	.7452	Spectacle Island	.6951
Spectacle Island	.7043	Spectacle Island	.7180	Deer Island	.6761
Wilmington	.6323	Wilmington	.6069	Wilmington	.6493
Stoughton	.6228	Stoughton	.5875	Stoughton	.6464
Walpole	.5770	Walpole	.5516	Walpole	.5940

FIGURE 4-24

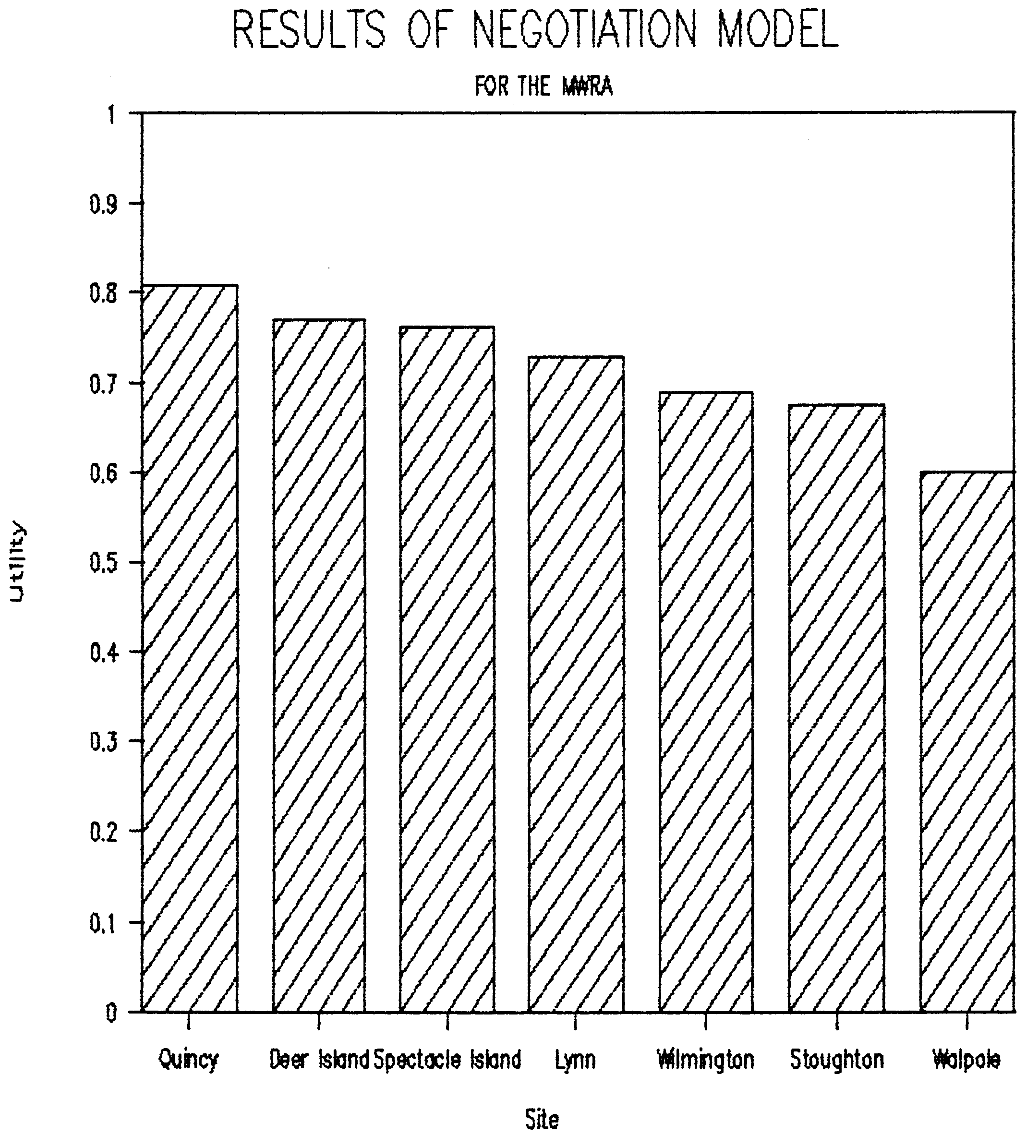

RESULTS OF NEGOTIATION MODEL
FOR THE MWRA
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Quincy
Deer Island
Spectacle Island
Lynn
Wilmington
Stoughton
Walpole
Site

FIGURE 4-25

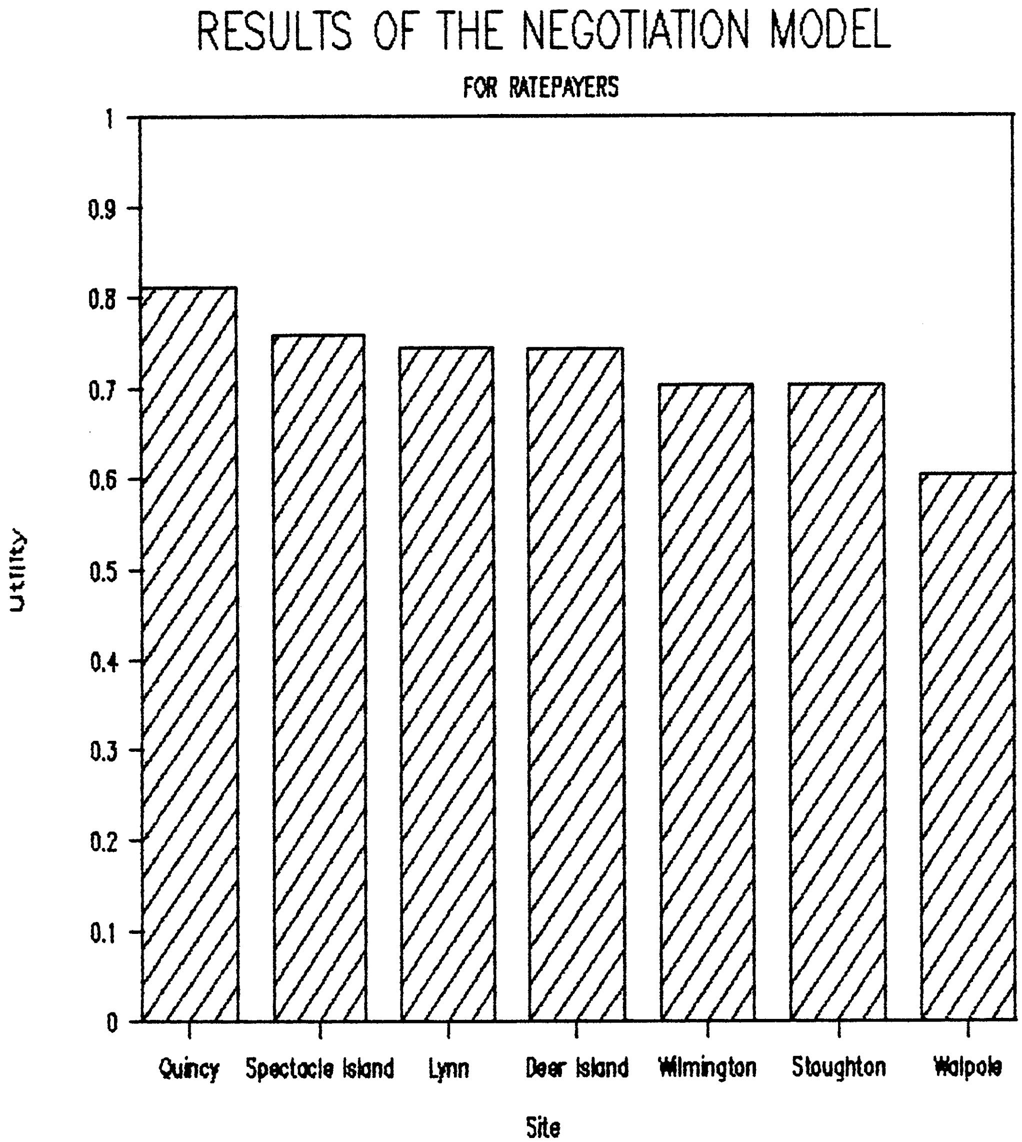

RESULTS OF THE NEGOTIATION MODEL
FOR RATEPAYERS
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Quincy
Spectacle Island
Lynn
Deer Island
Wilmington
Stoughton
Walpole
Site

