Working Paper

A DESCRIPTIVE MODEL OF CHOICE
FOR SITING FACILITIES:
THE CASE OF THE CALIFORNIA LNG TERMINAL

Howard Kunreuther
John Lathrop
Joanne Linnerooth

July 1981
WP-81-106

International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria

A DESCRIPTIVE MODEL OF CHOICE FOR SITING FACILITIES: THE CASE OF THE CALIFORNIA LNG TERMINAL

Howard Kunreuther
John Lathrop
Joanne Linnerooth

July 1981
WP-81-106

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

ABSTRACT

This paper develops a descriptive framework to provide a basis for prescriptive considerations for improving societal decision processes, such as that concerned with the siting of energy facilities that offer long-run benefits but at the risk of catastrophic consequences. The descriptive model incorporates multiple parties and multiple concerns in a dynamic setting. It emphasizes the potential for conflict emerging among the interested parties as a result of their differing objectives, mandates, and information sources. Of particular importance is the decentralized and sequential nature of the process. On the prescriptive side, the paper explores the role that analysis, including risk analysis assumption analysis, and multi-attribute utility analysis, can play in improving the decision process. The descriptive model and prescriptive considerations are illustrated by a concrete example—the siting of a liquefied natural gas terminal in California.

CONTENTS

A DESCRIPTIVE MODEL OF CHOICE FOR SITING FACILITIES: THE CASE OF THE CALIFORNIA LNG TERMINAL

Howard Kunreuther, John Lathrop and Joanne Linnerooth*

I. INTRODUCTION**

Large-scale, novel technologies such as nuclear power or liquefied energy gas promise to yield benefits to society, but only at the cost of potential catastrophic losses. Thus the siting of the facilities for these technologies presents a formidable challenge to political risk management processes. There are two features of these problems which make them particularly difficult to structure analytically. First, the decision on whether to site a facility in a particular location affects many different individuals and groups in society rather than being confined to the nor-

*Authors' names are in alphabetical order.

**The research reported in this paper is supported by the Bundesministerium fuer Forschung and Technologie, F.R.G., contract no. 321/7591/RGB 8001. While support for this work is gratefully acknowledged, the views expressed are the author's own and are not necessary shared by the sponsor. We greatly benefited from earlier discussions with Nino Majone and wish to thank Eric Ferguson, Paul Kleindorfer, Chris Mandl and Michael Stoto for their helpful comments on a preliminary draft of this paper.

mal relationship of a private market transaction, when one purchases items like food, appliances or a car. If a gas terminal is sited, there is a class of firms and consumers who stand to gain from the new energy source. Among other possible social costs, the individuals living near a proposed site will be exposed to a new hazard. Their views as to whether the benefits are worth the extra risks from the new technology are likely to differ from each other. Those who are not directly affected by the proposed site will see the problem somewhat differently. Hence there is the potential for conflict between interested parties.

A second feature of the siting problem is the absence of a data base which provides conclusive statistical evidence on the likely performance of the new technology and the probability distribution associated with potential accidents. Each of the interested parties may thus provide different estimates of the chances and consequences of certain events. There are *no* objective measures to settle these differences.

This paper proposes a descriptive model of societal choice for characterizing problems such as the siting of energy facilities where the above two features are present. We illustrate the model in the context of a particular case study--the siting of liquefied natural gas terminals in California. The final portion of the paper suggests how this framework for descriptive analysis might provide insights to aid political decision processes.

II. A DESCRIPTIVE MODEL OF CHOICE

A. BASIC CONCEPTS

1. Many Interested Parties

An important feature of the societal decision-making problem represented by the siting of a facility is the presence of a number of different interested parties, each with its own objectives, data base and constraints (Keeney 1980). For instance, locating an energy facility in a particular region will be perceived differently by each of the following relevant parties:

Government Agencies

Government organizations are constrained in their actions by legislative mandates. For example, in the siting of LNG facilities, the Department of Energy must determine whether this new source of energy is in the national interest. Regulatory agencies are an integral part of the political process. Their actions influence the nature and distribution of the public's preferences and provide advantages to some interests relative to others in their efforts to affect the outcome of the societal decision process (Jackson and Kunreuther 1981). These organizations are qualitatively different from those in the following three categories, in that government agencies, although they may in some cases have an interest in a particular outcome, are basically the rule makers and "referees" of the process, while the other parties are the "players" with costs and benefits directly linked to the outcome of the process.

Industry

Firms which are involved in the construction and operation of an LNG plant will focus on the potential economic benefits to them in relation to the cost. In addition to the cost of building and operating the facility, safety features of the plant are also a concern since the firm may be partially or fully responsible for the consequences of any accidents to the public.

Local Community

Residents in the community where the plant is to be sited may have different views of the situation. Some might see the economic benefits, e.g., reduced property taxes or employment, as justifying the increased risk associated with the plant. Others may feel differently. For instance, they may view the additional risk as unacceptable and/or they are opposed to new technologies on ideological grounds (Otway and von Winterfeldt).

Public Interest Groups

Recently we have seen the rise of very intense public interest groups. These organizations generally represent the interests and preferences of one component of the public. For example, the membership of the Sierra Club is concerned with the effects that the siting of any new facility will have on the environment. Wilson (1975) and Mitchell (1979) have pointed out that those attracted to such organizations have strong, particular interests which dictate the agenda of the organization and influence the type of information that is collected and processed.

2. Sequential Decision Process

A second feature of the siting problem is that the process is characterized by sequential decisions. March (1969) notes that individuals and groups simplify a large problem into smaller subproblems because of the difficulty they have in assimilating all alternatives and information. Often constraints due to legislation and legal considerations dictate the order in which certain actions must be taken. In the case of siting LNG terminals in California, for example, the California Coastal Commission was mandated to rank a set of alternative sites before the California Public Utilities Commission could select a site for approval. This type of quasi-resolution of conflict through formal decentralized procedures is very common in organizations where departments with different goals and constraints attend to different decisions at different times. Cyert and March (1963) provide empirical evidence suggesting that the organization factors its decision problems into subproblems each of which are assigned to different units.

If the process is sequential in nature then the setting of an agenda is likely to play a role in determining the final outcome as well as the length of time it takes to reach it. By agenda setting we are referring to the order in which different subproblems are considered. There is strong empirical evidence from the field as well as from laboratory experiments (see Downs 1973; Cobb and Elder 1975; and Levine and Plott 1977) that different agendas for the same problem frequently lead to different outcomes. There are two principle reasons for this. Once a particular decision has been made on a subproblem this serves as a constraint for the next subproblem. If the order of the subproblems is reversed then there would likely be a different set of choices to consider. Secondly, each subproblem involves a different set of interested parties who bring with them their own set of data to bolster their cause. The timing of the release of this information may have an effect on later actions. For example, citizens groups normally enter the scene with respect to siting problems only when their own community is being considered as a possible candidate. The data on the risks associated with siting would be released at a slower rate (but perhaps with greater emphasis and more political impact) if only one site was considerd at a time than if all potential sites were evaluated simultaneously.

