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Power Plant Siting: An Application of the Nominal Group Process Technique

A. H. Voelker

...ared for the U.S. Nuclear Regulatory Commission
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MARYLAND POWER PLANT SITING PROJECT REPORTS

Title	Author(s)	Document ORNL/NUREG/TM-	Date
The Maryland Power Plant Siting Project: An Application of the ORNL Land Use Screening Procedure	J. E. Dobson	79	1977
A Cell-Based Land Use Screening Procedure for Regional Siting Analysis	J. S. Jalbert J. E. Dobson	80	1977
Power Plant Siting: An Application of the Nominal Group Process Technique	A. H. Voelker	81	1977
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A. H. Voelker

ABSTRACT

The application of interactive group processes to the problem of facility siting is examined by this report. Much of the discussion is abstracted from experience gained in applying the Nominal Group Process Technique, an interactive group technique, to the identification and rating of factors important in siting nuclear power plants. Through this experience, interactive group process techniques are shown to facilitate the incorporation of the many diverse factors which play a role in siting. In direct contrast to mathematical optimization, commonly represented as the ultimate siting technique, the Nominal Group Process Technique described allows the incorporation of social, economic, and environmental factors and the quantification of the relative importance of these factors. The report concludes that the application of interactive group process techniques to planning and resource management will effect the consideration of social, economic, and environmental concerns and ultimately lead to more rational and credible siting decisions.

ACKNOWLEDGMENTS

The design and implementation of a group process technique dealing with a national problem requires the cooperation and integration of many individuals and organizations. Much credit goes to Jim Wright, a consultant with Marketing Management, Inc., for advising on process design and for leading two siting sessions. He in turn received advice from Andre Delbecq, the originator of the Nominal Group Process Technique. The fine support of various organizations in supplying siting experts must be noted. The Tennessee Valley Authority sent Don McLeod, Dick Foster, Rick Morgan, John Thurman, and Ron Domer. The Maryland Power Plant Siting Program supplied Paul Massicott and Bill Jackson. Allegheny Power Service Corporation sent Bill Benton, and Downey Brill came from the University of Illinois. Finally, Oak Ridge National Laboratory gave us Herb Guberman, Jerry Dobson, Arvin Quist, and Glenn Suter. Collectively, these people functioned as supportive and innovative teams.

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1. OVERVIEW

Today's planners or resource managers are often frustrated and confused by requirements to incorporate in their development plans what must seem to be irrational and unrelated concerns. They must contend with such diverse factors as environmental impact, human health and safety, secondary economic and social impacts, and citizen input (often dictated by law), in conjunction with traditional economic considerations.

The hearing process has been adopted by most planning and development agencies as the mechanism for assuring that these new and often competing interests are adequately treated in any particular plan or proposal. However, the hearing process generally occurs long after site decisions have been made, and the hearings may become a defense for past decisions. Furthermore, the presentation format used in hearings is one of carefully prepared written statements, and there is little or no interaction between groups. As a result, the natural polarization between interest groups can be and often is reinforced through the hearing process. There is seldom a feeling of mutual concern for achieving the best solution in the highly charged atmosphere of the hearing process.

In the last few years, a number of useful social science techniques which have the potential for facilitating group interaction have become available to planners and administrators for a number of purposes such as eliciting opinion, achieving consensus, identifying problem elements, and creating problem solutions. The use of such techniques can permit the planner or administrator to obtain "maximum feasible participation" at an early design stage, thereby helping to reduce or even eliminate the conflict which has become so characteristic of the later stages of modern large-scale development.

Participation can usefully include many levels of interest or expertise. The inclusion of comprehensive factors in the planning process requires the involvement of resource experts from many heterogeneous disciplines or functions. No single discipline commands sufficient technological expertise to develop solutions to complex problems unilaterally. For this reason, a technique which allows shared expertise to be directed toward planning problems would be extremely useful to the planner.

One such technique, which has been adapted to the gathering and organizing of diverse opinion and technical judgment, is known as the Nominal Group Process Technique.[1] This report discusses in detail the application of the NGT to the problem of facility siting, a pivotal problem in regional development. In particular, the use of the NGT to identify and weight factors important to the siting of nuclear power plants is discussed.

A brief description of the NGT is presented, followed by the particular designs created for the two independent sessions directed to the siting problem. Factor lists and weights generated in the sessions are then introduced. The report concludes with a discussion of the results and suggestions for employing the results in systematic siting procedures. It is assumed that the average reader will be interested in the design details covered in Sects. 2 and 3, but those interested primarily in results of the technique may turn directly to the factor lists in Sect. 4 and proceed to Sects. 5 and 6 for an evaluation of the factors and techniques.

2. THE NOMINAL GROUP PROCESS TECHNIQUE

2.1 Background

The Nominal Group Process Technique (NGT) was developed by Andre Delbecq and Andrew Van deVen in 1968.[2] It was derived from social-psychological studies of decision conferences, management-science studies of aggregating group judgments, and social-work studies of problems surrounding citizen participation in program planning. It has gained wide acceptance in health, social service, education, industry, and government organizations. Basically, it consists of four steps: (1) nominal (silent and independent) generation of ideas in writing by a panel of participants, (2) round-robin listing of ideas generated by participants on a flip chart in a serial discussion, (3) discussion of each recorded idea by the group for the purpose of clarification and evaluation, and (4) independent voting on priority ideas, with group decision determined by mathematical rank-ordering.

While it has been shown that "brainstorming" or interacting group members produce more ideas per individual than they do when working independently,[3] it has also been demonstrated that two characteristics of interacting groups limit the quality of group output. Dominance by strong or aggresive group members tends to squelch creativity and participation on the part of other members, and interacting groups tend to pursue a single train of thought for long periods, drifting from the intended goal.[4] It is possible to minimize these natural tendencies of groups by providing strong experienced leadership, but this is not often accomplished. The highly structured NGT is an attempt to overcome the observed shortcomings of interacting groups, and it has been shown to be superior in the quality of group ideas as measured by creativity, originality, and practicality.[5] The basic steps of NGT will now be considered in more detail.