FIGURE 4-26

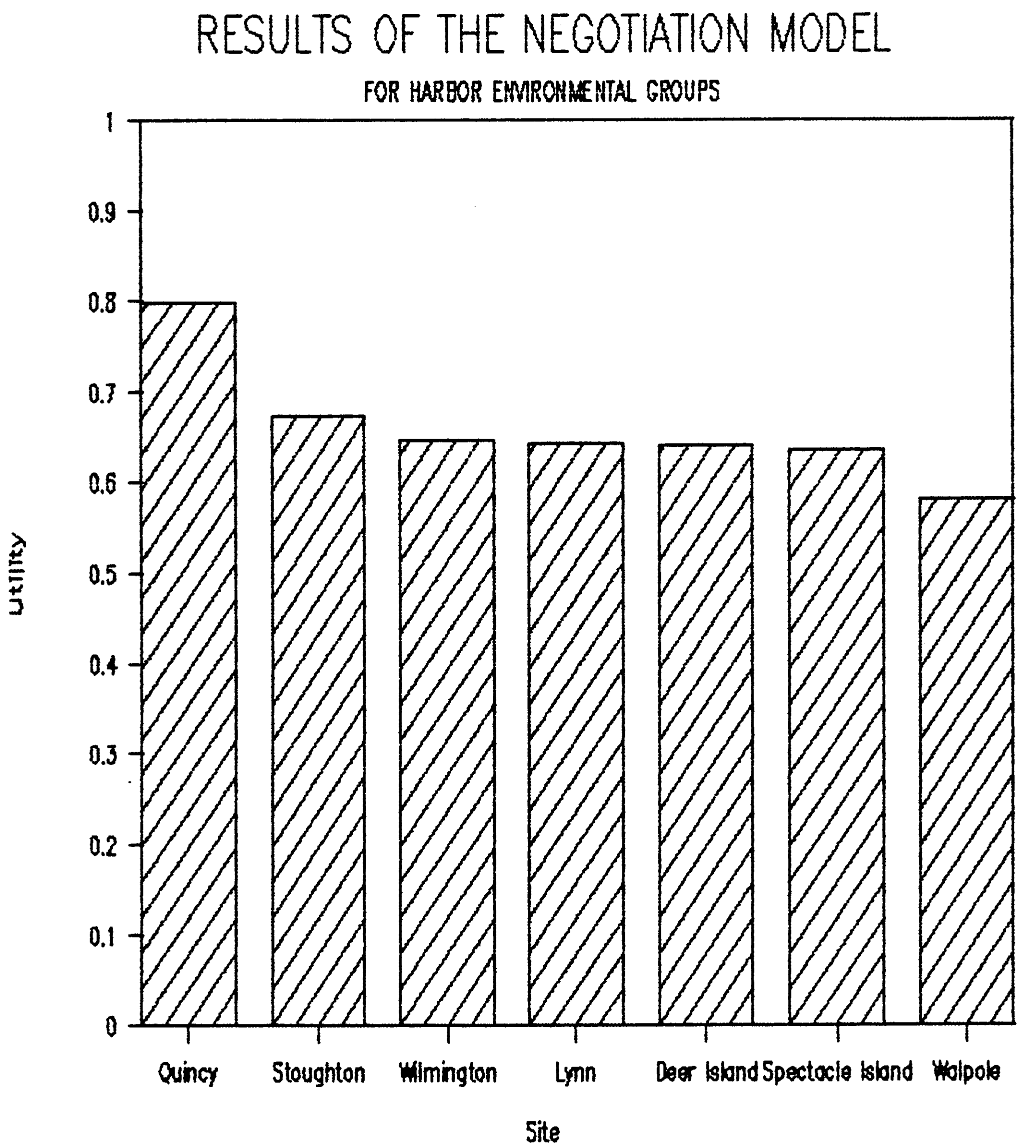

RESULTS OF THE NEGOTIATION MODEL
FOR HARBOR ENVIRONMENTAL GROUPS
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Quincy
Stoughton
Wilmington
Lynn
Deer Island
Spectacle Island
Walpole
Site