3. Differences in Information Utilized

Finally, there is considerable evidence from field and laboratory experiments suggesting that the small data base for judging outcomes and performance will cause systematic differences in the way information is utilized at different stages of the decision process. Tversky and Kahneman (1974) describe one of these phenomenon under the heading of availability whereby one judges the frequency of an event by the ease with which one can retrieve it from memory. Special reports on a recent disaster call attention to the dangers associated with a particular technology. These events may drastically change the estimates of specific outcomes and are also likely to stimulate efforts to induce new legislation to "prevent" the event from reoccurring (Walker 1977). Fischhoff, Lichtenstein and Slovic (1979) summarize their recent experimental studies by cataloguing the perceptions of individuals on the perceived probability of occurrence and consequences of different types of hazards. One of their principal conclusions is that these estimates tend to be labile and hence are likely to change over time because of events which are highlighted by mass media coverage. This finding reinforces the importance of focusing on changing perceptions of interested parties over time and the need to study the dynamics of societal decision-making.

B. A FORMAL STRUCTURE

The above concepts are now incorporated into a model of a sequential decision process which involves different interested parties at each stage. The approach focuses on more than one attribute and many interested parties. Hence we have labeled it the Multi-Attribute, Multi-Party (MAMP) approach. In developing this structure we have been greatly influenced by the concepts discussed by Braybrooke (1974) where he looks upon the political system "as a machine or collection of machines for processing issues." (p.1). Since we view the siting problem as a decision with multiple objectives, the notation we utilize below builds on that of Keeney and Raiffa (1976) who are primarily concerned with a single decision-maker. Our interest here is in extending these concepts to the case where there are many interested parties who interact over a finite horizon.

1. Rounds

The decision process can be separated into different rounds which we label by capital letters, A,B,... A round is simply a convenient device to illustrate a change in the focus of discussions. This new focus or direction can be triggered by (1) a key decision taken (or a stalemate reached due to conflicts among parties), or (2) a change in the context of the discussions due to an unanticipated event, the entrance of a new party or new evidence to the debate. Rounds are simply a convenient way of segmenting the decision process; there is no assumption, however, that they cannot be simultaneous or overlapping.

2. Problem Bounds

The decision process in each round is bounded by a set of issues, decision constraints and procedures. Braybrooke (1974) refers to an "issue-circumscribing" phase where the alternatives for discussion are bounded by generally accepted though not necessarily irrefutabble, facts and values, e.g., "it is technically feasible to import LNG to California" or

"California needs LNG". Other bounding constraints include legislative and legal mandates requiring specific parties to be part of the debate; resource constraints which have the effect of limiting certain parties from exerting an influence because they do not have adequate funds and means; and prespecified voting procedures indicating what parties have the power to influence the outcome of specific decisions and in what ways. As we have already noted the problem is also bounded by the decisions from earlier rounds. Clearly the agenda setting process will have an impact on final outcomes through this latter type of bounding constraints.

3. Initiating Events

Generally, a round of more-or-less official discussions is initiated by a formal or informal request. Informal discussions may be initiated simply by such actions as a request for information on the part of one of the parties or a request for preliminary discussions. Because the particular form of these initiating requests may further define or limit the bounds of the discussion, the careful scrutiny of their wording is important. For example, it may make a difference in the decision process if the question is framed as "Is there a site which is appropriate?", or "which of the sites x, y, and z is the appropriate site?" Braybrooke (1974) refers to the first question as a "whether question" and the second as a "which" question. Whether questions demand more complicated considerations and detailed thinking while which-questions can be approached with simpler rules of thumb and heuristics.

4. Alternatives, Attributes, and Decisions

No matter how a round is initiated it is characterized by a unique problem formulation which is presented in the form of a set of alternatives. We define the alternatives for Round A to be $A^1, A^2, A^3, \cdots$; Round B has alternatives $B^1, B^2, B^3 \cdots$. There can be several decisions made in any round but by definition they are based on the same set of alternatives. Each alternative is characterized by a set of attributes $X_1, \ldots, X_n$. The value of any attribute can change from round to round on the basis of new information or perceptial changes. For certain attributes any party involved may have target or aspiration levels which determine whether he considers a particular alternative in Round A to be acceptable with respect to attribute X_i. An aspiration level frequently used in siting decisions is whether the probability of a catastrophic accident at a particular site is below a present acceptable level (1980).

5. Interaction Phase

To understand a particular pattern of institutional choice it is necessary to analyze a set of policy actors $\{P\}$ their interactions with one other at different stages of the process, and the information available to them. We define P_k to be the kth interested party in the debate. His evaluation of alternative A^1 is given by A_k^1 and is based on his estimation of the levels of each attribute resulting from that option, the value to him of each of those levels, and the relative importance he gives to each attribute. Another party might have different estimates of the effects of an option, different costs and benefits resulting from those effects, or, assign different relative importance to each of the attributes. Because of any of these differences one party may rank alternatives differently than another. As we shall see in our analysis of the California case this happened frequently. Thus in the case of two interested parties and two alternatives it is possible that party 1 prefers A^1 to A^2 (i.e., $A_1^1 > A_1^2$), while party 2 has the reverse reaction (i.e., $A_2^2 > A_2^1$). Conflict frequently emerges for this reason.

Another important feature of the decision process is that the value of an attribute to the same interested party can change over time because of new information. For example, if a report provides new insight into the seismic risk associated with a particular site this may cause a change in the perception of this attribute by one or more of the parties involved. That change may take the form of a different estimate of the level of the attribute for that site, or even a different relative importance for the attribute.

The interaction among the parties is represented by the *main arguments* each brings to the debate in support of or in rejection of each of the alternatives at hand. Those arguments may relate to only one or two attributes. It is *not* suggested here that the arguments presented for or against a particular proposal necessarily reflect a concern of the party making the argument. For example, a party opposed to a site because of its concern for environmental quality may present an argument using seismic risk as the main reason to reject the site. The argument attribute may be selected to maximize the effectiveness of the argument, not to reflect the actual concern of the party. The argument reflects a *strategy* on the part of the actor in support of or opposition to the proposal.

Arguments or positions are generally well thought out since it is important that a policy maker take a position that cannot be shown to be inconsistent with past and ongoing policies or decisions. The strategy of the actors can reveal a number of underlying motives and desires of those concerned and may be essential in understanding the interpretation and use of scientific evidence, including risk analyses.

