AN ABSTRACT OF THE THESIS OF

Nancy L. Mills for the degree of Doctor of Philosophy in Industrial and Manufacturing Engineering presented on August 9, 1988.

Title: A Systematic Approach to Multi-Criteria Site Selection with an Analysis of Weight Sensitivity

Abstract approved: Signature redacted for privacy.

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Site selection decisions are major components of a company's overall corporate strategy, usually involving incommensurate and possibly conflicting goals, and having long term effects on the productivity and profitability of the firm. The nature of the process requires the application of multi-criteria decision analysis techniques. Multi-criteria site selection involves identification of site factors, development of measures for the factors, assignment of importance weights, selection of a scoring method (design of a model), calculation of a composite site score, and performance of sensitivity analyses.

Site factors may be classified into major categories such as land; utilities; transportation; markets; materials, supplies and services; labor; community characteristics; government and legislative; environmental and ecological considerations; and financing. The factors may require monetary or nonmonetary measures, with the latter

being objective or subjective. The relative importance (weight) of the factors usually varies depending of the business environment, the type of industry, the type of facility, and the objectives of those affected by the decision.

This research extends the features of previously developed techniques into a systematic methodology for analyzing site selection problems. The developmental efforts focus on minimizing the weaknesses of currently available methods through an integrated approach which emphasizes an analysis of selection sensitivity to the variability inherent in factor weights. Since the weights represent value judgments, they are most subject to uncertainty.

A comprehensive master list of site factors is developed which utilizes a hierarchical structure. This structure contributes to the effectiveness of the recommended procedures for developing importance weights. Factor measures, developed after the assignment of weights, utilize objective utility functions or descriptive class assessments on a common, dimensionless scale. The guidelines for the analysis of the results incorporate the consideration of costs and nonmonetary factors, and identify important trade-off points that can be used to guide the decision process. The application of this methodology provides the decision maker with additional measures of confidence in the choice of a site.

A Systematic Approach to Multi-Criteria Site Selection with an Analysis of Weight Sensitivity

by

Nancy L. Mills

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed August 9, 1988

Commencement June 1989

APPROVED:

Professor of Industrial and Manufacturing Engineering

Head of Department of Industrial and Manufacturing Engineering

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Date thesis is presented August 9, 1988

Typed by researcher for Nancy L. Mills

ACKNOWLEDGEMENTS

At the completion of this undertaking, I pause to thank those who helped this dream become a reality. My sincerest appreciation must go to Dr. Tom West, who provided me with wonderful teaching experiences, excellent resources and financial support, and who helped me see just how much I can do, even if I did not always appreciate it at the time.

I thank my friends who made the University and Corvallis a warm and friendly place. And extra thanks go to Paul, who provided support in so many ways and, most of all, showed me it could be done.

Special thanks are given to my parents, Ivan Glen and Jeanne Weber Mills, for their support and encouragement. They always believed in me and kept me supplied with Mom's chocolate chip cookies.

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CHAPTER 1.

INTRODUCTION TO THE PROBLEM

Site selection encompasses the processes of identifying, analyzing, evaluating, and deciding among alternative locations for facilities. Site selection involves the following activities: (1) recognition of future capacity shortfalls or surpluses; (2) consideration of short-term and long-term options for remedying capacity shortfalls or surpluses; (3) determination of the general area (or areas) where a new site, if needed, should be located; and (4) selection of the actual site (Schmenner, 1982). Three basic types of location decisions can be identified: the establishment of the first plant or facility of a new company, the relocation of an existing facility, or the establishment of a new branch location (Management and Economics Research Incorporated, no date).

The selection of a facility location must be considered a major component of a firm's overall corporate strategy. Site selection decisions usually have long term impacts on the productivity and profitability of firms. Geographic positioning affects most elements of the marketing mix[1] used by corporations to strategically position themselves in relation to their competitors. Effective placement or replacement of facilities can dramatically improve corporate profits by enabling lower production and distribution costs and by providing better servicing of key market segments. Thus, site location decisions should be viewed as equal in importance and value to the corporate enterprise as strategic product and market decisions (Wilson, 1987).

Unfortunately, even though site selection decisions impact all areas of operations, corporate executives may not appreciate the criticality of these decisions. Such lack of attention or failure to recognize the importance of such decisions may be compounded by the fact that these decisions are made infrequently in an executive's career; thus, the decision maker is not equipped with the background, experience, or theoretical or technical knowledge required. Other factors, such as corporate politics, may also influence the decision process. Evidence suggests that some site selection decisions are made subjectively by a chief executive who wants to be close to good skiing or golf courses. Goldstein (1985) reports that an estimated 40 percent of location decisions are arbitrarily based on subjective criteria and the personal desires of top executives. Tompkins and White (1984) describe this "phenomenon" as the "Site Selection Law":

> "If the decision maker will be directly affected by the location decision, it will be made subjectively; if the decision maker will not be directly affected by the location decision, it will be made objectively."

As implied by this "Site Selection Law" and reinforced by published reports on actual location decisions (Goldstein, 1985), there appears to be a large gap between the objective or quantitative site selection methodologies that have been developed to help improve the site selection decision process and the approach that is often used in the "real world". Decision makers in industry typically do not use the available methodologies or models for a number of different reasons. First, many of the models are (or appear to be) too complex mathematically. Second, if simplified, they may become too abstract to provide useful real-world solutions. Third, in many cases, not enough resources (time, money and manpower) are allocated to the decision process for the collection of the necessary data and the development and application of the models to provide a thorough analysis.