FIGURE 4-27

RESULTS OF THE NEGOTIATION MODEL

FOR LOCAL ENVIRONMENTAL GROUPS

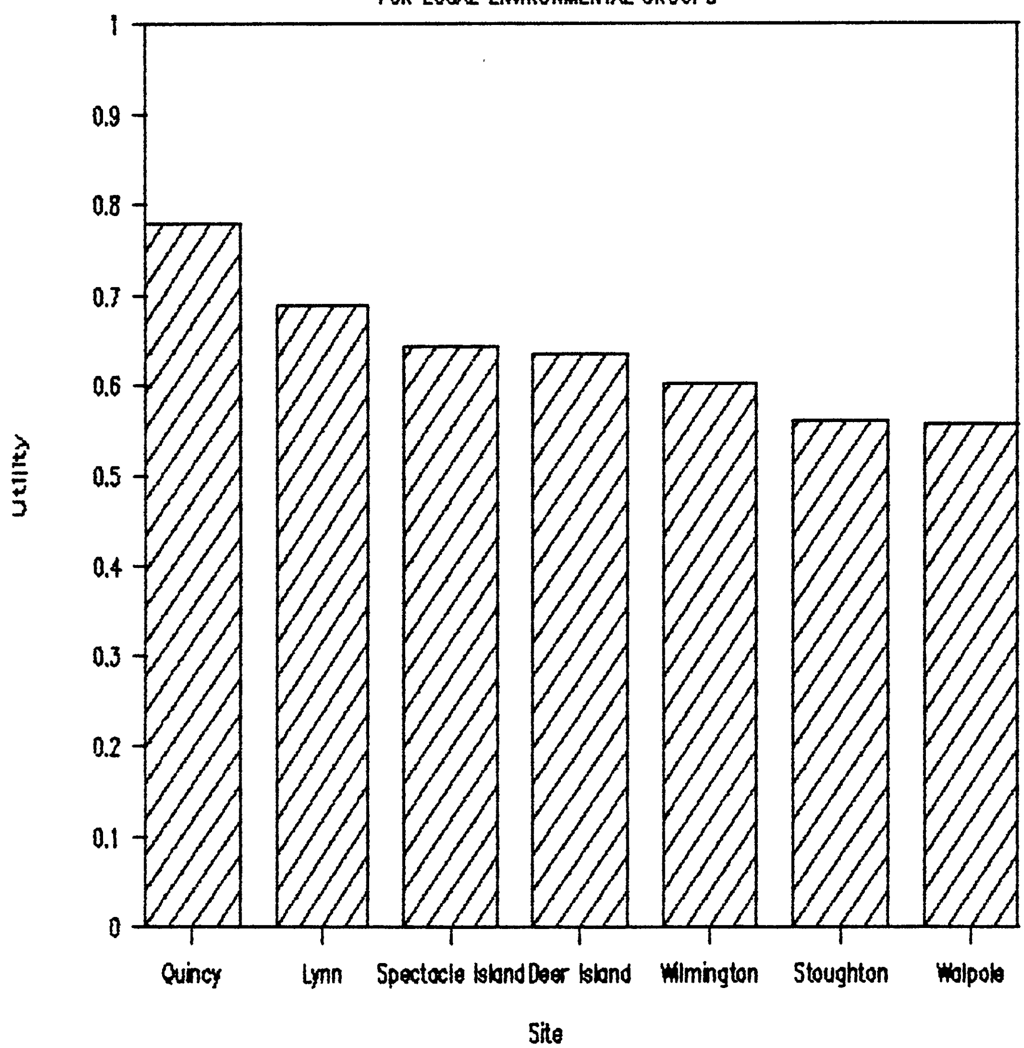


FIGURE 4-28

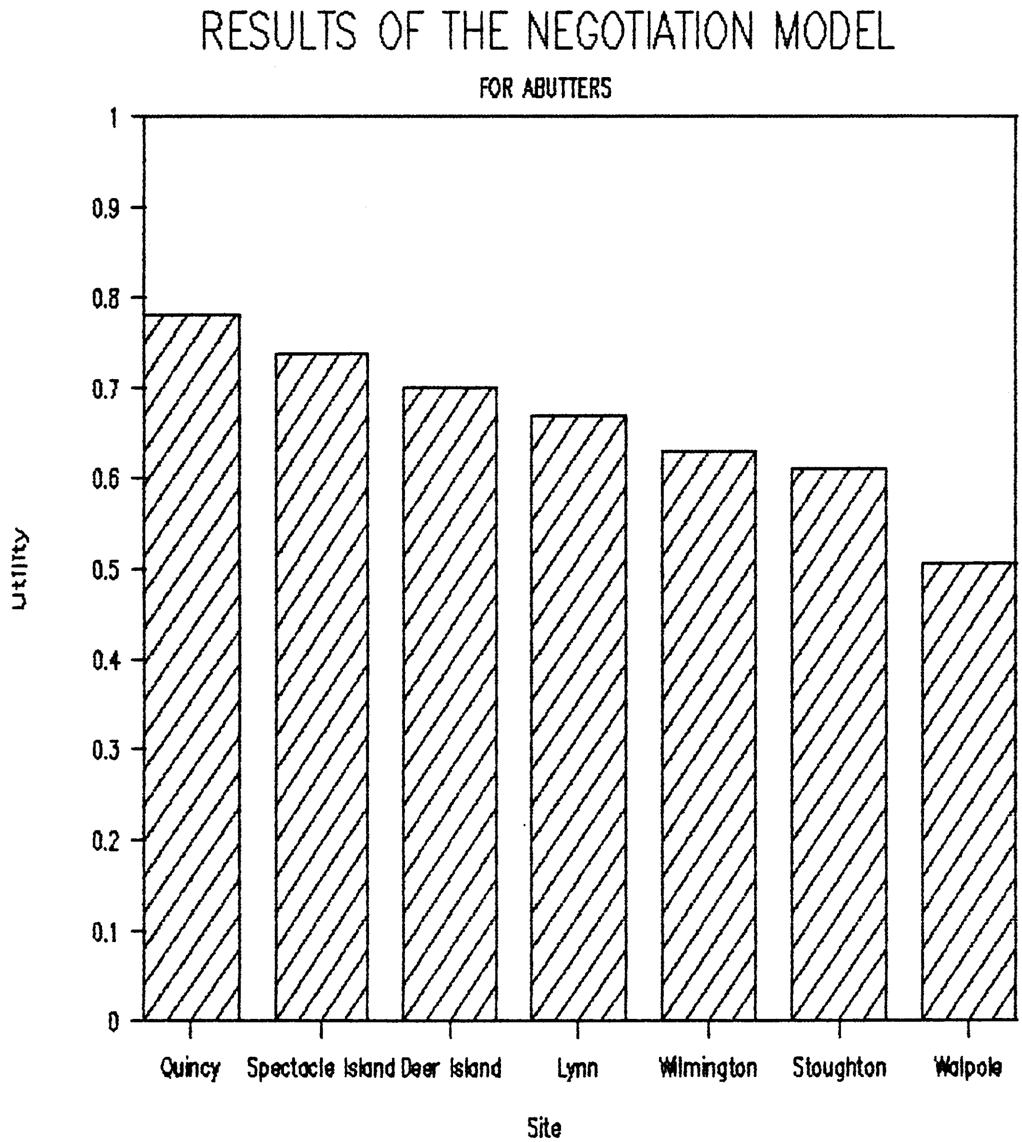

RESULTS OF THE NEGOTIATION MODEL
FOR ABUTTERS
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Quincy
Spectacle Island
Deer Island
Lynn
Wilmington
Stoughton
Walpole
Site