2.2 Independent Idea Nomination

Through its structure, NGT ensures that each participant has equal opportunity to contribute to the group task. The first way in which this is accomplished is a "nominal" or silent generation of ideas. Group members are presented with a carefully stated question and are then asked to independently nominate ideas which apply to the question. No discussion among participants occurs in this step. As might be expected, a variety of ideas which are nominated by this procedure become available to the group for interpretation, modification, and synthesis in subsequent steps. This is in direct contrast to interactive groups, which usually determine their direction by the first few ideas generated.

2.3 Idea Listing

In the second step, members are asked sequentially to submit one of their ideas (factors in our case) to be listed on a flip chart until all ideas are stated. Terse statements are requested, and no group discussion is allowed. The mechanical format of this step ensures equal opportunity by group members and ultimate consideration of all ideas. An interesting phenomenon occurs in this round robin. Members "hitchhike" on the ideas suggested by others. Additional ideas are triggered by those already listed, and these new ideas are added to the flip chart. By this time, the flip chart begins to assume a central role in the group; it becomes the focal point of the common effort being attempted by the group. It acts as a strong visual focus and provides a written record and guide.

2.4 Idea Definition

The third step of the technique is a sequential definition of each listed idea to clarify its meaning and significance. Unproductive arguments which can sidetrack or unduly delay the process are discouraged by the leader by limiting discussion time as the group moves from one idea to the next. In the case of highly technical factors such as those relevant to power plant siting, the participants will not be knowledgeable of all factors, and a fair amount of technical description will ensue. In this step, the group may wish to combine, disaggregate, eliminate, or generate new ideas. The relative differences in resolution between major groupings of ideas which occur in the listing step will force the group to make some of these modifications. For instance, it might be apparent that the group has generated many more siting factors, in greater detail, for water-related considerations than for other areas such as environmental impact. The group might then aggregate some of the water factors to maintain a level of resolution consistent with other areas. To reduce group pressure, any individual objecting to the removal of an idea is given veto power, and the group members are told that they may express their feeling in the weighting step.

2.5 Voting

The fourth step uses a voting procedure to aggregate the judgments of individual items. A common technique employed has each group member rank-order the ideas by assigning a value of 5 to the most important item, a value of 1 to the least important item, and values in between to the remaining items. The vote is then recorded on the flip chart in front of the group. A more sophisticated technique, used when the group is technically qualified to make refined distinctions, has the participants rate each item on a continuous scale such as 0-10. The ideas are judged as to their relative importance to the question being considered. The mean weight assigned each item is calculated from individual work sheets. This weight is then recorded on the flip chart for each item.

2.6 Second Iteration

The fifth and sixth steps are optional, but when incorporated in the technique they improve the accuracy of the group output and create a greater sense of completion among group members. In the fifth step a brief discussion of each item's vote distribution is conducted.

Exploring differences among assigned weights reveals misunderstanding, misinformation, or unequal information among the group members. Usually by this point in the process, sufficient trust and dedication exist within the group to allow open discussion in which individuals admit ignorance or misconception. Thus, it is possible to move the group closer to consensus in this step. The sixth and last step is a second vote following the discussion. Generally, large changes in weight means do not occur, but reductions in the dispersion of individual weights are obtained.

The above is a very brief description of NGT. There are many procedural details and aids which have been worked out through the years for the group leader, but since they are adequately covered in Delbecq's book describing the process,[1] they will not be discussed in this report. The session design used for the power plant siting question is considered in the next section. The NGT has been closely aligned during its brief lifetime with fields, such as health care, in which value questions predominate. To our knowledge, the NGT has never before been applied to siting, which has been considered primarily an engineering problem until now. As a result, the designs used in the two sessions conducted are still less than optimal. The evolution of design changes between the two sessions is discussed, and suggestions for future improvements are included in the conclusion of this paper.

3. THE SITING APPLICATION

The difficulty of planning and constructing a modern electric generating plant has increased tremendously in the last ten years.[6] Environmental concern, regulation, and public opposition have made the location and acquisition of suitable plant sites particularly difficult.[7] The creation of legislation in a number of states to facilitate site acquisition is an acknowledgment of the seriousness of this problem.[8]

Legislative relief will not be totally effective, however, unless the entire range of the new and often subtle factors which are likely to affect acquisition of power plant sites can be identified and incorporated into a systematic site screening and evaluation procedure. In order to offer utilities and state agencies a more rational basis for site selection and to help them to avoid unforeseen obstacles (often serious enough to preclude the use of a selected site), we turned to the structured approach of the NGT to identify and rank the importance of siting factors.

The NGT had been successfully applied to a number of problems, including the quantification of a transmission line location model called PERMITS[9] by the Bonneville Power Administration. The similarity between transmission line siting and power plant siting seemed to suggest that NGT might be suited to power plant siting. Since a number of systematic siting procedures, many computerized, are now being created, we were interested in identifying and weighting siting factors in such a way that they could be used directly in these procedures. Our design thus attempted to serve both the needs of those interested in the factors by themselves, such as impact statement writers, and those wishing to apply the factors in the development of systematic procedures, such as utilities and state siting authorities.

The transmission line siting application (PERMITS system) of the NGT was an attempt to quantify a multilevel spatial model consisting of four hierarchical levels: (a) determinant, (b) component, (c) variable, and (d) data element. For instance, the determinant "minimization of disruption to the natural system" was divided into four components: (1) greatest disruption to the vegetation system, (2) greatest disruption to the water system, (3) greatest disruption to the pedological systems, and (4) greatest disruption to the wildlife system. The component "greatest disruption to the water system" was divided into two variables, water quality and water type. The variable "water type" was expressed in turn by the data elements intermittent streams, sloughs, rivers, marshes, lakes, springs, and water wells.

The NGT was used only to rate the elements of each level as to their relative importance once they had been identified by the team developing the PERMITS methodology. In this restricted use, the Nominal Groups did not identify elements, they only rated them. An assumption was made that the elements of each level could be combined in a linear summation to calculate a score for each cell of a grid overlaid on a map of the study region. Thus, for example, a determinant score was found by combining the components of the next lower level through the following equation:

$$D_1 = W_1C_1 + W_2C_2 + \ldots + W_nC_n , \quad (1)$$

where W is the relative weight of the component C. The components are described by summations of variables, and variables by summations of data elements.