Location Theory

The basis for site selection decisions is founded in the body of knowledge known as (industrial) location theory. Reed (1967) and Browning (1980) provide summaries of the phases of the development of location theory. Some of the earliest published works in location theory were done by two German economists, Johann Heinrich von Thunen[2] and Alfred Weber[3], who attempted to incorporate a theory of location into general economic theory.

In 1875, von Thunen studied the factors affecting the location of different kinds of agricultural production to supply a city. He approached the problem from a highly theoretical standpoint, based on the economic theory of rent[4]. He assumed a totally isolated economic system in which all nonessential aspects of a real situation had been eliminated. He then considered the location problem under assumed conditions of perfect competition with price determined by supply and demand. Wages were considered equal for all production locations and any nominal wage differentials were assumed to be elements of the cost of land.

Von Thunen found location to be a matter of minimizing the combined costs of rent and transportation. He reasoned that the heaviest and least valuable product should be raised close to the city to minimize the cost of transportation. Furthermore, if two farmers produced the same product and sold it for the same price, the one closest to the city would earn greater profits or could spend more for machinery, labor, fertilizer, and other factors of production. Therefore, a site which provided the lowest cost of rent plus transportation was most desirable.

While von Thunen studied agricultural production, Weber was specifically concerned with the location of industry. In 1909, Weber expanded on von Thunen's use of transportation costs as a basis for industrial location. Weber, in his theory, considered three general location factors: the regional factors of labor cost and transportation cost, and the local factor of the agglomerating forces[5]. Although he recognized the factors of raw material costs and fuel costs, these were grouped under transportation cost by assuming added raw material or fuel costs were equivalent to transportation costs for a location further from the city or center of consumption.

Weber classified resources into two groups: those available everywhere (air and water) and those limited to certain locations (minerals, ores, other natural resources). From a manufacturing standpoint, he categorized materials as those that lose weight in conversion and those that gain weight in processing. For example, at a location close to the orange groves, the juice is removed from oranges and the water content is reduced. The resulting orange juice concentrate is then shipped to the rest of the country. The consumer buys the concentrate and adds the water back in without having to pay for the cost of transporting it. This principle is also illustrated in metal manufacturing, where fuel is a major ingredient in smelting. The decision must be made whether to ship the ore to the fuel or the fuel to the ore. When several raw materials are used, an intermediate location may be the point of least transport or transfer cost.

Recognizing that the cost of transfer is a major factor, Weber concluded that, if the materials lose weight in conversion to product, the location of production should be at the material source. On the other hand, if weight is gained in conversion, the location should be nearer the market. Weber's location theory coupled this conclusion with the effects of agglomerating (or deglomerating) forces.

As viewed by Weber, industry can also be divided into two groups: those oriented to labor and those oriented to transportation. When two alternative locations come out about equal on these two counts, then consideration of agglomerating factors becomes important. The savings from agglomeration due to proximity to auxiliary or support industries, better markets, and economies of size are evaluated against high rent, which is the major factor that encourages deglomeration. Weber concluded that labor is a critical force in agglomeration and can cause an industry to deviate from its optimum transport locations.

Weber's theory is relatively simple, but it does provide the foundation of modern location theory. Transportation, labor, and weight differentials during processing continue to be major elements in contemporary location determinations.

Von Thunen's and Weber's approaches differ in that von Thunen assumed a location was given and the objective was to determine the type of product for that location. Alternatively, Weber assumed the branch of industry known and sought to determine the proper location. These two opposite approaches are both applicable today. Political subdivisions, Chambers of Commerce, railroads, public utilities, and others who have a fixed site or region for location are faced, to a large extent, with determining the type of industry adaptable to the location (von Thunen approach). Attempts are then made to interest a firm involved in production of the selected product type in the location. Weber's approach, on the other hand, is illustrated by a firm which, having a determined product, seeks a location which appears to offer the desired potential for operations.

The second phase of the development of location theory can be illustrated by the work of Edgar Hoover[6]. In 1948, Hoover separated the cost factors of location into (1) transportation factors and (2) production factors. Transportation was defined as the cost of procuring the raw materials and distributing the finished product. Hoover recognized the error in assuming that transportation costs are proportional to distance and pointed out that this nonproportionality causes the impact of transportation costs to decrease as transport distance increases. Hoover defined production to include not only labor and other manufacturing costs but also the agglomerating forces. He included in agglomeration such advantages as better transfer services, a broader, more flexible labor market, more advanced banking facilities, better police and fire protection, and lower insurance costs and utility rates.

Hoover proposed that the locational relationship of an industry to its customers be viewed as a system of product market areas. The assumption is made that customers are scattered, so that any one producer must sell to customers at a number of locations in order to survive, which probably represents the most common location situation for manufacturing industries. Similarly, the locational relationship among buyers of raw materials appears as a system of supply areas. Hoover pointed out that the sellers may be small and highly scattered, requiring the buyer to purchase from scattered locations in order to survive.

In addition to his development of product market locational analysis, an important contribution of Hoover was his recognition of capitalistic influences on location and his consideration of the factors of taxation, utilities, banking, and public services. A major portion (five chapters) of The Location of Economic Activity is concerned with the effect of public policy on locational objectives, representing recognition of the influences of mid-20th century economic and political theory on location.

Another major contributor to the development of economic location theory during this period was Melvin L. Greenhut[7]. Greenhut divided location factors into four major measurable classifications: (1) transportation costs, (2) processing costs, (3) the demand factor, and (4) cost reducing and revenue increasing factors. Although Greenhut recognized the importance of personal factors in the final selection of the location, he concluded that such factors can be included in economic methodology by application of minimax principles to trade-off between financial rewards and personal satisfactions.