Observing the interaction phase over the various rounds can provide useful insights into the process. The stability of the system can, at least partially, be judged by the degree to which the actors--people holding certain recognized positions (i.e., officials experts, group leaders) or collections of these people, whether formally organized institutions or loosely working alliances--remain the same over each successive round. The interaction phase can also demonstrate the extent to which the political debate approximates an ideal or logically full debate, where each argument is confronted--heeded or rebuffed--by each actor,, followed by counter arguments, and so on. A social debate on an issue is merely symbolic if the actors respond to the arguments presented only as signals for asserting or reasserting their own unmodified views. In this connection, the MAMP model can indicate to what extent the debate falls short of being a full debate, and for what reasons.

6. Concluding a Round

The round is concluded by a decision, a stalemate, a change in information (changing the focus of the debate and hence initiating a new round), or an unanticipated event aborting the discussions and requiring a new round of inquiry. Each decision can, in turn, be described by the tradeoffs implicit in the choice made. These tradeoffs may not be explicitly recognized by the decision maker, or not explicitly analyzed in the process making the decision. The distinction between a "decision-maker" and a decision resulting from a process is an important one since the person responsible for the decision often cannot be identified (see Allison 1971 and Majone 1979).

Figure 1 provides a schematic diagram of the MAMP model. Each round is set in the context of certain constraints that circumscribe the issues and bound the problem. An initiating event determines an initial set of alternatives $\{J^{1,J^{2...}}\}$ which, in turn, induce a set of interested parties $\{P_k\}$ to enter the scene. Each of these parties has its own preferences over the above alternatives (and perhaps some new ones); these preferences are defended by reference to the attributes. Conflict between parties is likely to emerge.The interaction process results either in a clear decision or an outcome that does not have the appearance of a decision but that does conclude the round. The conclusion of round J can take one of two forms. If there is a feasible and agreed-upon solution or if no solution is possible, the process ends. However, if one or more parties is unsatisfied with the situation at the end of the round, and has recourse to other channels, or if the round ends in a request for further action, problem bounds are created for Round $J+1$ and the above sequence is repeated for another set of alternatives, interested parties (some or all may be the same as in J), etc.

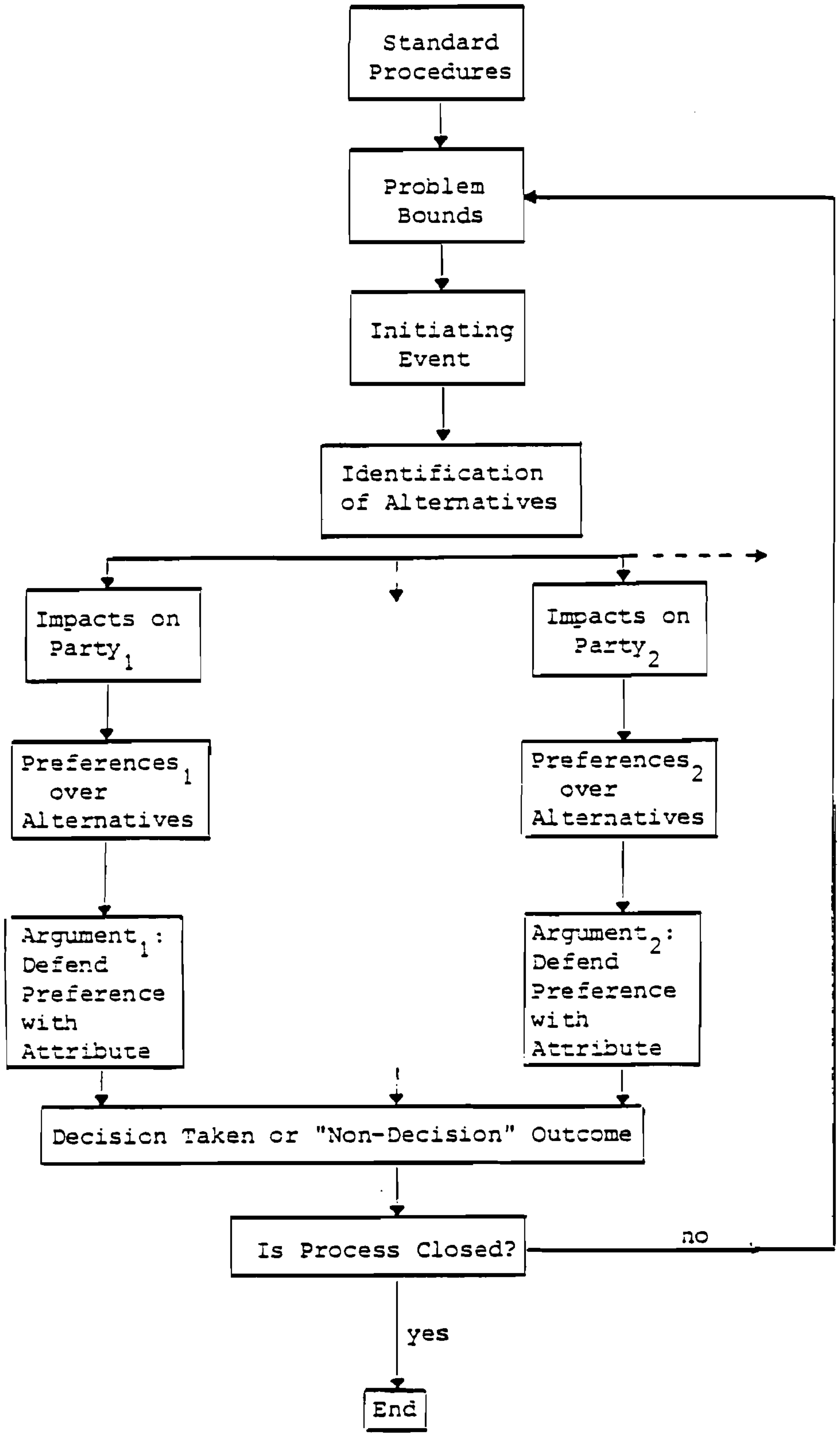

Figure 1: Multiattribute, Dynamic, Multiparty (MAMP) Model of Choice

III. APPLYING MAMP: THE SITING OF THE CALIFORNIA LNG TERMINAL

A. NATURE OF THE PROBLEM

Liquefied natural gas (LNG) is a potential source of energy which requires a fairly complicated technological process that has the potential, albeit with very low probability, of creating severe losses. For purposes of transporting, natural gas can be converted to liquid form at about 1/600 its gaseous volume. It is shipped in specially constructed tankers and received at a terminal where it undergoes regasification and is then distributed. The entire system (i.e., the liquefaction facility, the LNG tankers, the receiving terminal and regasification facility) can cost more than $1 billion to construct (Office of Technology Assessment 1977). In 1974, three LNG terminals were proposed for California. After seven years of negotiations, hearings and studies, on three levels of government, there is still no approved site for any of the proposed terminals in California. In this paper, we cannot begin to cover, much less assess, the many and varied aspects of this procedure, (for a review, see Linnerooth 1980 and Lathrop 1981). Our purpose here is to give a "bare bones" account, to illustrate how the MAMP model can be used to structure and understand the decision process.