FIGURE 4-29

RESULTS OF THE NEGOTIATION MODEL

FOR LOCAL OFFICIALS

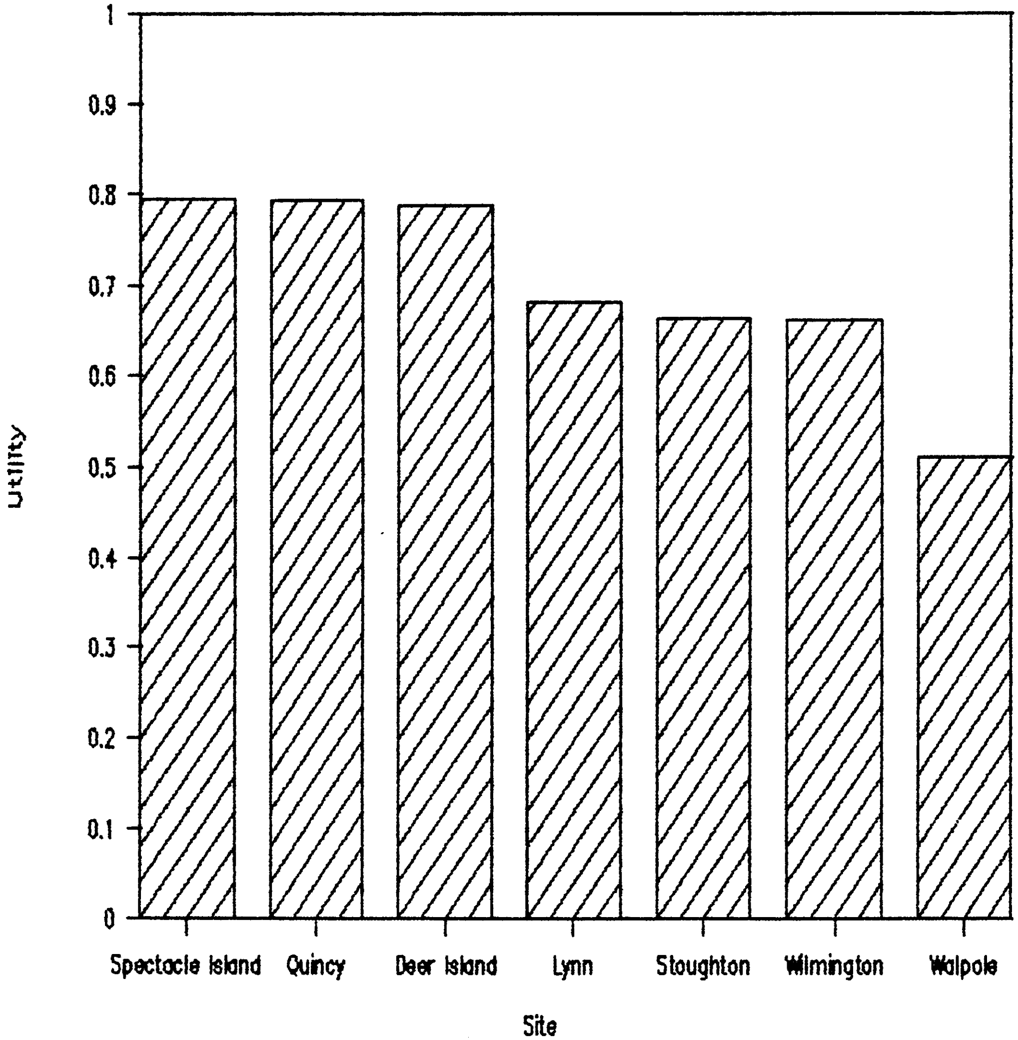


FIGURE 4-30

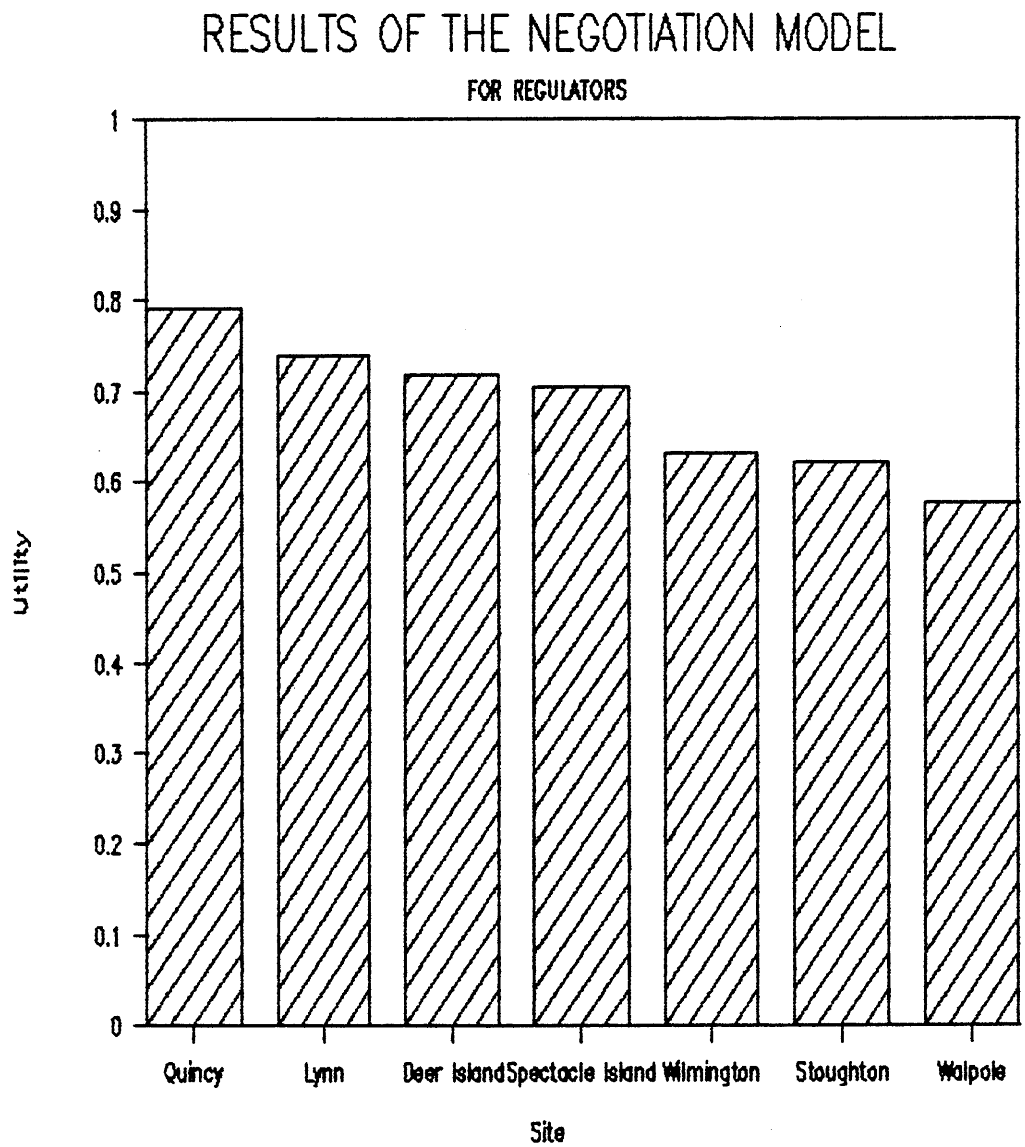

RESULTS OF THE NEGOTIATION MODEL
FOR REGULATORS
Utility
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Quincy
Lynn
Deer Island
Spectacle Island
Wilmington
Stoughton
Walpole
Site

TABLE 4-37
TOP THREE SITES FOR EACH STAKEHOLDER GROUP

MWRA
- Quincy
- Deer Island
- Spectacle Island

RATEPAYERS
- Quincy
- Spectacle Island
- Lynn

HARBOR ENVIRONMENTAL GROUPS
- Quincy
- Stoughton
- Wilmington

LOCAL ENVIRONMENTAL GROUPS
- Quincy
- Lynn
- Spectacle Island

ABUTTERS
- Quincy
- Spectacle Island
- Deer Island

LOCAL OFFICIALS
- Spectacle Island
- Quincy
- Deer Island

REGULATORS
- Quincy
- Lynn
- Deer Island

for four of the groups. She believes that she might be able to achieve a consensus agreement to choose these three sites for further study. The MWRA, abutters, and local officials already rank these three sites as their top choices. Smith examines the model for each of the remaining stakeholders to find out why the three sites--Deer Island, Quincy and Spectacle Island-- were not ranked more highly by these groups.

Harbor environmental groups rank the Quincy, Stoughton, and Wilmington sites as their top three choices. Deer Island and Spectacle Island are ranked fifth and sixth, respectively. Why are the scores for these sites so low? Is there anything Smith could do to improve these scores? The harbor environmental groups weighted the attributes of timely implementation, harbor ecology, harbor surface water, visual impacts and cultural impacts most heavily. Deer Island scores very low on the harbor ecology and harbor surface water attributes. The groups were very concerned about the replaceability of habitats for small mammals living on Deer Island. The site only had a .08 expected utility on the harbor surface water attribute, because stormwater runoff and airborne contaminants from Deer Island could directly pollute Boston Harbor. These groups rated Deer Island low on visual impacts, and their concern about the remains of an old fort on the site caused them to rank Deer Island low on cultural impacts, also. What can Smith do to convince these groups that the impacts on Deer Island will not be as heavy as expected? She cannot do anything about habitat replaceability on Deer Island. However, she can improve the harbor environmental groups' perceptions of surface water impacts by mitigating these impacts as much as possible--using scrubbers in the incinerator to reduce the amount or airborne contaminants leaving the stack, or managing stormwater so that runoff is not a problem. Visual impacts could be mitigated by buffering, and Smith could try to design the sludge facility so that it would not impact the fort. Smith also wonders if harbor environmental groups, whose primary concern is timely implementation of the harbor cleanup, would actually hold up a consensual agreement to use Deer Island for a sludge facility because of these concerns.

The Spectacle Island site also scores low on the attributes that are most important to harbor environmental groups. They worry that permitting problems, political problems, and competing public use will delay timely implementation of the harbor cleanup. They are concerned that stormwater runoff from the facility could damage lobster trapping grounds nearby, and that airborne contaminants from an incinerator on the island would pollute harbor water. They believe that a facility would have moderate or major visual impacts on harbor views, and they are eager to protect the archaeological site on the island. Smith can mitigate impacts from runoff and airborne contaminants through proper management procedures, and can try to design the facility so that it does not impact the archaeological site. If she must use an incinerator to treat the sludge, she can try to design a shorter stack so that visual impacts will be lessened. She does not believe that harbor environmental groups will hold up implementation of the sludge project over visual impacts.

Local environmental groups rate Quincy, Lynn and Spectacle Island as their top three sites. These groups have the same concerns about the Deer island site as do the harbor environmental groups. Smith believes that with assurances of mitigation, local environmental groups could be persuaded to drop the Lynn site and include Deer Island among their top three.

Quincy, Lynn and Deer Island are the three preferred sites for regulators. Spectacle Island is ranked fourth. The regulators share the concerns of harbor environmental groups about Spectacle Island--problems with timely implementation, impacts on harbor surface water, and visual impacts. Smith hopes that assurances of mitigation will convince regulators to move Spectacle Island up in their list.

Ratepayers rank Quincy, Spectacle Island and Lynn as their preferred choices. Deer Island is ranked fourth. However, the total utility score for Deer Island is only .0015 utiles less than the score for Lynn. Ratepayers share the concerns of environmental groups about environmental impacts on Deer Island. Smith believes that the mitigation measures she plans to propose will easily persuade ratepayers to accept Deer Island in their top three group.

Smith wonders if she can do anything to change the stakeholder groups' perceptions about the technology outcome. If the MWRA started an extensive enforcement program to rid the sludge of heavy metals and allow composting, would consensus among the groups about a site be more likely? Sensitivity analysis of the model results (Table 4-36) show that certainty about technology outcome changes the top three sites for several of the stakeholder groups. For example, abutters prefer Lynn to Quincy when composting is a certainty. Changing the groups' perceptions of technology probabilities does not appear to bring them closer to consensus, however.