Greenhut developed a general theory which was first presented as a non-mathematical formulation and later structured mathematically. The resulting general theory can be considered a profit maximization approach which combines both the cost and demand forces of earlier theorists into a single formulation. The maximum profit (or minimum real cost) location is defined as the site with the greatest spread between total receipts and total costs.

One criticism[8] of Greenhut's approach is that he postulated profit maximization as the objective of management. Even personal factors are assumed capable of equation to this by balancing personal desires against lost profits to arrive at an equilibrium point at which the maximum value of the joint objective of the entrepreneur is realized. On the other hand, the justification that Greenhut's model does represent modern practice, as well as theory, arises primarily from the attempt of firms to locate in the manner of the general theory, rather than on their actual accomplishment of this objective.

The direct application of industrial location theory is hindered by several factors: (1) the inability of the firm to satisfy the required inputs to the general economic location theory models, (2) the failure of the real world to remain in equilibrium, (3) the variation in the prime objectives of management, and (4) the inability to quantitatively measure personal factors influencing location. (Reed, 1967) Another problem with these theoretical approaches is that they presuppose a unique location that has a site equally advantageous for serving all areas of the market. In real life, a location may be the most profitable despite the fact that it has a high cost relative to other locations or to the market area. (Browning, 1980)

In spite of these shortcomings, the major purpose and resulting value of location exercises (applications of the theory) are in helping the affected parties separate themselves from personal preferences and in enabling them to calculate the financial benefits of alternative sites. For example, a firm would normally (1) design or assume a general approach to the problem, (2) establish a set of factors that affect selection, although this set may be incomplete with respect to all the possible factors that might affect the decision, (3) evaluate the factors, and (4) make a decision based upon available data. When making such site comparisons, one alternative may be chosen as a reference point, and the relative costs of sales, transportation, and other factors for the other options compared to it to arrive at the identification of the preferred site.

Regardless of how the decision is made, once it has been made and a facility constructed, management may have to live with that site for a substantial period of time due to the size of the required investment and the relative permanence of constructed facilities. As Hicks and Kumtha (1971) point out, "the more aggregate a facilities planning mistake, the more costly it will be; the less likely it will be changed; and the longer it will affect the operation." Thus, attention should be directed toward improving the decision-making process.

The Site Selection Problem

Developed from the applications of location theory, the present approach to the site selection problem involves the consideration of many different factors. To assist in the solution of such location problems, the techniques of multi-criteria decision analysis have been applied, including the development of multi-criteria models to assist in identifying the "best" site. However, many analyses end with a recommendation that "the highest number is the best site". Decision makers using such models are typically not left with an understanding of the confidence they should (or should not!) have in such a choice. Nor are explanations provided as to how they could use the same model to further analyze the results or to explore other options.

The purpose of this research effort is to develop a systematic site selection methodology which unifies the techniques described in the literature and addresses the weaknesses of earlier applications. The approach developed in this study builds on past work through an evaluation of previous applications of multi-criteria decision models to site selection problems. An examination is made of potential areas for improvement, and procedures to strengthen the identified weaknesses are described. This methodology includes a detailed examination of the results from a multi-criteria evaluation (including the "best" site recommendation) and sensitivity analyses, with a special emphasis on importance weights.

The following chapters provide the necessary background and the development efforts involved in this approach. Chapter 2 presents a review of the current "state of the art": the theoretical basis for and current applications in the use of multi-criteria decision analysis for site selection. Included in this chapter is a survey of the literature, and a description and evaluation of the components of a multi-criteria site selection model: site factors, methods of measuring and weighting the factors, and alternative means of calculating site ratings or rankings. The chapter concludes with a discussion of the comparative strengths and weaknesses of the current approach to the site selection problem. Chapter 3 presents the development of the methodology and includes a discussion of its use as an aid for decision makers involved in site selection analyses. Chapter 4 illustrates the proposed approach with an application to a specific site selection problem, the evaluation of alternative locations for a small biomass-fueled electrical generating plant. General conclusions and a summary of the results of the study are presented in Chapter 5. Recommendations for additional applications and extensions of the methodology, and future research areas are also provided.

Expected Contribution

A methodology such as described in this research should assist analysts in conducting more systematic site evaluations and help decision makers to better understand the results of the analyses of alternative sites for new or relocated company facilities. It could also provide a valuable tool for economic development agencies seeking to attract new industries by enabling them to offer this methodology as a service, assisting potential locators with a more comprehensive analysis. Such agencies could also adapt the model to use in identifying what their area has to offer and the types of industries it can best support.

A further discussion of potential applications for this methodology is presented in Chapter 5.

In the more general case, the methodology developed here could be applied to many other multi-criteria decision problems. The analysis of results and the examination of the effects of changing importance weights would be applicable to other, similarly structured decision models.

CHAPTER 2.

A DESCRIPTION OF THE MULTI-CRITERIA SITE SELECTION PROBLEM

Expanding from its foundations in industrial location theory, the study of the site selection decision process now encompasses a broad, multi-disciplinary range of disciplines. A review of the literature includes the fields of facilities planning (Tompkins and White, 1984) (Muther and Hales, 1980) (Conway and Liston, 1976), plant layout and location including location-allocation models (Reed, 1961, 1967) (Moore, 1969) (Stafford, 1979) (King, et al, 1979) (Schmenner, 1982) (Browning, 1980), regional and urban planning and geography (Oppenheim, 1980), geo-economics (Rushton, 1979), economic development (Management and Economics Research Incorporated, no date), and decision analysis (Bunn, 1984) (Goicoechea, Hansen and Duckstein, 1982) (Keeney and Raiffa, 1976).