B. INTERESTED PARTIES AND RELEVANT ATTRIBUTES

To structure the siting process we need to have a good understanding of the different concerns of the interested parties. For the LNG problem there were three categories of concern which are relevant: risk aspects, economic aspects, and environmental aspects. Each of these concerns can be described by a set of attributes. Table 1 depicts an interested party/attribute matrix showing the main concerns of each of the relevant groups over this seven year period.

The attributes listed have been selected to reflect the nature of debates in the process, that is, to reflect the attributes as perceived by the parties in the debate, rather than to characterize in some logical analytical manner the alternatives. For example, population risk (X_2) involves the risk to life and limb to neighbors of the LNG terminal due to accidents including earthquake-induced accidents. Earthquake risk (X_3), which involves both population risk and supply interruption risk due to earthquakes, is included as a separate attribute since it was handled as such in the process.

The filled cells in Table 1 indicate which parties pay particular attention to which attributes. Naturally, many of the parties care about all the attributes listed. However, either because of the incentives directly felt by the party or because of the role the party plays in society, each party makes its decisions as a function primarily of a particular subset of the

Table 1: Principal Party-by-Attribute Matrix for LNG Siting in California

Attributes		PRINCIPAL PARTIES[1]							
		Applicant	Government					Interest Groups	
		Utilities	Federal	State			Local		
			FERC	CCC	CPUC	Legis.	Municip.	Sierra Club	Local Citizens
		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
RISK									
supply interruption	x_1	•	•		•	•			
population	x_2		•	•	•	•	•	•	•
earthquake	x_3		•	•	•	•			
ENVIRONMENTAL									
air quality	x_4		•		•	•		•	
land use	x_5		•	•	•	•	•	•	•
ECONOMIC									
profit considerations	x_6	•							
price of gas	x_7		•		•	•			
local economic benefits	x_8						•		

[1] Key to Party Acronyms, Abbreviations:

FERC: Federal Energy Regulatory Commission, or in the first two rounds of the process, its preceding agency, the Federal Power Commission.
CCC: California Coastal Commission
CPUC: California Public Utilities Commission
Legis: California State Legislature
Municip: Municipal Government

attributes. For example, while the applicant is certainly concerned with environmental quality and risks to the population, its primary responsibilities and concerns are earning profits for shareholders and delivering gas reliably to consumers. Its actions are apt to be motivated by concerns for profits and gas supplies, and constrained by political and legal limits set by other parties' concerns for safety and the environment. Likewise, the Sierra Club cares about reliable gas supplies, but receives membership dues for being primarily concerned with environmental quality. Consequently, in a situation where a proposed action increases the reliability of gas supply at the expense of environmental quality it is reasonable for the applicant to favor the proposal and the Sierra Club to oppose it. These differences in primary concerns may determine a great deal of the behavior of the political decision process, and explain how that process is apt to differ from the single decision maker postulated by normative evaluation approaches. The important message of Table 1 does not lie in the details of exactly which cells are filled, but lies in the generally great differences between columns of the table. That is, the different parties in the process care about very different subsets of the attributes.

The applicant, Western LNG Terminal Associates, was a special company set up to represent the LNG siting interests of three gas distribution utilities: Southern California Gas Company, Pacific Gas and Electric, and El Paso Natural Gas Company. As domestic gas supplies seemed to be diminishing in the late 1960's, the gas utilities perceived an increased risk of supply interruption, which could be mitigated by additional supplies such as LNG. Quite naturally, the applicant was primarily concerned with profitability (X_6) and secure supplies of gas (X_1).

At the various government levels there are five principal parties. The Federal Energy Regulatory Commission (FERC) is the principal body in the Department of Energy which determines whether a proposed LNG project is in the public interest and should be allowed. In making its judgment it considers primarily the following attributes: risk factors (X_1 ,X_2 , and X_3), environmental guidelines as reflected in air quality (X_4) and use of land (X_5), and the expected LNG price (X_7).

At the state level, the California Coastal Commission (CCC) was created in 1976, and has the responsibility for the protection of the California Coastline. Its primary concerns with respect to LNG siting are with the use of land (X_5) and the associated risks (X_2 and X_3)from building a terminal at a specific site. The California Public Utilities Commission (CPUC) is the principal state body involved in power plant issues and is primarily concerned with the rate-setting process. Hence it focused on the provision of energy to California residents and need for gas (X_1) and the proposed price of the product (X_7). In addition, it has responsibility for evaluating the impact that a proposed facility would have on the environment and safety. The California state legislature is ultimately responsible for the outcome of any siting process. It determines which state and local agencies have final authority to rule on the feasibility of a proposed site. In addition, it can set standards to constrain any siting process. Hence the concerns of the legislators range over economic, environmental and safety attributes as shown in Table 1.

At the local level, the city councils evaluate the benefits of a proposed terminal in their jurisdiction in terms of the tax, business revenues, and jobs (X_8) it promises to provide. It has to balance this positive feature with the impact that the facility would have on land use (X_5) and risk to the population (X_2). Finally, the public interest groups, represented by the Sierra Club and local citizens groups, are primarily concerned with environmental and safety issues.

C. THE DECISION PROCESS

The siting process in California (which is not yet terminated) can be characterized up to now by four rounds of discussions as shown in Table 2, which provides a summary of the entire process. Each round, in turn, containa a summary of how the problem was defined, the initiating event, and how the discussions were concluded. The remainder of this subsection discusses in more detail the decision process within each of the rounds. The main elements of rounds A, B, C, and D are described in Tables 3, 4, 5 and 6, respectively.

Round A began in September 1974, when the applicant filed for approval of three sites on the California Coast--Point Conception, Oxnard, and Los Angeles--to receive gas from Indonesia. The application raised two central questions which defined the problem addressed in Round A: Does California need LNG, and if so, which, if any, of the proposed sites is appropriate?