Smith is disturbed about the guesses she had to make about the stakeholder groups' utility functions. To test the model results' sensitivity to the shape of utility curves, Smith calculates new figures for each group, this time assuming that the groups are all risk-neutral on each attribute.

The results, displayed in Table 4-38, show that the choice of the top three sites does not change for three of the groups (the MWRA, abutters and local officials). Two of the groups--ratepayers and regulators--replace Lynn with Spectacle Island in the top three rankings. The risk-neutral results show five groups in agreement over Quincy, Spectacle Island and Deer Island as the preferred sites.

From the results of this model, Smith could decide to reserve the Deer Island, Quincy and Spectacle Island sites for further study. She could also start to design mitigation strategies to deal with surface water impacts and visual impacts. She can also investigate the possibility of designing the facility to reduce visual and cultural impacts.

TABLE 4-38
NEGOTIATION MODEL RESULTS -- RISK NEUTRAL SENSITIVITY ANALYSIS

Original Model Results		Risk Neutral Results	
MWRA			
Quincy	.8077	Deer Island	.7211
Deer Island	.7692	Quincy	.7104
Spectacle Island	.7606	Spectacle Island	.6560
Lynn	.7287	Wilmington	.6120
Wilmington	.6888	Stoughton	.5729
Stoughton	.6739	Walpole	.5414
Walpole	.6009	Lynn	.5141
RATEPAYERS			
Quincy	.8118	Quincy	.7140
Spectacle Island	.7592	Deer Island	.6988
Lynn	.7447	Spectacle Island	.6570
Deer Island	.7432	Wilmington	.6193
Wilmington	.7031	Stoughton	.5997
Stoughton	.7027	Walpole	.5446
Walpole	.6037	Lynn	.5192
HARBOR ENVIRONMENTAL GROUPS			
Quincy	.7997	Quincy	.6995
Stoughton	.6729	Lynn	.6230
Wilmington	.6451	Stoughton	.5930
Lynn	.6423	Wilmington	.5800
Deer Island	.6406	Deer Island	.5608
Spectacle Island	.6353	Walpole	.5507
Walpole	.5805	Spectacle Island	.5028
LOCAL ENVIRONMENTAL GROUPS			
Quincy	.7782	Quincy	.7504
Lynn	.6883	Lynn	.6546
Spectacle Island	.6442	Deer Island	.6180
Deer Island	.6345	Spectacle Island	.6070
Wilmington	.6035	Walpole	.5265
Stoughton	.5618	Wilmington	.5113
Walpole	.5571	Stoughton	.4588

ABUTTERS

Quincy	.7809	Spectacle Island	.7325
Spectacle Island	.7381	Deer Island	.6438
Deer Island	.7003	Quincy	.6414
Lynn	.6693	Stoughton	.5172
Wilmington	.6298	Wilmington	.5143
Stoughton	.6091	Lynn	.5012
Walpole	.5055	Walpole	.3904

LOCAL OFFICIALS

Spectacle Island	.7952	Spectacle Island	.7803
Quincy	.7939	Deer Island	.7371
Deer Island	.7882	Quincy	.6819
Lynn	.6823	Stoughton	.5338
Stoughton	.6641	Wilmington	.5201
Wilmington	.6619	Lynn	.5044
Walpole	.5111	Walpole	.3899

REGULATORS

Quincy	.7923	Quincy	.7441
Lynn	.7390	Deer Island	.6644
Deer Island	.7174	Spectacle Island	.6224
Spectacle Island	.7043	Lynn	.6120
Wilmington	.6323	Wilmington	.5622
Stoughton	.6228	Stoughton	.5439
Walpole	.5770	Walpole	.5279

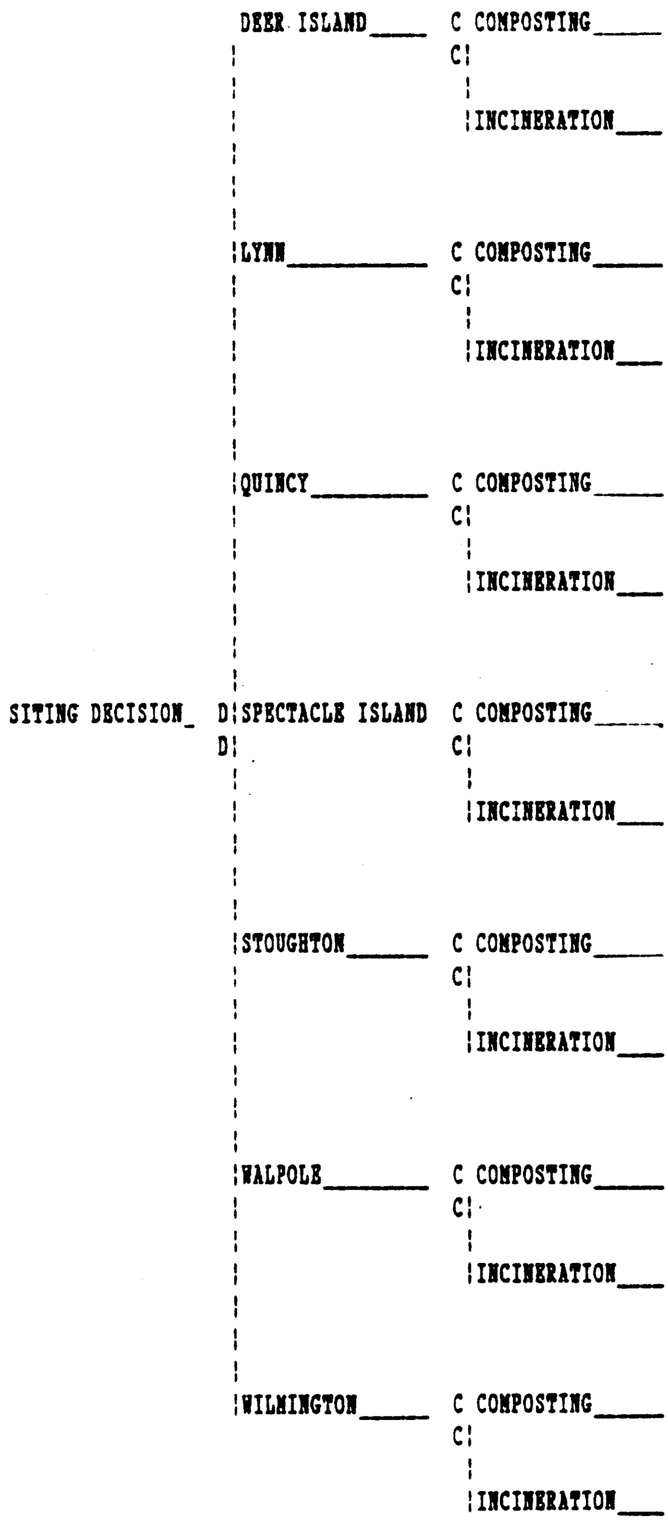
THE RISK PERCEPTION MODEL

Smith is pleased with the results of the negotiation model. She has gained new insights into the areas of agreement and disagreement among groups with an interest in the sludge facility siting decision. She believes there is one major weakness in the negotiation model, however--it does not treat public health risks. Surely stakeholder groups will be interested in the public health impacts of a sludge facility. Smith is also intrigued by the risk management theory of siting (Elliott, 1984). For her final cut at the siting problem, she decides to model the decision as a risk management problem.

Structuring Objectives for the Decision

Smith has only one objective under the risk management model--to build a facility at a site where the risks to public health will be low. Her decision is very dependent on the technology the MWRA will use to treat the sludge. If composting is the technology, any risks to public health from the sludge will be absorbed by the end users of the sludge--the people who put the compost on their gardens or eat food from farms that use the sludge. Because the compost will be sold in the same market no matter what site is chosen for the facility, the public health impacts of a composting facility are not site-specific, and are therefore eliminated from Smith's model. She therefore rates the public health risk from a composting facility at each site as low, with a utility of 1. She will concentrate on measuring the public health impacts of an incinerator. These impacts are site-specific. Smith builds a decision tree to represent her problem (Figure 5-1).