It did not appear to us that these simple linear models could be used to relate the complex factors important in power plant siting to available data. For instance, the siting of coal-fired power plants is influenced by the future availability and price of coal. The spatial data from which this factor can be built include the width and location of coal seams of various coals by heat value and potential pollutant content, the depth of overburden for these coals, the topography relative to the coal seams, the distance from the coal reserve to the site being considered, and the competing demand for coal through time. These data must be incorporated in a complex analysis which first determines the production cost of various coals (using a combination of spatial and nonspatial variables such as wage rates and cost of capital). By use of a nonlinear supply and demand curve, the analysis then estimates those coal seams which are likely to be brought into production first. Finally, using supply location and cost, the analysis must compute a delivered cost per ton to any site, considering both market and transportation cost. Delivered price can then be compared among the various potential sites. This brief description is intended to show that factors are often far removed from spatial data inputs through various integrative steps, thereby assuming a higher or more abstract character than the data from which they are constructed. It would be fallacious to portray the complex process which determines coal availability and price by a simple linear hierarchical model. Because of this we chose to use Nominal Groups to identify and weight the factors, leaving the construction of factor models to analysts.

In order to explore the use of the NGT in a systematic siting procedure, it is necessary to imagine the nature of the siting process and then fit the identified factors and weights into a mechanization of this process. Our view of the siting process is the subject of the next section.

3.1 The Siting Process

Before conducting the group sessions, we hypothesized the following multilevel siting process: (1) a utility or agency projects electrical demand by load center, (2) with sufficient demand, plants are designated to serve individual load centers, (3) the selected load centers are screened in a rough way with combinations of factors to locate candidate areas, (4) the candidate areas are scanned with a second set of factors to locate sites, and, finally, (5) sites are compared in detail, and the best site among the alternatives is selected. Support for this view of the siting process can be found in the literature.[10] It was felt that if the nominal groups readily accepted this hypothesized process, then the group output could become the basis for a systematic approach.

Because it was felt that site anomalies precluded the use of preselected factors in the comparison of alternative sites (step 5 above), the groups were not asked to list factors useful in choosing the final site from a group of alternatives. Instead, they were instructed to list factors for the candidate area level (called regional screening in this report) and for the site selection level (the level at which a collection of alternative sites is identified). In addition, it was hypothesized that there are two fundamental types of factors involved in siting which must be separated before weighting can be accomplished. Factors of the first type (exclusionary) eliminate an area from further consideration. An example of such a factor is the presence of dedicated lands, such as national parks. Factors of the second type (nonexclusionary) are ultimately combined with other factors to judge the suitability of a particular location. Construction costs exemplify the nonexclusionary factor type. At the beginning of the session, the group was first asked to identify all siting factors without regard to level or exclusion. From this list, the group then built four sets of factors, regional exclusionary, regional nonexclusionary, site exclusionary, and site nonexclusionary. Once identified, each of the sets was taken through steps 2 (idea listing) through 6 (second vote) of the NGP. The complete process was observed by the author, and tape recordings were taken to assist in the preparation of this report. In essence, then, from a single initial list of factors we conducted four separate runs of the technique in each session. However, as will be discussed, practical considerations of time, money, and the amount of discussion needed to explore highly technical factors kept us from obtaining four complete factor sets in both sessions.

The major design decisions faced in implementing the NGT are considered in the remainder of this section. They are included to give the casual reader a basis for judging the validity of the factors listed in the next section and to give the prospective user of the NGT aid in making design decisions.

3.2 The Group Question

The success of group processes is directly related to the precision with which the task is defined for the group.[1] The problem statement is usually presented to nominal groups by means of a carefully prepared question written on a flip chart. It must be structured in such a way as to constrain the discussion to the objectives of the session without at the same time inhibiting group creativity. Without proper constraints the group may wander far afield or may evoke high-level abstractions of little use to the originator of the session. Usually, a set of alternative questions is composed in the process design, and the best question is selected through pretests and dry runs. Hard work and trial-and-error learning go into this important preparatory step. In our case, a group of four questions (one per factor list) was generated after considerable discussion between staff and consultants. For example, the actual question employed with the site-level nonexclusionary factor set was:

> "What are the ten most important factors to be considered when selecting a site for a nuclear power plant of two unit configuration, 1100 MWe per unit, cooling tower option?"

The large number of engineering options available to a plant designer forced us to the "typical plant" characterization embedded in the question. For example, the requirements of a four-unit plant are considerably different than those of a one-unit plant, especially for critical factors such as water availability, and it is necessary to specify plant size. Major technology options such as nuclear or coal plants also place emphasis on quite different factors. A complete analysis of the options available to utilities would require a number of NGT sessions. This is not exclusively a limitation inherent in the NGT, however, and any complete explication of the complex siting question would consume a number of distinct reviews, workshops, planning sessions, etc., no matter what approach was followed.

Some initial guidance was supplied to the group on the type of responses expected from them in the form of sample factors. The list was included in a letter of invitation some weeks in advance of the session to prepare the group mentally, but enough in advance so as not to dominate their thoughts at the time of their session.

The group was instructed to identify factors without regard to the availability of data needed to quantify factors. The lack of data sometimes precludes the consideration of certain factors in real site decisions. The determination of air dispersion characteristics at the site level is an example of this problem. Few regions have enough existing monitoring stations to be able to specify the air dispersion characteristics of all potential sites, so this factor is usually measured only after the final set of alternative sites is selected. The group was asked to ignore such data limitations in order to avoid time-consuming squabbles about the fine points of data. Defining the models relating factors to data was more than could be accomplished in a single session. As a result, the generated factor sets contain several factors which cannot be measured adequately at this time. However, the recognition of these factors as important to the siting process should encourage the collection of the necessary data by responsible agencies. It is to be hoped that regulatory agencies and the courts will not arbitrarily force the results of comprehensive factor identification procedures like the Nominal Group on utilities without first considering the serious problem of data availability.

3.3 Group Selection

The most difficult problem faced in the session design dealt with the fundamental decision of whether the group composition was to be heterogeneous or homogeneous in regard to experience level, training, or special interests. In light of the objective to identify comprehensive sets of siting factors, it appeared initially that the most diverse mix of participants might develop the broadest set of factors. However, in designing the sessions some fear developed that the group might not coalesce if their backgrounds or disciplines were too disparate. It was felt that perhaps the unique use of certain terms and the lack of similar training or background might inhibit communication and cause confusion. It also appeared possible that regional differences might reduce the chance for group consensus if these differences were pronounced. Thus, at one point in time it appeared that the greatest chance for success was centered on the use of a homogeneous group such as a group of design engineers from one utility or region.