In certain cases, the selection of a site location can be a fairly straightforward procedure. Some decisions, including expansion on an existing site and the situation where only a single suitable site is available, can be made easily. Other site selection problems, such as the location of certain types of new facilities based on quantifiable criteria such as distances or costs, can be solved using such optimization techniques as minisum or minimax location methods, location/allocation models, and quadratic assignment techniques. The results obtained from such models provide numerically optimal or near-optimal solutions.

In other cases, selecting a site is a more complex decision process. The process may involve multiple facilities to be located, multiple sites (which may not yet be identified) to be considered, multiple criteria or objectives (usually of differing levels of importance in the decision and sometimes in conflict) to be evaluated, and multiple stages of the decision process.

Since site selection decisions are conducted in a dynamic environment, the key factors can change over time and with changes in the environment. For example, during the 1974-1978 energy crisis, fuel and power costs assumed great importance in site location decisions. Today, environmental restrictions or development incentives may play bigger roles than in the past (Johnson, 1986).

Shifting demographics can affect the relative importance of factors such as labor rates, taxes, and transportation. For example, wages have been a significant factor, but the narrowing of wage differentials may cause wage rates to make a less critical difference, according to

Goldstein (1985). He proposes that the Southern United States may be losing its relative advantage with respect to manufacturing wages, with labor costs that rose eight percent annually between 1972 and 1982, compared with increases of less than six percent in the North.

Demographic changes also reflect a move toward equilibrium in regional tax incentives, as well as pay structures. Tax breaks have become a virtual commodity, available everywhere, and now typically account for no more than a three or four percent difference in a facility's operating costs. Large gaps in transportation and energy costs have also diminished. Research indicates that operating costs, which were between twenty and forty percent lower in the South ten years ago, have narrowed to a five to fifteen percent difference (Goldstein, 1985).

Nevertheless, the movement of manufacturing industries still is predominantly from the Northern states to the South, reports the Wall Street Journal (1988). Although unions have lost much of their strength in the North and the North-South wage gap is narrowing, lower labor costs are still a powerful lure to the Southeast. Since the cost of labor has traditionally been lower in the South, this factor continues to attract industries, particularly those that are labor-intensive.

In addition to lower wage rates, other factors are contributing to the loss of manufacturing plants in the North. As the age of the plants increases and the efficiency decreases, manufacturing becomes more expensive in the North. Land costs also tend to be higher. Furthermore, many areas of the South still offer lower taxes, cheaper energy rates, and lower housing costs. The cost and quality of living also contribute to companies' decisions to move South, with relocations to places where key people in the company want to go. And in a compounding effect, the migration of people to the Sun Belt helps to create other jobs. As the population grows, so does the demand for products, which leads companies to build new facilities to meet that demand.

However, the move to the Sun Belt states is not the only relocation option being exercised by American industries. In the three-year period from November 1984 to November 1987, the nation lost nearly 400,000 manufacturing jobs, many in heavy industries like steel, automobiles, bulldozers and farm equipment, largely because of deep inroads by foreign producers. In order to compete, American companies are moving to off-shore sites for new production facilities.

Advantageous foreign wage rates and investment incentives are just two of the factors that have made site selection an international decision, as companies consider additional alternatives to operate and serve customers nearly anywhere in the world (Benson, 1986) (Conway, 1987). Differences between locations may become more critical when considering the impacts of foreign wage scale differentials, security of assets, and communication and transportation requirements. Determining the most cost effective location is more complex due to the proliferation of financial incentive packages offered by different countries (and states within the United States) (Benson, 1986) (Koretz, 1987). The decision is further complicated by the consideration of risk factors that include foreign currency exchange rate fluctuations, governmental instability, terrorism, and environmental concerns such as toxic wastes and nuclear radiation (Conway, 1986, 1987).

In addition to such changes in the business environment, those seeking a site may also find their needs changing as the requirements for the site are further defined and the focus of the site selection process moves from a "macroscopic" to a "microscopic" view. Furthermore, those involved in the site selection process may need to consider development phases for the long-term utilization of a site, and to evaluate trade-offs between short-term versus long-term solutions. At the various stages in the decision process, the requirements for input, including expert opinions, from different "affected parties" results in a changing cast of involved individuals.

The complexity of the site selection problem results from the need to consider these multiple facets. In order to incorporate consideration of multiple factors in the decision process, the use of multi-attribute[9] decision analysis or multi-criteria[9] decision making techniques is appropriate. Multi-criteria decision making attempts to integrate common sense with empirical, quantitative, normative, descriptive, and value-judgment-based analyses for the purpose of improving the decision-making process (Haimes, 1985).

Multi-Criteria Decision Analysis

Most, if not all, real-world decision making problems are characterized by multiple, incommensurate, and frequently conflicting objectives. Multi-objective problems arise in the study of many complex systems in the areas of industrial production, urban transportation, health delivery, public programs, layout and landscaping of new cities, energy production and distribution, wildlife management, operation and control of the firm, portfolio theory, agricultural and livestock production, and local government administration (Goicoechea, et al, 1982). For example, in the energy field, a decision on siting a nuclear power plant would require evaluations of criteria such as cost, reliability, safety, health, and environmental impacts (Bunn, 1984).

In most complex problems, there exists a hierarchy of objectives, subobjectives and sub-subobjectives, which may be conflicting in nature. In modeling, it is important to identify this hierarchy of objectives and avoid inappropriate comparisons and trade-offs among objectives that belong to different levels (Haimes, 1985).