FIGURE 5-1
DECISION TREE STRUCTURE FOR THE RISK PERCEPTION MODEL



Defining Attributes and Performance Measures

How should Smith measure the public health risk from a sludge incinerator at each site? Decisions involving health risk involve the problem of defining consequence scope (Lathrop and Watson, 1982). Should Smith measure the facility's impacts on health during the life of the facility (1995--2020)? Or should she try to predict the facility's more long-term impact on public health? Which health impacts should she measure? Should she count the predicted number of deaths from cancer due to the facility, or should she include acute and chronic diseases that do not result in death? Who is the "public" whose health she is concerned with? Is it the workers in the sludge facility, or is it the people who live near the site? How far away from the site must one live before Smith no longer has to be concerned about health impacts?

Smith's definition of health risk is severely limited by the amount and type of information she has on the sites. She has no risk assessments for any of the sites; nor does she have figures on how many deaths or cases of illness could result from emissions from an incinerator burning sludge containing certain levels of heavy metals. Instead, she has maps showing the dry deposition rate of particulates from an incinerator at each site. She also has a copy of the EPA's proposed regulation on sludge treatment. (U.S. EPA, 1989). This rule sets limits on the amount of heavy metals and other toxics that sludge can contain for each type of treatment technology. The limits are based on EPA's assessment of what level of health risk is acceptable from each of these technologies. The acceptable risk standard is based on mortality figures--the additional number of cancer deaths in a population due to the sludge treatment--and does not deal with illness and other causes of death.

Smith is frustrated by her lack of information about health risks at each site, but decides to build a model using the information she has to see if it will give her any insights into the risk management aspects of the sludge facility siting problem. The dry deposition rate maps show her generally how much particulate matter is expected to settle on what areas around a facility. She uses the information on the maps to construct a scale measuring health risk. The levels of the scale range from 0 (no health risk) to 4 (extremely high risk). Low risk (level 1) means that particulates fall on populated areas at a rate of 5000 grams per minute (g/m); moderate risk (level 2), 10,000 g/m; and high risk (level 3) 15,000 g/m. If 30,000 g/m or more would settle on a populated area, the risk is judged to be extremely high (level 4).

Assessing Impacts and Probabilities

Next, Smith must decide who will make the assessments of risk at each site. Should she ask risk assessment experts to judge each site? Or should she use the risk assessments of lay people--especially those living near each site-- as inputs in her model? Because she is interested in defining the siting decision as a problem in dealing with and managing differing risk perceptions, she decides to use her own risk assessments and those of abutter groups in the model. As in the negotiation model, she will try to make educated guesses at how abutters would perceive the risks of a sludge facility.

The maps for the site at Deer Island show that high levels of particulates will settle on unpopulated harbor islands. Low level of deposition might reach the Winthrop neighborhood of Point Shirley. Smith judges that the probability that there will be no risk impacts from a facility at Deer Island is 80 percent, and there is a 20 percent probability that risk will be low. Smith guesses that abutters would believe the probability of no impacts to be 10 percent; the probability of low impacts, 40 percent; and the probability of moderate impact, 50 percent.

The air modeling results predict that high levels of particulate matter will settle on the downtown Lynn area. Smith believes that there is a 60 percent probability that health impacts will be moderate, and a 40 percent chance that they will be high. Abutters judge that there is a 50 percent probability that these impacts will be extremely high; a 40 percent chance they will be high; and a 10 percent chance they will be moderate.

At the Quincy site, very heavy levels of particulates could settle on nearby populated areas. Smith predicts that the probability that health impacts will be extremely high is 40 percent; that they will be high, 40 percent; and that they will be moderate, 20 percent. Abutters believe there is a 70 percent chance that impacts will be extremely high at the Quincy site. They also judge that the probability that impacts will be high is 20 percent; and that they will be moderate, 10 percent.

Heavy levels of particulates from a facility on Spectacle Island might impact a hospital on nearby Long Island. Low levels from the facility would reach Castle and Thompson Islands, areas used for recreation. Smith judges the probability that the impacts from a facility on Spectacle Island will be low to be 70 percent; and that they will be moderate, 30 percent.

Abutters (people who live on the harbor) predict that there is a 30 percent chance that health impacts from a facility will be high; a 50 percent chance that they will be moderate; and a 20 percent chance that they will be low.

At the Stoughton site, moderate levels of particulates may settle on a nearby industrial part, and low levels could reach moderately populated areas. Smith judges that there is a 50 percent chance that impacts will be low, and a 50 percent chance that they will be moderate. Abutters believe that there is a 10 percent chance that impacts will be low; a 40 percent chance they will be moderate; and a 50 percent chance they will be high. Low and moderate levels of particulates from an incinerator at the Walpole site could settle on moderately populated areas. Smith judges that there is a 50 percent probability that impacts at the site will be low, and a 50 percent probability that they will be moderate. Abutters believe that there is a 10 percent probability that impacts will be low; a 40 percent probability that they will be moderate; and a 50 percent chance that they will be high.

Smith does not have a dry deposition rate map for the Wilmington site. She therefore bases her assessments on the rates at other inland sites. She judges that there is a 20 percent chance that there will be no impact from a facility at the Wilmington site; a 60 percent chance that impacts will be low; and a 20 percent chance that they will be moderate. Abutters believe there is a 30 percent probability that impacts will be low; a 50 percent probability that they will be moderate; and a 20 percent probability that they will be high.

Assessing Preferences

Smith now assesses her preferences for the various health impact levels. She also guesses at utility assessments for abutters. The utility functions are graphed in Figure 5-2. Smith's function shows that she embraces the EPA's concept of "acceptable risk". She believes that impacts that are low or moderate are "acceptable"--therefore she is risk-neutral for these impact levels. Abutters, on the other hand, are extremely risk-averse to health impacts.

Results and Conclusions

Because Smith is only measuring one attribute--health risk defined as increased cancer mortality rates--she does not have to make tradeoffs among many objectives. She calculates the expected utility for impacts at each site (Table 5-1), and feeds these figures into the decision tree. Smith judges the probability that the technology will be composting at 50 percent, while abutters believe that probability to be only 20 percent.

The results for the MWRA are as follows:

Deer Island	.985
Wilmington	.925
Spectacle Island	.9025
Stoughton	.8875
Walpole	.8875
Lynn	.81
Quincy	.67