However, because our goal was to reach a national audience and explore the use of group processes, we opted to broaden the participation to a significant degree and include various experts representing disciplines involved in site selection and power plant impact assessment. We made a deliberate decision not to mix experts and the public, fearing that the presence of experts might intimidate untrained members of the public and thereby squelch their innovativeness. While we now know that diverse experts can work together on the siting problem, our hypothesis about mixing experts and public remains unproven. Furthermore, the siting of a power plant is a highly technical problem, and there is some doubt that the lay public possesses either knowledge or experience to allow it to relate to the problem. Selected members of the public may be able to add insight to the siting process, however. Individuals having experienced the construction of a large facility in their local area would be able to introduce a number of potential impacts. Furthermore, public response can and should be sought at the stage when actual alternative sites are being evaluated.

In the session, invited experts included engineers, ecologists, economists, and natural resource specialists. This range included regulatory personnel, utility representatives, university staff, and researchers. All members were invited personally. The primary personal traits sought were forthrightness and a broad perspective. A concerted effort was made to find people actually making or influencing siting decisions.

A wide regional representation was also sought, with the exception that the participants were limited to the eastern United States, since it was felt that siting was a distinctly different process on the West Coast. As often occurs with busy people, some cancellations were experienced by each group. This was responsible for one disappointment; the only member specifically working on social impacts was lost to the process. However, as will be seen, social factors were represented adequately in the final factor sets. Individuals participating in each group are listed below:

Group 1 participants

	Member	Organization	Specialty
1.	Donald McLeod	TVA	Engineering, Site Acquisition
2.	William Jackson	State of Maryland	Power Plant Site Acquisition
3.	Jerome Dobson	ORNL	Geography, Siting Methodology
4.	Arvin Quist	ORNL	Impact Statements, Cost-Benefit Analysis
5.	Glenn Suter	ORNL	Impact Statements, Ecology
6.	Richard Foster	TVA	Engineering Design
7.	Richard Morgan	TVA	Forest Resource Management

Group 2 participants

	Member	Organization	Specialty
1.	John Thurman	TVA	Wildlife Biology
2.	Paul Massicott	State of Maryland	Power Plant Site Evaluation
3.	William Benton	Allegheny Power Service Corporation	Engineering, Generation Planning
4.	Downey Brill	University of Illinois	Research in Siting Strategy
5.	Herbert Guberman	ORNL	Impact Statements, Alternative Site Analysis
6.	Ron Domer	TVA	Design Engineering

3.4 Design Changes

Several procedural changes were introduced after analyzing the performance of the first session. The three most significant changes are discussed below.

1. At the first session, factors were sometimes presented as data or concepts without specifying their relationship to power plant siting. For example, we were uncertain if all participants clearly understood the significance of "Rural/Urban Continuum" to siting, or if they correctly distinguished this factor from "Institutional Ability to Manage Change." Even though a round-robin clarification (step 2) was conducted, it was uncertain in the subsequent analysis of vote distributions whether a common understanding was achieved for these factors. To circumvent such problems in the second group session, we asked the group to specify the functional relationship and direction of effect within the factor descriptor. Thus, in place of "geology" the second group listed "Provide an Adequate Foundation for the Plant," and in place of "Flood" they listed "Minimum Susceptibility to Maximum

Hydrological or Meteorological Events." While difficult to enforce, this request for a more carefully defined factor resulted in an improved factor list more closely tuned to power plant siting.

2. Participants recorded weights in the first session by listing all factors on a piece of paper and then placing the respective weight (0-100) by each factor. To improve the ability of participants to visualize the relative magnitude of differences among factors in the second session, a sheet of paper was supplied with a scale of 0-100 drawn on the far right-hand side. The participants wrote out factors on the sheet and drew a line from each factor to its position on the scale. Thus, all factors and their relative position were visible in a single glance in a graphic form. Instructions were to imagine the worst case of each factor relative to the total set of factors. Participant response indicated that this was a superior technique even though the resolution on the rating scale was finer than some members of the group felt necessary for weights.

3. Some difficulty was experienced by the first group in creating unique sets of factors for each of the four hierarchical levels in turn. Fearing that perhaps we had structured artificial levels for the siting process, we eliminated any level considerations from the initial list generation in the second session. Once all factors were available, the group was asked to separate them into the appropriate level and exclusion categories. Some modification of factors occurred in this process, but the group felt more at ease with this procedure than the first group had with theirs. There was less difficulty in defining the size of the spatial unit appropriate to regional site screening than in the first group, at least partially the result of having knowledge of the total set of factors.

The following is a synopsis of the idealized siting process actually identified by the second group as representative of the steps followed by utilities. There appeared to be little objection within the group to the specifics of this process.

a. The total service area is divided into load centers if the service area is sufficiently large.
b. The load centers are divided into regions of approximately 2000 square miles (40 x 50). There should be a potential for four or five sites in each region.
c. Some regions are then eliminated on the basis of re[illegible] exclusionary factors such as seismic conditions.
d. The best regions are selected from those that remain [illegible] considering the total set of regional nonexclusionary factors. The group referred to this as a "rough pass" — probably referring to the resolution of data at this scale.

e. A group of sites is selected from the best regions by use of site-level factors. Some sites are excluded in this step through site-level exclusionary factors.
f. Finally, a detailed analysis is done of the sites identified to select the single best site from the alternatives.

As can be seen, the process outlined conforms closely to that hypothesized prior to the first session. This concludes the discussion of design questions. Next, the actual factors produced by the two group sessions are listed, followed by a discussion of the applicability of NGT to siting.

4. THE FACTORS IDENTIFIED

4.1 First Session

Table 4.1 contains the site-level factors and associated weights determined by the first group. The weights shown are the result of averaging individual votes from two rounds. The group offered no defining terms for some factors.