Trying to simultaneously satisfy multiple objectives introduces new dimensions in the areas of modeling and mathematical programming. Traditionally, procedures for building models would consist of the following steps: (1) choosing a collection of goals and defining the corresponding objective functions, (2) gathering relevant information, (3) building a model, (4) validating and operating the model, (5) determining a feasible control policy, (6) applying the policy to the model, and (7) assessing the extent to which the stated goals are achieved. However, when the formulation of a problem recognizes a collection of objective functions, two or more of these functions may be incommensurate and the search for a single optimal solution is no longer appropriate (Goicoechea, et al, 1982).

Even if a optimum mathematical solution to a model could be found, it would not necessarily correspond to the optimum for the real-life problem. An optimum solution to a real-life problem depends on factors which are not easily quantified, such as the biases of the modeler, the credibility of the data base, and the decision makers and their perspectives (Haimes, 1985).

Nevertheless, problems which involve conflicting objectives are considered by people every day, and often decisions are made with far-reaching consequences. Unfortunately, limited resources in capital, manpower, and available time may prevent a careful formulation of the problem, including a complete statement of needs and objectives. Resource constraints may also preclude the application of a methodology to generate alternative solutions, and an evaluation of the trade-offs among the alternative solutions in terms of the stated objectives. Alternatively, the resources may be available, but an appropriate methodology is lacking. Then, through a process that may involve merely guesswork, intuitive feelings, and cursory inquiries, a decision is made to select a particular solution from a set of alternative solutions.

At other times, decisions are reached after a careful review of criteria, goals, and rigorously stated results. Such decisions are aided by the development of a number of methods which are capable of dealing with multi-objective problems in a formal manner (Goicoechea, et al, 1982). Much research and development work has been done in the field of multi-criteria decision analysis. Methodologies to incorporate linear and non-linear utility functions, and uncertainty in estimating attribute values and levels of attainment have been developed and evaluated. Assessments of alternative methods of developing attribute weights and of involving groups in the decision making process have been studied. (Litchfield, et al, 1976) Many of the advances in multi-criteria decision making are supported by advanced systems concepts, such as data management procedures, modeling methodologies, and optimization and simulation techniques (Haimes, 1985). Although a detailed discussion of the many aspects of multi-criteria decision analysis will not be presented here, additional information is provided in the description of its application to the site selection problem.

The Multi-Criteria Site Selection Problem

The generalized site selection procedure shown in Figure 1, adapted from West (1977), illustrates the process of narrowing the focus from a general region of interest to candidate areas within the region to potential sites within the preferred area. These levels of analysis may be defined as regional analysis, area or community analysis, and individual site analysis (Management and Economics Research Inc., no date). The techniques of multi-criteria decision analysis are applicable at all stages of the site selection problem.

Models developed to aid in the selection of sites generally have been designed for a specific facility location decision. Such procedures incorporate a situation- or project-specific set of criteria for the comparison of previously identified candidate sites. The following sections describe the basic components (site factors, measures, weights, and rating methodologies) of a site selection decision model and present an overview of various approaches that have been employed.

A multi-criteria decision analysis model designed to aid in the site selection process can be viewed as being composed of the following key components, leading to the selection of a site: (1) site factors (or attributes) and