Table 2: Summary of Rounds in California LNG Siting Case

		Date
ROUND A		
Problem Definition:	Should the proposed sites be approved? That is: Does California need LNG, and if so, which, if any, of the proposed sites is appropriate?	
Initiating Event:	Applicant files for approval of three sites.	September 1974
		(34 months)
Conclusion:	Applicant perceives that no site is approvable without long delay	July 1977
ROUND B		
Problem Definition:	How should need for LNG be determined? If need is established, how should an LNG facility be sited?	
Initiating Event:	Applicant and others put pressure on state legislature to facilitate LNG siting.	July 1977
		(2 months)
Conclusion:	New siting process set up that essentially assumes a need for LNG, and is designed to accelerate LNG terminal siting.	September 1977
ROUND C		
Problem Definition:	Which site should be approved?	
Initiating Event:	Applicant files for approval of Point Conception site.	October 1977
		(10 months)
Conclusion:	Site approved conditional on consideration of additional seismic risk data.	July 1978
ROUND D		
Problem Definition:	Is Point Conception seismically safe?	
Initiating Event:	Regulatory agencies set up procedures to consider additional seismic risk data.	
Conclusion:	(Round still in progress)	

Table 3: Elements of Round A

Problem Definition: Should the proposed sites be approved? That is: Does California need LNG, and if so, which, if any, of the proposed sites is appropriate?

Initiating Event: Applicant files for approval of three sites.

Alternatives:

Site at Point Conception:	A^1
Site at Oxnard:	A^2
Site at Los Angeles:	A^3
Site at any combination of:	A^1, A^2, A^3

Interaction:

Involved Parties		Attributes Used as Arguments			
Applicant	P_1	X_1			
FERC	P_2	X_1		X_3	
CCC	P_3		X_2		
City Councils	P_6		X_2		X_5
Sierra Club	P_7		X_2		X_5
Local Citizens	P_8		X_2		X_5

Key Decisions:

1. A^1 could be preferred to A^2, and A^3, based on the fact that the decrease in population risk outweighs the increase in environmental degradation.
2. A^3 would be approved because the seismic risk is greater than an acceptable threshold.

Conclusion:

Applicant perceives a stalemate, i.e., that no site is approvable without long delay.

Table 4: Elements of Round B

Problem Definition: How should need for LNG be determined? If need is established, how should an LNG facility be sited?

Initiating Event: Applicant and others put pressure on state legislature to facilitate LNG siting.

Alternatives:
Consider offshore sites: B^1
Consider remote onshore sites: B^2
Consider non-remote onshore sites: B^3
One-stop licensing: B^4
Licensing Agency: CPUC = B^5, CCC = B^6, CEC = B^7*
Any consistent combination of B^1 through B^7.

Interaction:

Involved Parties		Attributes Used for Arguments		
Applicant	P_1	X_1		
CCC	P_3		X_2	X_5
CPUC	P_4	X_1		
State Legislature	P_5	X_1	X_2	

Key Decisions:

3. Initial legislation introduced which included B^1, B^2 and B^5.

4. Final legislation passed which incorporated B^2, B^4 and B^5.

Conclusion:

Passage of LNG Siting Act of 1977 (S.B.1081) which defines a custom-tailored siting procedure for LNG. Some features:
- -- CCC nominates and ranks sites in addition to the one applied for.
- -- CPUC selects a site from the CCC-ranked set, not necessarily the top-ranked site.

*CEC = California Energy Commission

Table 5: Elements of Round C

Problem Definition: Which site should be approved?

Initiating Event: Applicant files for approval of Point Conception site. (The only site of its original three meeting the remote siting constraint of S.B.1081.)

Alternatives: (Sites nominated by CCC plus applied-for site.)
Site at Camp Pendleton: C^1
Site at Rattlesnake Canyon: C^2
Site at Point Conception: C^3
Site at Deer Canyon: C^4

Interaction:

Involved Parties		Attributes Used for Arguments			
Applicant	P_1	X_1			
FERC	P_2	X_1			X_5
CCC	P_3			X_3	X_5
CPUC	P_4	X_1	X_2		
Sierra Club	P_7			X_3	X_5
Local Citizens	P_8				X_5

Key Decisions:

5. $C_3^1 > C_3^2 > C_3^3 > C_3^4$.

6. C_3^3 approved conditional on further determination whether or not seismic risk at Point Conception is acceptable.

7. C_3^2 considered acceptable.

8. Court requires FERC to consider additional data to determine whether or not seismic risk at Point Conception is acceptable.

Conclusion:

FERC and CPUC to consider additional seismic data.

Table 6: Elements of Round D

Problem Definition:	Is Point Conception seismically safe?
Initiating Event:	FERC and CPUC set up procedures to consider additional seismic risk data.
Alternatives:	Declare Point Conception safe: D^1 Declare Point Conception not safe: D^2

Interaction:

No interaction yet, as study groups for FERC and CPUC examine seismic data in preparation for hearings.

Currently Active Parties		Attribute Considered
FERC	P_2	X_3
CPUC	P_4	X_3

Key Decisions:

None yet. Future hearings are to determine whether or not seismic risk is acceptable for Point Conception.

Although the issue was at this stage broadly circumscribed, the agenda for discussion was set more narrowly. The wheels of the process were set into motion, not by a broadbased energy-policy question initiated in Washington, but by a proposal from industry for three preselected sites. The importance of this process--where the initiative is taken *first* by industry--in preselecting the agenda for debate cannot be overemphasized. The initiating proposal framed the problem as "Should the proposed LNG sites be approved?", and *not* "Should California have an LNG terminal in view of the alternatives, costs, risks, etc.?" Setting the agenda in this manner did not preclude the "need" question from entering the debate, but it did ensure that the question was only considered in the contentious context of a siting application.

Table 3 also specifies the relevant interested parties who were involved in the interaction phase of Round A. There were four primary attributes which were utilized in the ensuing debate among the parties. The need for LNG or the risk of an interruption in the supply of natural gas (X_1) supported the locating of a terminal in at least one of the three proposed sites. While environmental, land-use considerations (X_5) suggested a non-remote site (Los Angeles and Oxnard), the risks to the population (X_2) argued for siting the terminal in a remote area (Point Conception). Finally, concerns about earthquake risk brought about opposition to the Los Angeles site, which was found to be crossed by a significant fault.

The interaction phase of round A (see Table 3) indicates the attributes used as arguments by each of the major involved parties. It is important to distinguish this listing of attributes from the listing in Table

1. While Table 1 specifies which attributes are of *primary concern* to each party, Table 3 specifies which attributes were *used as arguments* by each party. Thus while the applicant is concerned with both profit considerations and supply interruption risk, naturally enough its arguments in support of each site stressed supply interruption risk.