Table 4.1. Factors and weights, first group, site level continuous

First vote	Second vote	Factor	Definition
100	100	1. Water availability, quantity	1. For cooling
96	96	2. Seismicity	2. Earthquake hazard
96	96	3. Presence of rare or endangered species	3. Flora/fauna
87	93	4. Population densities	4.
74	89	5. Flood hazard	5.
82	85	6. Geology/soils	6. Subsurface foundation
69	79	7. Population distribution	7.
77	77	8. Hazardous area, man-made	8. Proximity to airports and industry
71	76	9. Aquatic/ecological	9. Flora/fauna
69	73	10. Water availability, quality	10. For cooling
73	73	11. Transmission system requirements	11. Distance, complexity, topography
73	73	12. Proximity to areas of designated natural significance	12.
70	70	13. Water quality	13. Existing quality to be impacted
67	67	14. Institutional ability to manage change	14. Presence of planning
62	67	15. Terrestrial/ecological	15. Flora/fauna
64	66	16. Water availability	16. Ownership
64	66	17. Local perception of plant desirability	17. Attitude
63	63	18. Transportation accessibility	18. Rail, barge, highway
60	60	19. Land use	19. Onsite and adjacent to site
60	59	20. Radiological dose estimate	20.
54	54	21. Construction work force availability	21. Cost and social impact
53	53	22. Cultural significance of site	22. Historical or archaeological
43	43	23. Availability of land for acquisition	23. Cost, difficulty of condemnation, social impact
41	41	24. Meteorology	24. Fogging and icing
43	39	25. Background radiation	25. Man-made and natural
37	39	26. Land surface slope	26.
33	33	27. Position of site on rural/urban continuum	27.
33	33	28. Subsurface hydrological characteristics	28. Water flow
27	29	29. Visual compatibility	29.
29	29	30. Emergency heat-sink system	30. Water
29	29	31. Climatological hazardous areas	31.

Table 4.2 contains the regional-level factors listed by the first oup in step 1 of the Nominal Group process. Time limitations kept ie group from proceeding beyond this step. Although the factors isted are not very useful because they were not subjected to clarifi- ition and subsequent refinement, when compared with the regional list group 2 they illustrate the vast improvement achieved by a group ping through the whole process. It is also apparent that the same isic concerns were expressed by both groups. There was insufficient ime for group 1 to list exclusionary factors.

Table 4.2 Factors and weights, first group, regional continuous

irst vote[a]	Second vote[a]	Factor	Definition
		1. Population distribution	
		2. Population density	
		3. Land-use compatibility	
		4. Seismicity	
		5. Availability of construction work force	
		6. Transmission system	
		7. Transportation accessibility	
		8. Water quantity	
		9. Terrestrial ecology	
		10. Proximity to areas of designated national significance	
		11. Geology	
		12. Regional attitude of population	
		13. Water quality	
		14. Aquatic ecological	
		15. Rural/urban continuum	
		16. Population growth trends	
		17. Long-range system growth trends	
		18. Transmission system reliability	
		19. Accumulative impact of plant	
		20. Proximity to load centers and transmission grid	
		21. Fuel availability	
		22. Climate hazards	
		23. Climate	
		24. Flood hazard	
		25. Tax base	
		26. Unique natural communities	
		27. Land surface slope	
		28. Background radiation	
		29. Agricultural land use	
		30. Recreational land use	

[a]o votes were taken.

4.2 Second Session

Table 4.3 lists the regional exclusionary factors generated by group 2. While the list contains few entries, the factors shown have the potential for excluding large portions of individual load centers.

Table 4.3. Factors and weights, second group, regional exclusionary

First vote	Second vote	Factor	Definition
NA	NA	1. Proximity to geological faults	1. Active seismic area
NA	NA	2. Maximum availability of suitable water supply	2. Threshold criteria like 20-year low flow
NA	NA	3. Undesirable population distribution	3. NRC guideline
NA	NA	4. Minimum G value for DBE	4. Threshold value of acceleration from seismic activity
NA	NA	5. Dedicated land use	5. Areas such as national parks or forest

Table 4.4 lists the regional nonexclusionary factors generated by group 2. While some factors would be difficult to quantify and several questions can be raised about scale, the list is quite comprehensive, bringing into perspective social, environmental, and economic concerns.

Table 4.5 lists the site-level nonexclusionary factors generated by group 2, a surprisingly long and diverse list with a minimum of duplication. Because of this and a superior set of definitions, we feel this list to be better than that produced by the first group. Concentrating heavily on the site level, the second group had insufficient time to create site-level exclusionary factors.

Table 4.4. Factors and weights, second group regional continuous

First vote	Second vote	Factor	Definition
92	98	1. Availability of water	1. Reflected in costs for acquiring water (example – reservoir), impact of getting and using water, and chance of future conflict with growing use by others
95	97	2. Minimize proximity to undesirable population distribution	2. NRC guidelines
93	94	3. Minimum adverse geological features	3. Geology and soils related to foundation cost and safety considerations of subsidence
95	90	4. Minimum adverse impact on regional aquatic biota	4. Rare and endangered species and loss of habitat
85	88	5. Minimum susceptibility to maximum hydrological/meteorological events	5. Includes such things as dam failures and floods
89	85	6. Minimum adverse impact on regional terrestrial biota	6. Rare and endangered species and loss of habitat
80	83	7. Minimum adverse impact on existing and potential land use	7. Incompatibility with perceive* future or present use of site and surrounding area
75	72	8. Minimum G value for DBE	8. Calculation of potential acceleration caused by seismic activity. Tectonic province used at this scale. Determines if standard plant design can be used
71	70	9. Regional water quality	9. Impact on quality by plant and quality of input for plant
57	58	10. Presence of acceptable transportation systems	10.
43	58	11. Topography	11. Rough terrain leads to excessive grading costs and poor accessibility
53	55	12. Minimum proximity to man-made hazards	12. Airports, military installations, etc.
46	46	13. Acceptable air diffusion	13. Poor diffusion leads to double containment and increased costs
53	43	14. Minimum adverse impact on historical/archaeological areas	14. Proximity to important sites or presence of unexplored sites as Indian mounds
45	41	15. Adverse impact on regional economy	15. Housing, services, etc.
43	38	16. Minimum impact on regional recreation	16. Affect patterns of recreation or type of recreation
31	35	17. Maximum proximity to load	17.
36	29	18. Unfavorable attitude of regional population	18. Potential for local opposition
17	17	19. Maximum reliability of offsite power	19. Power to run plant, a safety concern