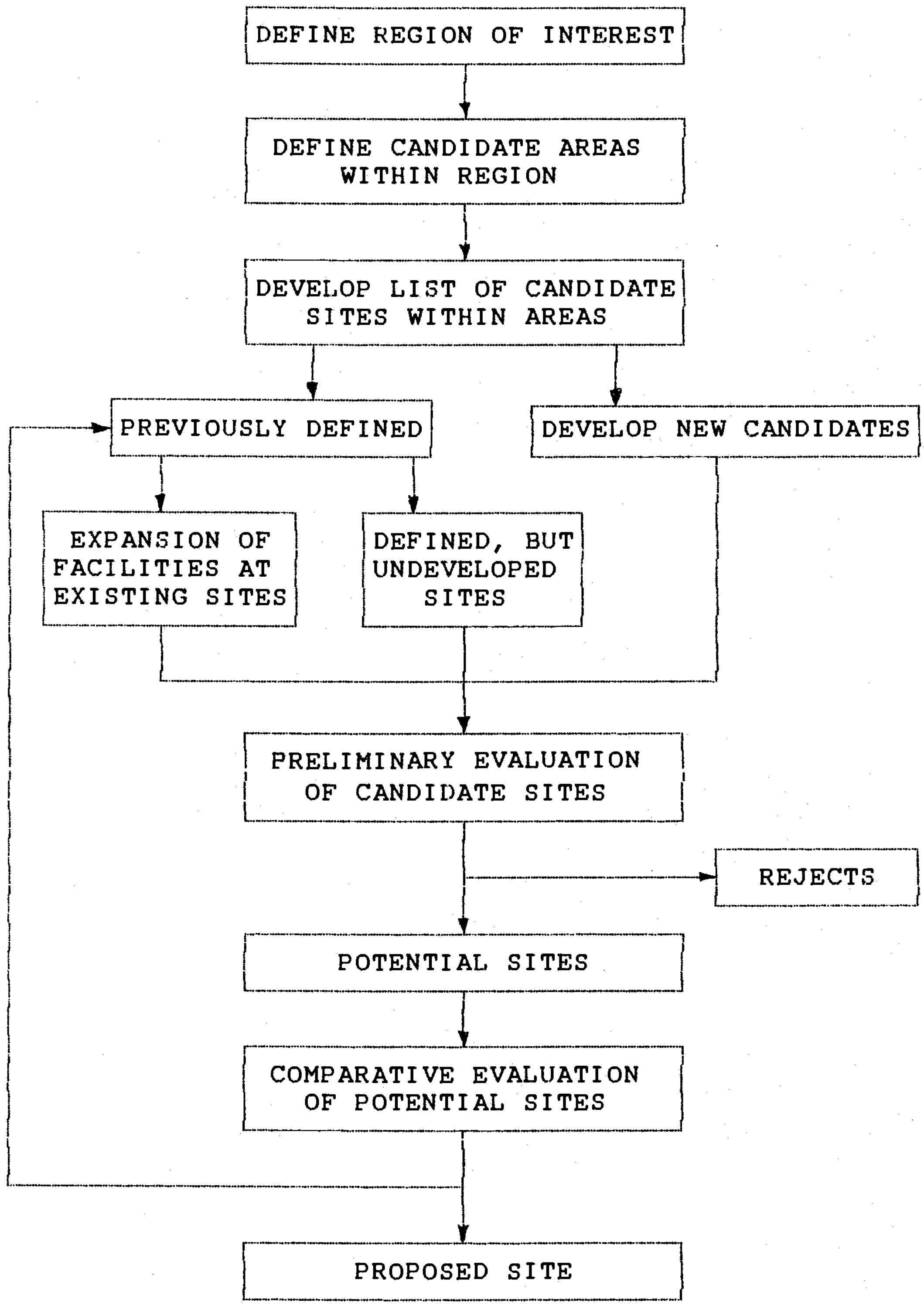

Figure 1. Generalized Site Selection Procedure

subfactors; (2) site factor measures, both objective and subjective; (3) factor weights; (4) overall site ratings or rankings; and (5) sensitivity analysis. The activities involved in developing these components are shown in Figure 2.

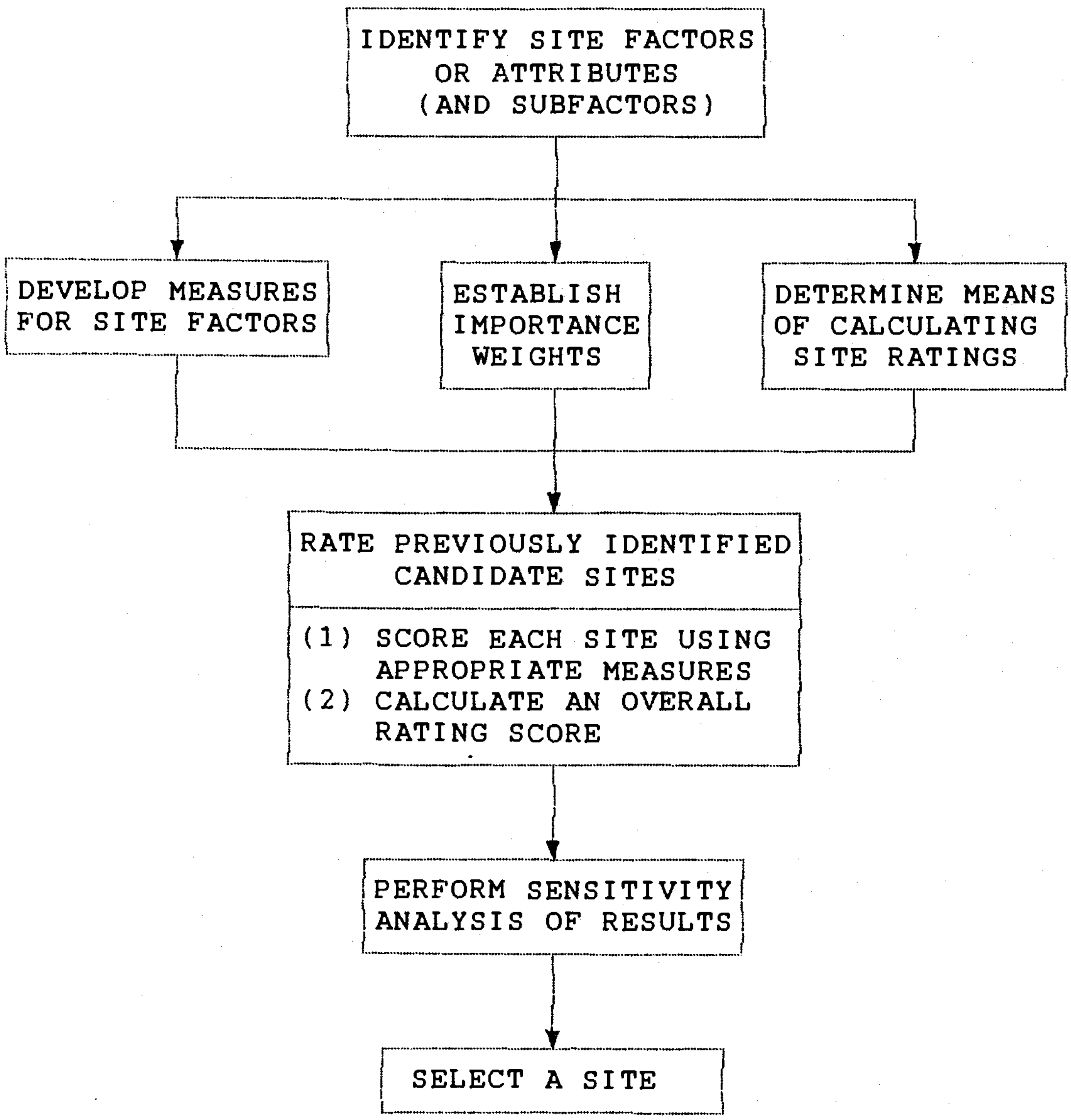

Figure 2. Components of the Multi-Criteria Site Selection Problem

Site Factors

One of the primary considerations in the site selection decision process is the identification of the many different factors or criteria which affect a firm's ability to efficiently produce its products or services and to compete effectively in its markets. A review of the site selection/facility location literature reveals many different lists of site factors. These range from a brief list of eight high level "Enterprise Success Factors" as identified by Wilson (1987) to the "The Checklist of Expansion Planning and Site Selection Factors" from the Site Selection Handbook (1979), which provides an extremely detailed list of more than 1,500 criteria. Representative lists of applicable site factors can be found in Muther and Hales (1980), Waldrep (1985) and Riggs (1987). Browning (1980) and Moore (1969) both include a guide originally published in Factory Management and Maintenance. Other lists of factors are identified and classified in Johnson (1986), Levine (1986), Reed (1967), and Schmenner (1982). The following sections present an overview of these lists of site factors and illustrate the diversity and complexity of such lists.