Two key decisions were made during Round A. First, the CCC, concerned about the catastrophic potential of LNG, indicated that it might favor Point Conception over the non-remote sites. This decision represents a trading off of population risk against land-use environmental quality; in the words of the CCC, this was a "people over birds" decision. (This decision did not, however, tie the CCC to approval of Point Conception. In fact such an approval could be difficult to obtain.) Second, the FERC indicated disapproval of the Port of Los Angeles as an acceptable site because a recently discovered earthquake fault increased the seismic risk above an acceptable threshold. The round was concluded with a possible stalemate, at least as perceived by industry (Ahern 1980). Los Angeles would not receive federal (FERC) approval, Oxnard was not likely to receive state (CCC) approval, and Point Conception would face very difficult approval challenges at the county and state (CCC) levels because of its adverse land-use impacts.

The stalemate of Round A bounded the problem for Round B. It was clear to all the parties involved that it was difficult, if not impossible, for the applicant to gain approval for a site under the existing siting procedure in California. In particular, there were possibilities of vetoing proposals at either the federal, state, or local levels as evidenced by the respective reactions to the three proposed sites. Rather than trying to operate within the existing constraints of the process, the interested parties in the process frequently try to change the rules of the game (Majone 1979). This is precisely what triggered Round B, where the problem was redefined into two new questions: How should need for LNG be determined? If need is established, how should an LNG facility be sited? Round B was thus initiated when pressure to change the siting procedure was brought to the state legislature by the utility companies, the business community and the labor unions in California. Table 4 depicts the relevant alternatives which formed the basis for the debate on the elements of proposed legislation.

The industry and business interests, saw the nearly inevitable problem of obtaining local approval for a project in the national interest, but with costs to the local community. So the utility companies went to battle for a bill (S.1081) which would vest the CPUC with one-stop licensing authority, precluding any real interference from local communities. The environmental and local interests, on the other hand, objected to a one-stop licensing process and favored a bill which required remote-siting.

The resulting legislation was a compromise between the environmentalists, who supported consideration of off-shore sites, and those who saw an urgent need for an LNG facility to assure energy and jobs. The CPUC was chosen over the more conservation-minded CCC or the California Energy Commission as the agency with state permit authority, preempting local governments. As a bow to the conservationists, the CCC was given the mandate to choose and to rank possible sites, and to pass these rankings on to the CPUC. It was agreed that the site would not be off-shore, as some environmentalists wished, nor could it be in a populated area, as the gas utilities wished. Indeed, a nonpopulated area was strictly defined. There could be no more than an average of 10 people per square mile within one mile of the terminal, and no more than 60 people per square mile within four miles of the terminal.

The passage of the Siting Act of 1977 (S.1081) opened up a new procedure for finding an acceptable site and led to Round C with the following problem definition: Which site should be approved? The round was initiated by the CCC which, after considering 82 sites meeting the remote-siting constraint, ranked the top four sites, Camp Pendleton, Rattlesnake Canyon, Point Conception, and Deer Canyon, in that order, on the basis of seismic, soil, wind and wave conditions, rough cost, and coastal resource considerations. (Point Conception was included in the candidate set because S. 1081 required that the applied-for site be included). These four alternatives form the background for the interaction among the interested parties in Round C as shown in Table 5. The CCC pased these rankings on to the CPUC which chose, by process of elimination, Point Conception, on the grounds that the two higher-ranked sites would involve unacceptable delay and would cause unacceptable risk to transients (i.e., campers, swimmers, etc.) at the nearby beaches and public parks. The CPUC, however, could only conditionally approve Point Conception subject to the utility company's ability to show that earthquake faults discovered in the area presented an acceptable risk to the terminal.

At the federal level, the FERC staff determined that the risks of both Oxnard and Point Conception were acceptably low, so that Oxnard should be preferred on land-use grounds; however, the FERC, choosing to avoid a federal-state confrontation ruled in favor of Point Conception. It would appear that with both the CPUC and the FERC in favor of Point Conception as a compromise site, the issue would be decided. But the checks-and-balances of the U.S. system assures that not total authority is vested in the legislative branches. After an appeal by the environmental and local interests, the Washington, D.C. Court of Appeals remanded the case back to the FERC on the grounds that not all available seismic risk data were considered by the FERC in its ruling. This decision concluded Round C.

Round D is still in progress at this time. As shown in Table 6 the initiating proposal is bounded by the activities in Round C which frame the alternatives as simply whether or not to declare the Point Conception site seismically safe. Only two parties, the FERC and the CPUC are currently active in the process, and they are considering only one attribute, --the seismic risk at Point Conception. A final decision will depend upon whether the new studies show this risk to be above or below some acceptable level.

D. RESULTS AND INTERPRETATION OF THE MAMP DESCRIPTION

The purpose of the MAMP representation is not simply to describe a political decision process, but to bring a structure to that description that might suggest institutional reforms. The California decision process illustrated in this paper can be interpreted from many varied perspectives. It is a good example of conflicting national and local interests; it is a study of the workings of the adversial nature of U.S. regulatory proceedings; it is a precedent-setting report of procedural practice for setting energy policy; as well as an account of introducing a controversial large- scale technology with a small probability of a catastrophic accident. Clearly, a full exposition of these interpretations would go beyond the more narrow scope of this paper, i.e., to illustrate a framework of descriptive analysis. In this spirit we will briefly present two insights from this approach which are of particular concern to the IIASA Risk Group: the role that risk and risk analysis have played in this process and the limitations that sequential decision-making places on the role of analysis in general.

In the siting of large-scale, hazardous technologies, a great deal of attention has been paid recently to the topic of risk assessment, as evidenced in a large and growing literature (see Conrad 1980 and Schwing and Albers 1980). It is of interest, to examine the role risk assessments, which have been concerned primarily with risk to life and limb, have played in the California LNG case.

During the course of the LNG debate in California, six studies assessing the safety risks of the proposed terminals were conducted by the utility and local, state and federal government agencies (for a critical review of these studies, see Mandl and Lathrop 1981). The assessments of risk commissioned by the applicant and the FERC showed very low numbers on various probabilistic measures of risk (expected fatalities per year and individual probability of fatality per year), these numbers were interpreted to mean that the risk was acceptable. Alternatively, a risk assessment commissioned by the Oxnard municipal government produced similarly low probabilistic measures of risk (though expected fatalities were 380 times higher than the applicant's assessment), but interpreted as unacceptably high! The explanation lies in the format for presenting the results. The Oxnard study described maximum credible accidents (MCAs) without accompanying probabilities. Opposition groups interpreted these results as evidence that the terminal was not acceptably safe. The municipal government, itself, originally in favor of the site, began to waver in its support, probably influenced by the apparent uncertainty of the risk and the strength of the opposition groups (Ahern 1980). In sum, risk assessments did not provide a single, coherent assessment of acceptability of the risk of an LNG terminal; their results were subject to interpretation depending on party positions (Lathrop 1980). In fact, risk assessments were used both to promote and to oppose terminal applications.