Table 4.5. Factors and weights, second group, site level continuous

First vote	Second vote[a]	Factor	Definition
97		1. Provide adequate foundation	1. Licensability, concern with liquefaction and solution channels
94		2. Minimum proximity to geologic faults	2. Capable faults avoided, ancient faults cost to investigate
90		3. Maximum availability of suitable surface water supply	3. Both quantity and quality of intake water. Cost of taking and cleaning water – only considered insufficient low flow
90		4. Acceptable site air diffusion characteristics	4. Radiological diffusion. High costs to overcome poor characteristics
90		5. Minimum conflict with existing and potential land use	5. Present use of site. Loss of opportunity costs
88		6. Minimum impact on aquatic biota	6. Sensitive life stages of important species
88		7. Minimum adverse impact on threatened-endangered species or habitat	7.
87		8. Minimize total economic costs	8. Differential costs of plant, transmission system, water, and relocation of people
87		9. Minimum susceptibility to maximum hydrological/meteorological events	9.
86		10. Minimum proximity to undesirable population distribution	10. NRC guidelines are maximum limit for this factor
86		11. Minimum impact on water quality	11. Impact on water quality from radiological, thermal, and chemical output
83		12. Minimum impact on unique cultural, historical, or archaeological sites	12.
79		13. Minimum adverse impact on local institutions	13. Includes hospital, school, and social impact
79		14. Maximum availability of groundwater	14. Availability without affecting offsite users
78		15. Minimum construction problems	15. Stems from roughness of terrain and presence of groundwater
76		16. Minimize impact on terrestrial biota	16. Habitat destruction
75		17. Minimum adverse impact on local economy	17
75		18. Minimum proximity to industrial hazards	18. Danger to plant from hazardous industrial processes in surrounding area
70		19. Availability of land parcels of sufficient size	19. Being able to aggregate site from individual parcels with minimum cost and delay
69		20. Maximum compatibility with local government attitudes	20. Attitude of local government toward development
68		21. Maximum G value for OBE	21. Calculation of potential acceleration caused by seismic activity
66		22. Minimum aesthetic impact	22. Includes both visual compatibility and noise
65		23. Minimum distance to acceptable transportation systems	23. Construction costs to get to rail, barge, and highway
64		24. Minimum adverse impact on recreation	24. Proximity to incompatible recreation use such as national wildlife refuge
63		25. Minimum adverse impact on regional economy	25.
56		26. Unfavorable attitude of local population	26. Potential for local opposition
51		27. Maximum proximity to load	27. Affects system reliability, costs, and stability
48		28. Maximum beneficial multiuse	28. Recreation, education, developmental
43		29. Unfavorable attitude of regional population	29. Potential for organized regional opposition
42		30. Minimum distance to transmission grid	30. Line construction costs and environmental impact
41		31. Maximize reliability of offsite power	31. Power to run plant, a safety concern

[a] No second votes were taken

5. DISCUSSION OF THE SITING APPLICATION

5.1 The Session Output

In the view of both session organizers and participants, the siting sessions were successful. The factor lists obtained from the second group using the improved process design were especially good when tested for comprehensiveness, reasonableness, agreement with siting literature, and internal consistency. This is particularly notable considering that the NGT does not force the group toward these goals. To ensure creativity, the group is allowed to submit factors in a relatively unrestrained manner. Furthermore, the group operates under the handicap of individual veto, even though the veto is seldom utilized, and gentle group pressure usually is sufficient to persuade a holdout to drop a marginal factor. Because creativity is protected by design in the NGT, it is never possible to tune the group output completely to the question being addressed. This is because the assessment of the relevance and completeness of each factor depends on the judgment and experience of other group members who are often unable to model a factor mentally or are reluctant to criticize the factor proponent. Evidence of some lack of tuning can be observed in the factors of Tables 4.1-4.5. A suggestion for refining NGT output in the use of this information is presented in Sect. 5.4.

A review of the factor lists in the preceding section shows that water and engineering considerations are rated high, followed closely by ecological concerns. Cultural impacts fall somewhat below these, with the exception of land-use compatibility, which is an issue that the utilities and their opponents clearly perceive as central to site selection. The beneficial impact of plant development was essentially ignored by the second group with one exception — the factor called "maximum beneficial multi-use" is a nod in the direction of possible benefits. It is possible that having asked the group to state the relationship of each factor to plant needs made this task more difficult. For example, instead of listing "recreation" as a factor, we asked for the direction of the impact to be included, as in "minimum adverse impact on recreation in the vicinity of the plant." The factor presenting the converse, "maximize the

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recreational resources in the vicinity of the plant," was not suggested, however. This probably reflects the segmented approach we take to planning in this country, wherein most utilities do not concern themselves with developing regional recreation plans and thus are only concerned with avoiding offense to those who do. Since there is little coordination between utilities and planning agencies, it is seldom realized that building a power plant could represent a vehicle for satisfying recreational needs.

The range of weights for site-level factors was 29-100 for group 1 and 41-100 for group 2. This is attributed to the better definition and clarification done by group 2. Some of the lowest group 1 factors were combined with more important factors by group 2.

In order to give the reader a feeling for the spread of weights among members of the groups, the distributions of weights within group 1 for four representative factors have been included in Table 5.1.

Table 5.1. Individual and group mean weights, round 1, site level nonconclusionary, group 1

Factor	Participant vote							Group mean
	1	2	3	4	5	6	7	
9 Impact on fauna and flora	80	80	90	50	10	70	70	64
14 Institutional ability to manage change	80	80	80	70	80	70	60	73
22 Cultural significance of site	30	1	50	50	30	0	40	29
1 Water availability	100	100	100	80	100	100	30	87

An occasional factor such as 22, the "cultural significance of site," revealed the underlying value systems of the participants through its wide range of weights. The two "50" votes were cast by an ecologist and a forest resource manager, probably reflecting their conservation or preservation viewpoints. The engineers assigned low values to this factor.

A more typical distribution occurs in factor 14, "institutional ability to manage change." The engineers assigned the lowest weights to this factor, while the State Site Evaluator assigned the highest weight. The difference in weights probably reflects concern and past experience with local governments. The consensus achieved through the group mean makes this factor of medium high importance.

A few factors, such as 9, "impact on fauna and flora," have an unexplained vote distribution; in the case of factor 9, a single low value. Patterns of this type can probably be attributed to the lack of specificity in the factor definition. This can lead to confusion or outright rejection by some group members.