Wilson's "Enterprise Success Factors" include market proximity and access, work skills and flexibility, reasonable operating costs, site and facility access, responsive business services, technological infrastructure, traditional infrastructure, and excellent living conditions. Riggs identifies five main location factors: labor, livability, services, sites, and taxes. He further breaks these factors down into rating categories as shown below.

I. Labor
   A. People available in each skill, age, and sex category
   B. Wage rates by skill category and fringe-benefits cost
   C. Employment by labor-force percentage and strike records
   D. Degree of unionization and right-to-work laws

II. Livability
   A. Education
      1. Pupils per teacher
      2. Dollars spent per pupil
      3. Higher education
      4. Community support
   B. Recreation and culture
      1. Parks and programs
      2. Live arts and museums
      3. College and/or professional sports
      4. Athletic facilities
   C. Housing
      1. Ratio of population to houses available
      2. Building cost per square foot
      3. Land cost per square foot
   D. Services
      1. Doctors per 1000 population
      2. City expenditures per capita
      3. Civic organizations

III. Services
   A. Availability, type, and cost of personal transportation
   B. Reliability, speed, convenience, and cost of material transportation
   C. Electricity and fuel availability and cost

IV. Site
   A. Zoning, quality, and cost of land; fire and crime protection
   B. Adequacy of buildings to lease or buy and availability of local financing
   C. Availability of special features such as access, parking, railroad sidings, storage, etc.

V. Taxes
   A. Amount of sales, income, property, inventory, machinery, and franchise taxes
   B. Workmen's compensation tax and unemployment insurance tax
   C. City, county, and state tax trends.

Riggs also presents another list of site factors, which includes technical skills, cost of labor, raw-material sources, highway system, railway hub, seaport facilities, airport, nearness to markets, proximity of suppliers, in-place utilities, community facilities, climate, low taxes, available financing, and land costs.

In Systematic Planning of Industrial Facilities - Volume II, Muther and Hales present a twelve-page "Site Selection Factors Checklist", which utilizes an indication of importance of the factor to the firm and a rating for each factor of interest for a particular site. The major categories and subcategories are shown below.

I. Transportation
   A. Water
   B. Rail
   C. Truck
   D. Air

II. Labor Supply
   A. History

B. Availability
C. Local practices
D. Labor laws
E. Unions
F. Management potential

III. Raw Materials and Services
A. Raw material supply
B. General services and supplies
C. Special services
D. Construction services

IV. Power and Utilities
A. Electricity
B. Coal
C. Gas
D. Fuel oil
E. Water
F. Telecommunications

V. Environment and Pollution
A. Climate
B. Air-pollution control
C. Water-pollution control
D. Solid-waste disposal

VI. Government and Taxation
A. State regulation
B. State taxation
C. Local taxation
D. State and local incentives

VII. Community Features
A. Population
B. Housing
C. Education
D. Health and welfare
E. Culture and recreation
F. Meeting facilities
G. Shopping
H. Police and fire protection
I. General business climate

VIII. Specific Site Features
A. Location
B. Zoning
C. Site conditions
D. Soil characteristics
E. Power and utilities
F. Transportation
G. Existing buildings

H. Legal factors
I. Cost factors

A list similar in design although with a different arrangement of factors is recommended by Browning. His list has the following major categories.

1. Labor History
2. Labor Availability
3. Influence of Local Industry on Labor
4. State Taxes
5. Community Financial Picture
6. Rail Transportation
7. Truck Transportation
8. Air Transportation
9. Water Transportation
10. Miscellaneous Transportation
11. State Business Climate
12. Electric Power
13. Fuel Oil
14. Natural Gas
15. Coal
16. Water Supply
17. Water Pollution
18. Raw Material Supply
19. Physical Climate
20. Community Business Climate
21. Planning and Zoning
22. Commercial Services
23. Community Employer Evaluation
24. Management Potential
25. General Community Aspects
26. Maturity of Citizens
27. Residential Housing
28. Education
29. Health and Welfare
30. Culture and Recreation
31. Specific Site Considerations
32. Police Aspects
33. Fire Aspects
34. Roads and Highways
35. Trash and Garbage
36. Sewage

In identifying factors which play major roles in plant location decisions, Wardrep presents two lists. First, he identifies quantifiable location factors: (1) site and preparation costs, (2) construction (renovation) costs, (3) equipment costs, (4) labor and fringe benefit costs, (5) startup costs (e.g., training), (6) working capital requirements (e.g., inventories), (7) freight (in and/or out) expenses, (8) property taxes, (9) workman's compensation premiums, (10) unemployment compensation premiums, (11) relocation expenses, and (12) revenue forecasts. Wardrep also provides a list of major factors in location searches, which includes an indication of quantifiable (*) and partially quantifiable (**) factors.