Turning to the importance of sequential decision-making, the most fundamental message of the MAMP approach is that political decision processes such as the one studied here tend to be disaggregated over agencies and over time. In the California case the disaggregation over agencies does not seem to have had a significant effect on the outcome. As indicated in the preceding tables, power was in the hands of the California Legislature, the CPUC, and FERC, each of which considered most of the relevant concerns (see Table 1) and each of which was able to apply its own subjective weights. The important decision affecting the disaggregation over agencies in the process by the diminishment of local sovereignty (and applicant control) was embodied in the California LNG Siting Act (S. 1081).

In contrast to the disaggregation over parties in the process, the sequential aspect of the decision process seems to have been crucial. In the seven year course of the process, the need for imported natural gas in California diminished greatly. Instead of examining this need, the process, "locked in" by previous decisions, is presently dictating a slowly-paced examination of seismic data.

A second example of sequential constraints is the remote onshore condition of S. 1081, which represented a balancing of costs and benefits that have probably changed over time. A final example of undesirable effects from sequential constraints concerns the risk of an interruption in the supply of natural gas. Initially, the applicant stressed supply interruption risk due to shortage of natural gas as a major reason for importing LNG to three separate sites. During the course of the decision process, for reasons beyond the control of the applicant, the three sites were reduced to one site, and the number of storage tanks at that site were reduced from four to two. The planned Point Conception throughput of 58,000 m^3 LNG/day, equivalent in energy flow to roughly 15 modern nuclear reactor units (Mandl and Lathrop 1981), is large for one geographical location. Because of this concentration in one small area, and the possibility of routine closures or nondelivery resulting from bad weather etc., the net result of the sequential decision process is that a project originally meant to *decrease* supply interruption risk has been shaped over time into a project that may *increase* supply interruption risk.

IV. SUGGESTIONS FOR PRESCRIPTIVE MEASURES

The use of the MAMP model for structuring the decision process concerning LNG siting in California makes clear how the roles, agendas, values and power of the different parties, and the dynamics of their interaction, determine the way in which the process steers its path through a complex multiattribute choice problem. Since a motivation of this descriptive analysis is to provide insights for proposing changes in institutional procedures, and especially for suggesting constructive uses of analyses to aid those procedures, it is appropriate to suggest prescriptive measures. Of course,institutional change encompasses a range of possible measures from radical reforms in the power structures of society to more modest proposals for aiding existing decision structures through analysis in order to facilitate solutions. As we have shown in this paper, the model brings to light problems arising from the sequential nature of a multi-party decision process that might be remedied by a more imaginative use of analyses. In this spirit we select two problem areas to illustrate directions that analyses could take.

A. ANALYSIS TO OVERCOME SEQUENTIAL DECISION SHORTCOMINGS

A general conclusion to be drawn from the MAMP description is that the political decision process examined here solved a complex question one piece at a time, much as described in the work of Cyert and M .rch (1963) mentioned in Section II. This disaggregation of problem solution by sequential constraints could be explained in terms of information processing limitations of the process, terms that correspond to some concepts of bounded rationality (Simon 1957). The examples presented at the end of the previous section illustrate a fundamental problem with this disaggregation: The fact that the political decision process is sequential, with each decision constraining the ones that follow, means that the outcome of that process is apt to be inappropriate if important variables change over time.

While the complexity of siting decisions may make problem disaggregation necessary, analyses can be designed to alleviate the undesirable effects of that disaggregation in at least two ways. First, technical and economic analyses can make clear the implications for the overall process of the particular alternative and constraints being considered at any one time. For example, the California process might have been helped considerably had the decisions to reduce the number of storage tanks at Point Conception been accompanied by analyses making clear to all parties the resulting risk of an interruption in supply.

A second way in which analyses might help alleviate disaggregation problems is to demonstrate the point at which previously-set constraints may no longer be appropriate, and so help identify when previous parts of the process should be re-opened for consideration in the light of new data. While such a role for analyses could be seen as contributing to delays in the siting process, that tendency could be corrected by incorporating delay and cost of delay explicitly in the analyses.

B. ANALYSIS TO CLARIFY PROBLEM BOUNDS AND PARTY POSITIONS

Before one begins the process there must be a clear understanding of the problem bounds which are likely to emerge at different stages of the process. To the extent possible the interested parties should be made aware of the different decisions which have to be made, how long these decisions are likely to take and the mechanisms utilized to determine the final outcome. In other words, some type of normal process should be established.. In the same spirit it appears appropriate for each of the interested parties to specify the constraints which guide its decisions and the assumptions upon which they are based.

Each party might defend its position by stating the basis for its conclusion regarding site preference. Mitroff, Emshoff and Kilmann (1979) have proposed a technique called assumptional analysis whereby the parties undertake a dialectical approach to the problem by being forced to defend the assumptions on which they base their position with the opportunity to challenge the assumptions of others. Majone (1979) has suggested that the knowledge base on which to make decisions for these type of problems is currently so inadequate that such a process would enable one to explore avenues of disagreement and improve his understanding of the problem.

It is likely, however, that conflicts will continue to exist between the parties because they have different assumptions on which they base their actions. As we have seen from the MAMP model, public interest groups like the Sierra Club focused entirely on environmental and safety considerations because that is the basis for their existence; public utilities were primarily concerned with economic factors while government agencies were forced by legislative mandate to focus on specific attributes.

There are two analytic approaches which may be helpful in structuring the multi-party problem so that policy alternatives can be evaluated before attempting to introduce them into the political process. Both approaches incorporate the differing values held and concerns felt by the different parties, and use those to represent and predict each party's ranking of alternatives. The first is multiattribute utility (MAU) analysis, developed by Keeney and Raiffa (1976). In that approach a utility function is developed for each party which is fitted to measures of the relative weights over attributes that party seems to employ in making its choices. These measures can be developed in the course of direct value elicitations of members of each group, or in some cases can be estimated from past decisions or policy stands.

A second analytic approach, the analytic hierarchy process (AHP), has been recently developed by Saaty (1980). This approach is conceptually similar to the MAU approach, except that it uses ratios of relative importance over attributes, and ratios of relative impacts of each of the alternatives, as opposed to the more complete utility functions of the MAU approach.