The final factor in Table 5.1, "water availability," was included to show a common occurrence. One participant assigned a relatively low weight, 30, to this factor in the round 1 voting. However, Table 5.2 shows that the discussion conducted between voting rounds persuaded this participant to modify his weight from 30 to 70. This change reduced the weight dispersion, indicating a definite movement toward group consensus between rounds. Table 5.2 contains the round 2 weights for the four factors listed in Table 5.1. The table shows that participants tended to stick with round 1 decisions for all but a few factors, and even for these factors, individual changes tend to be - 11. There is little movement of the group mean, but where it does occur it usually reflects a better group consensus.

Shifts in the mean of factor weights between votes were shown to be less than 5% on the average. Participants altering their vote seldom changed by more than 20%. The variance in factor weights was seldom more than 10 but went as high as 25 for a few factors. The process does not guarantee that a group consensus can be obtained for all factors. Even if questions of fact are resolved, differences in value judgment may still prevail. However, wide dispersion appears to be related more closely to poorly specified terms than to different views of the siting process.

While the weight means have been listed as two-digit numbers, it is clear that particular site anomalies which cannot be reflected in such general factors decrease the resolution of factor weights to the point

Table 5.2 Individual and group mean weights, round 2, site level nonexclusionary, group 1

Factor	Participant vote							Group mean
	1	2	3	4	5	6	7	
9 Impact on fauna and flora	90	80	90	50	10	70	70	66
14 Institutional ability to manage change	90	80	80	70	60	70	80	73
22 Cultural significance of site	30	1	50	50	30	0	40	29
1 Water availability	100	100	100	80	100	100	70	93

where they should be rounded to the nearest ten or perhaps, as one participant suggested, to the rougher classification high, medium, and low. The overall sensitivity of systematic siting procedures using weights as coefficients in calculating site suitability probably would not be adversely affected by classifying weights in broader categories.

5.2 Benefits of the Nominal Group Technique

The following points are distilled from our experience and represent the major strengths of the Nominal Group Technique in the identification and rating of siting factors. Some of the arguments apply equally well to other group processes and thus can be considered generic arguments for systematic approaches. Limitations in using the NGT are considered in Sect. 5.3.

From the position of a public utility, the greatest benefit of NGT is that it allows the utility to argue that it has invoked systematic procedures which allow competing concerns to be voiced as it fulfills its obligation to meet electrical demand. This should counter some of the contention of arbitrariness on the part of siting opponents. Clearly the position of a utility on the hearing stand would be improved if it could claim a systematic procedure as the basis for its decision. Furthermore, since the NGT has the attributes of a survey instrument, it can be used periodically to poll the changing values of society to update and reassess its site acquisition program.

The second benefit of the NGT stems from its interactive nature. Each participant generally has an in-depth knowledge of one group of factors and less familiarity with the others. Because it is interactive, the NGT allows the group to be educated by the group expert in each factor. Information is exchanged freely since it facilitates the group goal. Furthermore, the information is received openly and retained because individuals are motivated by the interactive situation. More than once, a group member would exclaim, "Do you really think about that when looking for a site?" It is possible that utilities could realize more educational benefit from a few simple interactive group sessions involving the public than from the same resources expended on literature and open meetings.

High group satisfaction is a third benefit of the NGT. Few traditional task-oriented group work efforts result in a high level of satisfaction on the part of the participants, yet this is the case with the NGT. Very early the group develops team spirit, which results in group discipline and overcomes role playing and individual uneasiness. For instance, because of the sensitive nature of utility siting, some group members at first expressed concern with the possible misuse of information generated in the sessions. This fear was minimized as the session proceeded, in large measure because of the openness and group spirit of the NGT.

The heart of the NGT is the independent silent period in step 1 of the process. The use of a silent period was justified in our session by the quality of factors submitted and the sense of involvement created by this procedure. The groups contained several individuals who, because of their titles and experience, could have dominated the session. The silent period and round-robin procedures of NGT mitigated the status and conformity pressures which might have stemmed from these individuals.

Finally, the interactive nature of the NGT helped us to test the validity of our hypothesis concerning the nature of the siting process while accomplishing the identification and weighting goal of the session.

It was possible to induce discussion of the hypothesized process at the start of the factor identification for each level, and then to cut off discussion as needed.

The benefits listed above prove that the NGT is a powerful tool for dealing with complex modern processes. But what are the limitations of NGT? We will consider them next and then balance benefits and limitations in the conclusion of this report.

5.3 Limitations of the Nominal Group Technique

Several problems with the NGT in connection with the siting question became apparent in the course of the two sessions. The most severe of these restricts the use of the technique in building systematic siting methodology. Such methodology requires that factors be well defined, at the same scale or resolution, that they be the most elemental set possible, and that they be quantifiable. None of these is necessarily assured through the NGT. A group will sometimes list factors without discussion. The observer cannot be certain of the definition held in common by the group or if, in fact, a single understanding is held within the group. As to resolution, it is possible that the group might identify factors with very different levels of resolution, for instance, one general ecological factor and six detailed water-related factors might be listed. There is no way to force the group to either disaggregate the ecologic factor to a group of more detailed factors or to aggregate the water factors into fewer, more general factors. If the siting method should combine factors in linear summation of suitability, as is commonly the case, water would then dominate the actual selection by "double weighting," as the group members referred to it.

The theory of hierarchical structure[11] dictates that the siting process, like other complex processes, is structured in functional levels of increasing detail. For instance, one might hypothesize a siting structure which places suitability at the top or most abstract level and the four factors environmental impact, economic costs, social impact, and safety concerns at a second or lower level. The relative importance of these four factors might be determined through the NGT. The next level down then would consist of factors which further define the four basic factors. This third factor level roughly would contain the factors listed in Tables 4.1-4.5. Factors which further define a higher level factor are weighted relative to each other and not against factors assigned to other higher level factors. This process can progress downward through multiple levels.