FIGURE 5-2

THE MWRA'S AND ABUTTERS' UTILITIES FOR PUBLIC HEALTH IMPACTS

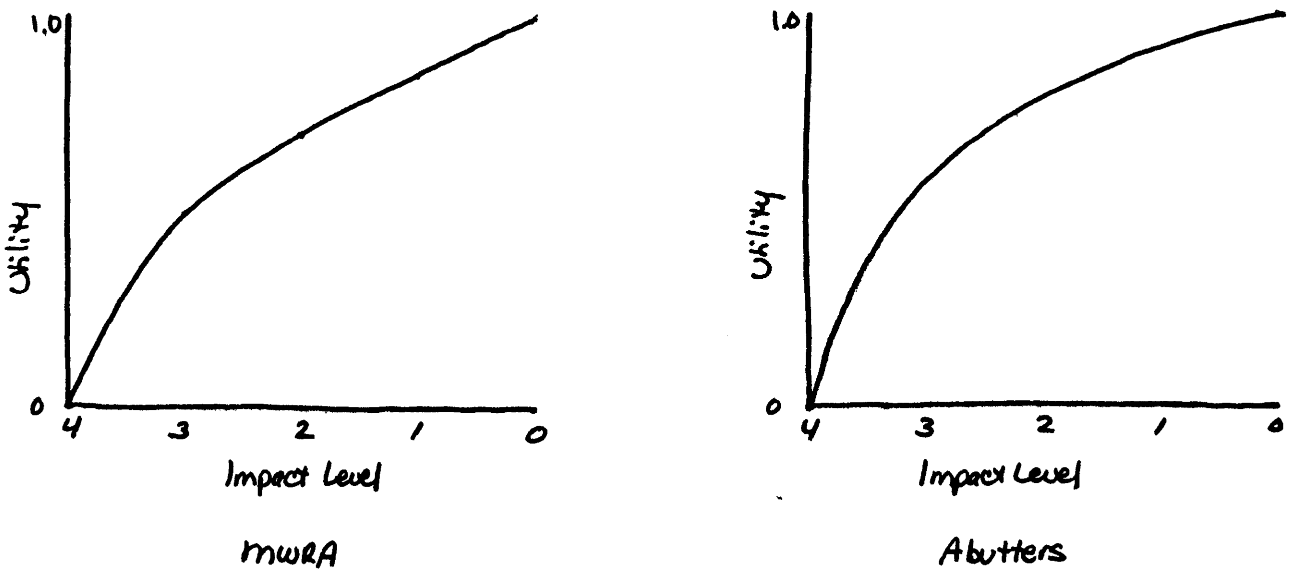


TABLE 5-1
EXPECTED UTILITY OF IMPACTS

Site	EU for the MWRA	EU for Abutters
Deer Island	.97	.864
Lynn	.62	.312
Quincy	.34	.196
Spectacle Island	.805	.756
Stoughton	.775	.701
Walpole	.775	.701
Wilmington	.85	.789

The results for abutters are:

Deer Island	.8912
Wilmington	.8312
Spectacle Island	.8048
Stoughton	.7608
Walpole	.7608
Lynn	.4496
Quincy	.3568

Both the MWRA and abutters agree in their rankings of health risks. Even so, Smith is dissatisfied with the results of this model. She is not very confident in the judgments she made to get these results. She might conclude that she should eliminate the Stoughton, Walpole, Lynn and Quincy sites from further consideration. However, she is wary of doing so, because of the many uncertainties in this model. She is not at all comfortable with the amount of information she had to use in the model. She is also unsure whether she should use the EPA's acceptable risk example to measure her utilities. Her impact levels do not correspond to any information in the EPA regulation. How can she be certain that moderate risk, as she has measured it, is really acceptable? She is also concerned about an information mismatch between the deposition maps her air quality specialists produced and the EPA's measurement of risk from incinerators. Her maps predict the amount of particulates that will settle on certain areas. The EPA, on the other hand, bases its figures on the assumption that particulates will remain in the air, and that people will get cancer from breathing them. Her two information sources, therefore, do not measure the same risk pathways.

Smith also expected differences between the MWRA's and abutters' perceptions of risk. The abutters believe that severe health impacts are more likely to occur than does the MWRA, but the differences are not enough to change the rankings of sites. Smith suspects that a richer model, evaluating many types of health risks and using more complete information, might capture these differences in perception much better.

Smith does not believe she has learned enough from this model to be able to choose among the seven sites. She has learned, however, that the health risk issue is very uncertain, and could be extremely important to her decision and choice of siting strategy. She therefore decides to seek further information about the health risks at each site.

CONCLUSIONS

Now that Smith has completed modeling the sludge facility siting problem four different ways, she tries to decide what insights into the problem she has gained from the modeling exercise. First, she looks at each model separately. How comfortable is she about the model's results and the modeling process itself? Is the model comprehensive? Does the simplification and aggregation necessary for decision analysis modeling result in the loss of any important components of the problem? Does the model accurately reflect the problem? How clear are the decision points--is the choice of three sites for further study obvious from the model results? How do the model results contrast with Smith's intuitions about the problem? Were the results a surprise to her in any way?

Analysis of Models

Smith is fairly comfortable about the technical model's results and the judgments she made in building the model. She does not believe that any important technical considerations were lost through simplification in this model--in fact, she was surprised at how little information really mattered to the decision, and how many of the technical criteria considered in the consultants' reports simply did not matter when comparing sites. She does not think the technical model accurately represents the siting decision, however, because it contains little analysis about the facility's impacts on people. The decision points in the model are clear--there are real differences in the utilities of the sites, and the top three site choices are easy to make. Smith was a bit surprised by the results of this model. Before beginning the modeling exercise, she had believed that the Lynn and Spectacle Island sites would rate fairly high on technical criteria, since they have been used for industrial purposes before. She was surprised to see that they ranked low in the technical model results.

Although Smith is comfortable with the judgments she made in the political model, she would not like them to become public. She believes that making her beliefs about the probability that political actors will act in a certain way public will "reveal her hand" in subsequent negotiations with them. She feels that the model handles the political considerations of the siting decision comprehensively, and that nothing was lost in the simplification process. The results of this model do not point to a clear choice of three sites for further review. Many sites have the same scores. Before modeling the problem, she had believed that the state Senate President would be the primary political roadblock to using Spectacle Island. She was surprised to learn that a synergy existed between the Senate President's and the Secretary of Transportation's support of the site for other uses.

Smith is uncomfortable with the guesswork she had to make to build the negotiation model. She learned a lot from her discussions with representatives of stakeholder groups, but wishes that the probability, utility and tradeoff assessments she made for these groups were more precise. She also believes that some important elements of the problem were lost in the simplification process of modeling. To make the model less cumbersome, she chose to aggregate the seven groups of abutters into one group. This simplification makes consensus appear more easy to achieve than it actually might be. True, abutters' interests were best addressed by choosing Spectacle Island, Deer Island and Quincy as possible sites for a facility, but the individual abutters at these sites would not favor use of these sites.

Smith also believes that many important interactions between attributes are left out of the negotiation model because of the additive utility independence assumption. For example, ratepayers preferences for various levels of environmental impacts may be dependent on the level of construction costs at a site. Simplifying the model does not allow Smith to study these dependencies.

While there are noticeable differences among the utility scores for each site by each stakeholder group, the final conclusions of the negotiation model are not all that clear. Several groups might rank Deer Island, Spectacle Island and Quincy as their top three choices, but it is not certain that the other groups will agree to drop their choices in favor of these sites, even if mitigation and compensation measures are offered. Smith was surprised that the equitable distribution of regional responsibility and concerns about the stigma effect would be so important to abutters. Before engaging in the modeling exercise, she had assumed that neighbors would be most concerned with noise and odor impacts and transportation safety issues.

Smith is extremely uncomfortable with the results of the risk model. She is frustrated by the lack of information about health risks, and wary of the many manipulations of data she had to perform and value judgments she had to make to model the problem. She is also uncomfortable with having to assess the desirability of various levels of risk. She would not want these assessments to be made public, even if she had proper information about the risks at each site. She is aware of the many assumptions that went into the EPA's definition of acceptable risk for sludge incineration, and believes that the definition is really very uncertain.

The risk model does not accurately represent the sludge siting problem. Because it only measures cancer mortality rates, it is concerned with only a fragment of public health. Smith would like more information about a sludge incinerator's impacts on minor and serious illnesses.

What has the exercise of modeling the sludge siting problem four different ways taught Smith about choosing three sites for further consideration? Table 6-1 shows each model's recommendation of whether to drop a site or keep it for further study. No one site is chosen by all four models. The results of all four models determine that only one site, Lynn, should definitely be dropped. The Quincy site rates high in three of the models--the technical, political expediency and negotiation models--but low in the risk model. The results of the negotiation and risk perception models tell Smith to keep Spectacle Island, but the technical and political expediency models tell her to drop it.

Smith believes that the negotiation model represents the siting problem most comprehensively, so she decides to follow its recommendations and retain Deer Island, Quincy and Spectacle Island for further study. Because she is so uncomfortable with the uncertainties and data deficiencies of the risk perception model, she decides to order detailed health risk studies on all of the sites except Lynn. If the results of these studies show that a facility at Quincy would pose high health risks, she could replace Quincy with one of the inland sites. She remains wary about the political problems at Spectacle Island, but decides that if that site appears to be the clear choice after further analysis, she might risk delay caused by negotiation with the Senate President and Secretary of Transportation.