Both approaches run into difficulty in trying to represent equity considerations. In any problem of social conflict, such as the siting problem described here, the alternative selected depends crucially on the relative weights given to each party in the process. If full weight would be given to the applicant, it would be free to select a denesly populated site; if full weight were given to neighbors of the proposed plant, no siting application would be successful without attractive compensation schemes. Neither analytic approach offers a convenient means to assign weights over parties. In both cases, some individual must assign the weights, which begs the question of who that individual should be. Keeney (1976) has suggested that there is some referee agency which implicitly assigns these weights, so the MAU (or AHP) process could simply elicit the weights from representatives of that agency. In the California case, however, it is not clear whether that agency should be the FERC, the CPUC, or another agency. Perhaps the best way around the equity problem is to use the MAU or AHP approaches with each of several plausible sets of weights over parties. A sensitivity analysis would then shed light on what conclusions could be drawn from a range of weights.

Either the MAU or the AHP approaches can be combined with instruments of policy analysis, helping the analyst to determine the effects of, for instance, incentive schemes and regulations on the performance of alternative scenarios. For example, the relevant state or federal agencies might consider the possibility of compensating those who are exposed to the risks of a terminal, similarly, additional safeguards might be considered. The MAU or AHP approaches would suggest how changes in the values of particular attributes might effect the relative desirability of different scenarios. Of course, other social and political considerations might enter these types of decisions.

V. SUMMARY AND FUTURE RESEARCH

In this paper we have developed a descriptive model of choice, the MAMP model, and drawn some presecriptive recommendations where analyses might improve societal decision making with respect to siting problems. The seven year experience in California in trying to site LNG terminals points out the need for a well-articulated set of procedures for dealing with energy problems in the United States. It also suggests the need for examining how other countries undertake their siting decisions.

At IIASA we are now completing a cross-cultural, comparative study of siting decisions in four countries: the Federal Republic of Germany (ATZ 1981), the United Kingdom (Macgill 1981), the Netherlands (Schwarz 1981), and the United States (Lathrop 1981). We will apply the MAMP model to each of these cases in the hopes of learning about the similarities and differences among countries and developing a broader set of guidelines for improving the siting process based on these descriptive analyses. Problems of siting new technologies will become more important as our energy resources become more scarce. We are hopeful that through international comparative studies we will gain a better appreciation as to what can be done in the future.

REFERENCES

Ahern, W. 1980. "California Meets the LNG Terminal." *Coastal Zone Management Journal*, *7* pp. 185-221.

Allison, G.T. 1971. *Essence of Decision*. Boston: Little, Brown and Company.

Atz, H. 1981. "Decision-Making in LNG Terminal Siting: Wilhelmshaven, F.R.G.", Draft Report, IIASA, Laxenburg, Austria.

Braybrooke, D. 1974. *Traffic Congestion Goes Through the Issue-Machine*. London: Routledge and Kegan Paul.

Cobb, R., and C.D. Elder. 1975. *Participation in American Politics: The Dynamics of Agenda Building* Baltimore, John Hopkins University Press.

Conrad, J. (ed.). 1980. *Society, Technology and Risk Assessment*. London: Academic Press.

Cyert, R., and J. March. 1963. *A Behavioral Theory of the Firm.* Englewood Cliffs, N.J. Prentice Hall.

Downs, J. 1973. "Up and Down the Attention Cycle." *Public Interest.*

Fischhoff, B., S. Lichtenstein, P. Slovic, R. Keeney, and S. Derby. 1979 "Approaches to Acceptable Risk: A Critical Guide." NUREG/CR-1614. Washington: U.S. Nuclear Regulatory Commission.

Jackson, J., and H. Kunreuther. 1981. "Low Probability Events and Determining Acceptable Risk: The Case of Nuclear Regulation." PP-81-7, IIASA, Laxenburg, Austria. May.

Keeney, R. 1976. "A Utility Function for Examining Policy Affecting Salmon in the Skeena River," RM-76-5, IIASA, Laxenburg, Austria.

Keeney, R. 1980. *Siting Energy Facilities.* New York: Academic Press.

Keeney, R., and H. Raiffa. 1976. *Decisions with Multiple Objectives.* New York: John Wiley.

Kunreuther, H. 1980. "Societal Decision Making for Low Probability Events," WP-80-164, IIASA, Laxenburg, Austria.

Lathrop, J. 1980. "The Role of Risk Assessment in Facility Siting: An Example from California." WP-80-150. IIASA, Laxenburg, Austria.

Lathrop, J. 1981. "Decision-Making on LNG Terminal Siting: California, U.S.A.", Draft Report, IIASA, Laxenburg, Austria.

Levine, M.E., and C.R. Plott. 1977. "Agenda Influence and its Implications." *Virginia Law Review*, 63 (4).

Linnerooth, J. 1980. "A Short History of the California LNG Terminal." WP-80-155, IIASA, Laxenburg, Austria.

Macgill, S.M. 1981. "Decision-Making on LNG Terminal Siting: Mossmorran-Braefoot Bay, United Kingdom." Draft Report. IIASA, Laxenburg, Austria.

Majone, G. 1979. "Process and Outcome in Regulatory Decisions." *American Behavioral Scientist 22* pp. 561-583.

Mandl, C., and J. Lathrop. (Forthcoming). "Assessment and Comparison of Liquefied Energy Gas Terminal Risk." WP, IIASA, Laxenburg, Austria.

March, J. 1969. "Bounded Rationality, Ambiguity and the Engineering of Choice," *Bell Journal of Economics*. 9:587-608. Spring.

Mitchell, R.C. 1979. "National Environmental Lobbies and the Apparent Illogic of Collective Action." In *Applying Public Choice Theory What are the Prospects*. Edited by C. Russell. Washington, D.C.: Resources for the Future.

Mitroff, I., J. Emshoff and R. Kilmann. 1979. "Assumptional Analysis: A Methodology for Strategic Problem Solving." *Management Science, 6* pp. 583-593.

Office of Technology Assessment (OTA). 1977. *Transportation of Liquefied Natural Gas*. Washington, D.C.: Office of Technology Assessment.

Otway, H., and D. von Winterfeldt. (in press). "Judgments of Technologies and their Risks," proceedings of a workshop on risk research conducted by the ZIF, Bielefeld, FRG. November 1980.

Saaty, T.L. 1980. *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Schwarz, M. 1981. "Decision-Making on LNG Terminal Siting: The Netherlands." Draft Report. IIASA, Laxenburg, Austria.

Schwing, R.C., and W.A. Albers (eds.). 1980. *Societal Risk Assessment: How Safe is Safe Enough*? New York: Plenum Press.

Simon, H.A. 1957. *Models of Man: Social and National*. New York: Wiley.

Tversky, A., and D. Kahnemann. 1974. "Judgment Under Uncertainty: Heuristics and Biases." *Science* 185:1124-31.

Walker, J. 1977. "Setting the Agenda in the U.S. Senate: A Theory of Problem Selection." *British Journal of Political Science*. 7:423-445.

Wilson, J.Q. 1975. *Political Organization* New York: Basic Books.