Used only in the traditional way, it is doubtful whether a Nominal Group could structure the multilevel model being suggested. By design, the NGT does not allow a group leader to demand consistency of scale or that the group either supply or eliminate factors to satisfy the structural needs of a model. Vesting veto power in the individual group member to protect creativity is inconsistent with the hard choices necessary to build models. However, in the last couple of years, several techniques for interactively organizing issues in a tree structure hierarchy[12] have evolved and might be combined with the NGT to accomplish the structuring goal. This remains to be demonstrated in future sessions of the NGT. Table 5.3 is an attempt to structure the output of the second group into a form suitable for a systematic model. When organized in this manner, it is necessary to reassign some of the elements of the individual factors. For instance, seismic concerns probably include cost, delay, licensing problems, and public attitude. Thus, the cost to overcome potential damage from earthquakes might be included in "foundation conditions," while delay, licensing problems, and public concern might be reflected in "presence of capable faults." It is not clear that the group could have been directed to identify and properly assign detailed elements of abstract factors in a single session.

A modeler must contend with another problem in adapting the NGT output to a systematic procedure. The level of detail represented by the factors making up each functional group of Table 5.3 — social, environmental, economic, and safety — varies considerably. For instance, there are 4 general environmental factors and 11 detailed social factors. Since the levels of resolution between environmental and social factors are significantly different, it would be necessary to disaggregate the

Table 5.3. Ordering site-level factors

Weight	
	Social
90	1. Land-use compatibility
83	2. Impact on cultural entities
79	3. Impact on local institutions
75	4. Impact on local economy
69	5. Local government attitudes
66	6. Minimum aesthetic impact
64	7. Impact on recreation
63	8. Impact on regional economy
56	9. Attitude of local population
48	10. Multiple use of site
43	11. Attitude of regional population
	Environment
89	1. Endangered species
89	2. Impact on aquatic biota
86	3. Water quality
76	4. Impact on terrestrial biota
	Economic
97	1. Foundation conditions
90	2. Surface water availability
87	3. Total plant cost
79	4. Groundwater availability
80	5. Construction problems
70	6. Availability of land
65	7. Transportation accessibility
42	8. Distance to transmission grid
51	9. Proximity to load
	Safety
94	1. Presence of capable faults
92	2. Air diffusion characteristics
87	3. Maximum hydrological/meteorological event
86	4. Population distribution
75	5. Industrial hazards
68	6. Minimum G value for DBE
41	7. Reliable offsite power

environmental factors or aggregate several of the social factors to achieve a better balance. Thus, the modeler has a choice in employing the NGT. He may ask for a comprehensive list of factors without regard to model structure and then force the factors identified into a structure, or he may hypothesize a structure and ask the group to fill it. For instance, he could ask for a structure similar to Table 5.3 of social, environmental, economic, and safety factors having about the same level of detail.

5.4 The Optimum Use of the NGT in Model Building

Considering the difficulty of obtaining more than a minimal level of idea structuring through a traditional application of the NGT, it would seem that the optimum use of the NGT in model building is a series of iterations between the modeler and selected Nominal Groups in which the modeler organizes ideas generated by groups.[1] Using NGT, this might be done in the following manner:

1. A group first creates an unstructured set of factors which defines the elements of the process being modeled.
2. The modeler organizes the information obtained from the group and hypothesizes a model structure with sets of relationships.
3. Different NGT groups then list factors in successive sessions using the boundaries created by the modeler as a guide. The group sessions would first verify the soundness of the structure hypothesized and would then offer new or more precise factors to improve the model. The strength of hypothesized relationships could be verified also. The NGT can be repeated until no further improvement is obtained.

The suggestions of an iterative use of the NGT raises the question of time and cost. To integrate the NGT into model building would consume considerable time, perhaps three man-weeks per session. However, in light of the model improvements possible by use of the NGT, the extra investment of time and money would probably justify its use. The prospective user must be cautioned, however, not to attempt to reduce costs by tracting more from a group than it can deliver. For instance, the group ould not be asked for more than two factor sets based on carefully comed questions in one sitting. Also, it is best to limit any given ssion to 5 hr, since fatigue causes the group to be unproductive in nger sessions.

The discussion of time utilization brings us to another observed mitation of the NGT. It was apparent in conducting our session that a mber of the factors identified were technically difficult to understand d that some members of the group never gained a clear understanding of rticular factors. This was reflected in the divergence of weights that s observed for a few factors in the rating step. Developments in the eld of structural modeling[13] point the way for the interaction of deler and content specialists using graphic devices called "intent ructures."

It might be possible to force a more technically complete definition om participants in the clarification step of the NGT. Such a definition uld have to describe the technical problem, possible solutions, cost d uncertainty, and the relationship of the factor to siting. It is kely, however, that a careful definition of factors would push the ssion beyond 5 hr and affect the spontaneity of the session. For these asons, we suggest that 2 hr be set aside in the morning of the session r a minicourse on the technical problem being considered, preferably ught by persons other than participants and designed to cover topics on ich there may be lack of understanding. The NGT session could then be ld in a single 5-hr period in the afternoon. If two days are available, good approach would be to hold the minicourse on the afternoon of the rst day and the NGT session the following morning. Our experience in ying to document the definition of factors from tape recording indicates at participants should still be asked to create a succinct definition of ch factor during the NGT. This will have to be carefully controlled, ough, to avoid using excessive amounts of time.

6. CONCLUSION

The application of the NGT to power plant siting has been discussed in some detail in this report. The actual output of two sessions has been presented, and an analysis of the lists created by these sessions shows they are pertinent to siting and surprisingly comprehensive. The factors identified can be used either as a checkoff list by agencies charged with writing impact statements or gathering data, or they can be incorporated into systematic siting procedures. An iterative procedure involving Nominal Groups and modelers was suggested as a means of using the NGT in creating systematic siting procedures. This approach should lead to finely tuned models which reflect the consensus and collective knowledge of expert participants.

There is no inherent reason why the NGT cannot be extended to siting any major facility, not just the nuclear power plants discussed. There is also the possiblity that a broader spectrum of participants could be involved in the NGT, for instance, the nonexpert public. The potential for effective use of the NGT has not begun to be tapped and is only limited by the imagination of possible users.

Beyond the expert judgment which can be elicited and ordered by the use of the NGT, probably the most important benefit is the collective sense of involvement generated by the process. Coupled with cross education, it allows participants to transcend individual limitations and produce a group output superior to individual effort or to unstructured group effort. The future of group process techniques seems assured as the problems faced by society become more complex and we seek better ways to structure this complexity.

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