TABLE 6-1
COMPARISON OF MODEL RESULTS

Site	Technical	Political	Negotiation	Risk
Deer Island	Retain	Drop	Retain	Retain
Lynn	Drop	Drop	Drop	Drop
Quincy	Retain	Retain	Retain	Drop
Spectacle Island	Drop	Drop	Retain	Retain
Stoughton	Drop	Retain	Drop	Drop
Walpole	Drop	Retain	Drop	Drop
Wilmington	Retain	Retain	Drop	Retain

What has the decision analysis modeling exercise taught Smith about what strategy of siting to use? She believes that none of the four models represents the problem completely, but that the negotiation model comes close. She decides to use a mix of the negotiation and risk management strategies. She will try to negotiate with the stakeholder groups to choose a final preferred site. She will try to validate her guesses about the groups' probability assessments, preferences and value tradeoffs. While she will not build another model, she will use the insights gained from the negotiation model exercise to offer compensation packages and mitigation strategies. She will involve the abutters to the final three sites in the risk assessment studies, so that she can learn about their perceptions of the health risks posed by the sludge facility.

Constraints and Pitfalls in the Further Use of Modeling

Smith is pleased with the results of the modeling exercise, and is tempted to make her decision of a preferred site from among the three finalists by using a new negotiation model, this time involving real probability, utility and value tradeoff assessments for the stakeholder groups. There are several constraints and pitfalls Smith would face if she were to attempt to build a new model to make the next decision. Some of these problems are institutional ones a public policy decision maker faces; some of them are inherent in decision analysis modeling techniques.

First, decision analysis presents unfamiliar measurement problems to decision makers and stakeholder groups. The public is not used to quantifying many intangible values--for example, equity or aesthetic values--and may not be able to make the measurement judgments necessary to decision analysis modeling. (Keeney and Raiffa, 1972). Decision analysis also forces decision makers to make unfamiliar choices in situations with which they have little experience--most notably, making choices between gambles to assess utilities. (Covello, 1987). These unfamiliar measurement problems may cause decision makers and stakeholder groups to give imprecise and inaccurate judgments for the model. The model results might therefore not represent these groups' true values at all.

Second, because decision analysis is built upon subjective judgments of probabilities, it is vulnerable to the biases and cognitive illusions that can affect probability judgments. Tversky and Kahneman (1974) identify three types of heuristics--mental procedures to simplify the analysis of complex probability judgments--that could bias a decision maker's probability assessments. "Representativeness" is used by decision makers to classify an unknown event into a category with which the decision maker is already familiar. For example, an individual's estimate of the probability of high health risks at a sludge facility is likely to depend on whether he or she perceives an incinerator to be like a nuclear power plant or a local trash dump. (Elliott, 1984). Decision makers also use the heuristic of "availability" to judge the probability of impacts at a facility. This cognitive simplification tool allows individuals to assess the probability of an impact by the ease with which other instances of that impact can be brought to mind. For example, if an individual has read many recent news reports about old leaking landfills, he or she may be more likely to believe that a new landfill might leak. Finally, decision makers make adjustments to an anchor when they are assessing probabilities. An individual might start his or her probability assessments from a certain value (the anchor) and adjust this value to get the rest of the probability judgments. For example, Smith may assess the probability of high ecological impacts at a site to be 80 percent, and then base her assessment of the probability of surface water impacts on this figure.

Other types of biases may affect probability inputs into a decision analysis model. Experts are likely to build safety margins into their judgments (Covello, 1987). Lay people who live near the proposed site of a project are more likely to believe that the project's risks outweigh its benefits than are people who live away from the site. (Marks and von Winterfeldt, 1984).

Another problem with using decision analysis for siting decisions is that the method requires decision makers to make their values explicit. Decision makers may not want to use a model that reveals their utilities for such things as human lives. To the public, the method may seem callous. (Fischhoff, et al., 1981). The decision analysis methodology assumes that decision makers and stakeholder groups will reveal their true preferences and value tradeoffs. (Covello, 1987). In fact, these groups may not reply honestly to questions about their probability judgments and preference values for strategic reasons. For example, the MWRA might not want to reveal that it believes that the probability that the sludge facility will be a composting facility is only 50 percent. Smith might believe that it will be easier to get people to accept a composting facility, so she might not want to reveal publicly that the technology outcome is an uncertainty. Stakeholder groups might engage in "gaming"--deliberately exaggerating their probability assessments or providing inaccurate value tradeoffs--to influence the results of the model. (von Winterfeldt and Edwards, 1986).

Decision makers might not want to make their judgments on political issues public. (Keeney and Raiffa, 1972). For example, Smith might believe that if her probability assessments about whether the state Senate President will oppose siting the sludge facility on Spectacle Island are made public, her negotiating position with the President would be weakened.

Decision analysis also assumes that decision makers and stakeholder groups have values about everything that goes into the model. In many cases, this may not be true--for example, ratepayers, who are concerned only about construction and operating costs at a facility, may have never considered how they feel about visual impacts, or about equity issues. But in order to build a model, these groups must articulate values about these issues. The preferences and value tradeoffs assessed from these groups may not be accurate, because the group's values are unformed. (Fischhoff, 1980).

Another pitfall of using decision analysis, or any kind of formal analytic method, for that matter, is that the modeling of a problem may <u>become</u> the problem. (Quade, 1980). A decision maker may find himself or herself caught up in the modeling process, and may lose sight of the bigger policy problem. For example, in the risk perception model, Smith had little information, but felt forced to use the information she did have in perhaps inappropriate ways for the sake of completing a model.

Decision analysis may not fit into the legal institutions that currently exist to make siting decisions. Decision analysis allows a decision maker to focus on only the information that is necessary to differentiate between and decide among sites. Most siting decisions are subject to federal and state environmental impact assessment laws and regulations. For example, the sludge siting decision must be reviewed under the Massachusetts Environmental Policy Act (MEPA) and the National Environmental Policy Act (NEPA). These statutes require the MWRA to study information about many different impacts, not just those that are crucial to a decision. The philosophy of these laws is that an agency should gather all of the information about every factor that could influence a decision, and then make a decision. Decision analysis, on the other hand, focuses on narrowing a problem to its vital components, and then gathering more information about those factors that are really important to the decision. (Behn and Vaupel, 1982).

Finally, using decision analysis to make facility siting decisions may perpetuate the mystique of a "technical fix" for societal problems. (Fischhoff, 1980). Problems are believed to be easily solved by building models and manipulating data. In fact, facility siting conflicts may be insoluble problems. The "not in my backyard" syndrome may represent deeply rooted societal conflicts about equity, governmental power, and technology. Decision analysis, by presenting a seemingly "easy" way to solve problems, may allow decision makers to believe that they can ignore these conflicts. (Fischhoff, 1980).

If Smith were to use decision analysis to decide among the final three sites for a sludge facility, she would have to wrestle with all of these problems. The benefits of the analysis might not be worth the time, money and effort that would go into this next phase of modeling. No matter how she decides to approach the next stage of the siting problem, Smith has benefited from using decision analysis for problem formulation. She has looked at the problem through different lenses, and has discovered the many different facets of the siting decision. She has gained some insight into possible siting strategies. She has learned what further information she needs to make a decision, and has decided where to concentrate her scarce time and money resources. She has put herself in the shoes of stakeholder groups, and has thus learned about their values and concerns in a much more active way than if she had merely discussed the problem generally with them. Her uncertainties about the guesses she made about these groups' probability assessments, preferences, and value tradeoffs form a basis for further learning. She has identified the uncertainties inherent in the siting problem, and has evaluated how to resolve the ones that are important. Her own preferences and tradeoffs among objectives are clearer to her. Building decision analysis models forced her to systematically look at the problem in its entirety. She now has a "big picture" of the problem in her mind, and can avoid making decisions based on only one element of the problem. Perhaps most importantly, using decision analysis has given her a deep personal understanding of the problem that she would not have had if she had merely relied on consultant and staff reports. She can now design a strategy to site the sludge facility, confident that she has brought some order to an extremely messy problem.

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