I. Access to Markets/Distribution Centers
   A. Cost of serving markets **
   B. Trends in sales by areas
   C. Ability to penetrate local market by plant presence

II. Access to Supplies/Resources
   A. Cost of transporting supplies **
   B. Trends in supplier by area

III. Community/Government Aspects
   A. Ambience
   B. Cost of living *
   C. Cooperation with established local industry
   D. Community pride (appearance, activity, citizen views)
   E. Housing (availability, pricing)
   F. Schools, cultural and recreation programs
   G. Colleges, graduate programs
   H. Churches, civic groups

IV. Competitive Considerations
   A. Location of competitors
   B. Likely reaction to this new site

V. Environmental Considerations

VI. Interaction with the Remainder of the Corporation
   A. Is this supposed to be a satellite plant?
   B. Supplied by or supplier to other company plants?
   C. Extent of engineering/management assistance from headquarters

VII. Labor
   A. Prevailing wage rates *
   B. Extent and militancy of unions in the area
   C. Productivity
   D. Availability
   E. Skill levels available

VIII. Site Itself
   A. Area of site -- layout of structures *
   B. Price of site and structures *
   C. Construction/remodeling costs -- insurance *
   D. Condition

IX. Taxes and Financing
   A. State income tax
   B. Local property and income taxes
   C. Unemployment and workman's compensation premiums
   D. Tax incentives/concessions
   E. Industrial/pollution control revenue bonds

X. Transportation
   A. Trucking service
   B. Rail service
   C. Air freight service

XI. Utilities/Services
   A. Availability, quality and price of water, sewerage, electric, and natural gas services
   B. Quality of roads, police, fire, medical, etc. services

Probably the most comprehensive list of siting factors is that contained in the "Checklist of Expansion Planning and Site Selection Factors" from the <u>Site Selection Handbook</u>, which includes more than 1,500 criteria. The major categories from the checklist index are listed below.

COMPANY ORGANIZATION AND PREPARATION FOR EXPANSION PLANNING
I. Corporate Strategy
II. Company Organization Structure
III. Criteria for Site and Facility

LOCATION AND SITE ANALYSIS
I. Market and Demographic Data
II. Work Force, Wages and Productivity
III. Transportation
IV. Energy and Utilities: Electric, Gas, Communications
V. Materials, Supplies, Services
VI. Government Programs: National
VII. Government Programs: State
VIII. Government Programs: Local
IX. Water and Waste Systems
X. Ecological Factors
XI. Quality of Life Factors
XII. Climate
XIII. Specific Sites -- Planning Factors
XIV. Buildings: Office, Warehouse, Industrial
XV. International Projects

DECISION-MAKING
I. Facility Feasibility Analysis
II. Financing
III. Lease Versus Buy

CONSTRUCTION, START-UP, PROPERTY MANAGEMENT
I. Construction and Implementation
II. Property Management

In discussing the development of siting criteria, Johnson identifies two classes: "musts" are absolutely essential criteria for the success of a project and "wants" are desirable but not essential criteria. Criteria fall into the following broad categories: (1) transportation/ logistics; (2) utilities, including (electrical) power supply, natural gas supply, and water supply; (3) labor: supply and relations; (4) site characteristics; (5) environmental permitability and government support; and (6) community factors, such as local support services, community acceptance, development incentives, and quality of life. Johnson also illustrates a qualitative comparison of sites using excellent, good, fair, and poor judgments for each of the criteria.

Levine presents a list of factors ranked by area-development experts and classified as pivotal, vital, important, and secondary.

I. Pivotal
   A. Worker productivity
   B. Receptivity to business and industry
   C. Market access
   D. Skilled/technical/professional workers
   E. Transportation access

II. Vital
   A. Living amenities
   B. Market growth potential
   C. Preference of company executive
   D. Industrial buildings available
   E. Water supply
   F. Unskilled/semi-skilled workers

III. Important
   A. Proximity to services
   B. Energy supplies
   C. Attitude toward business and industry taxes
   D. Energy costs
   E. Raw materials, components, supplies accessibility
   F. Waste-treatment facilities

IV. Secondary
   A. Cost of property and construction
   B. Personal income tax structure
   C. Attitudes on environmental control
   D. Financial health of region
   E. Financial incentives
   F. Proximity to other company facilities

From a study conducted in 1980, Schmenner presents an ordered list of factors which influence site selection. The order is determined by the percent of those opening new plants that cited each factor as "desirable, if available", with the highest percentage listed first. The factors include: (1) favorable labor climate; (2) low land costs; (3) near markets; (4) low taxes; (5) on expressway; (6) rail service; (7) low construction costs; (8) low wage rates; (9) college nearby; (10) low energy costs; (11) government help with roads, sewerage, water, labor training; (12) near suppliers; (13) government financing; (14) available land/buildings; (15) near other division facilities; (16) air transportation; (17) quality of life; and (18) ability to retain labor force. Schmenner also presents a table of major factors that shape plant location searches. The data from this table is combined with Reed's list of ten major factors and the resulting information presented in Appendix I.

Certain factors are common to all lists. These key factors can generally be summarized into the following major categories.

(1) Land: availability, cost, zoning, topography, site preparation requirements.

(2) Utilities: availability, cost, delivery methods, reliability/dependability (interruptibility).

(3) Transportation: types (rail, truck, air, ship), cost, ease of access, service.

(4) Markets: availability of, proximity and accessibility to existing and potential markets for delivery of products and services.

(5) Materials, Supplies and Services: availability of, proximity and accessibility to sources of raw materials and services required to support production, including location with respect to other company facilities.

(6) Labor: type (professional, technical, skilled, semi-skilled, unskilled), availability, wage rates, productivity, union or non-union.

(7) Community Characteristics: quality of life considerations with respect to attracting and keeping the required work force and the potential location's attitude toward the plant.

(8) Government and Legislative: constraints and assistance expected from legal and regulatory standpoints: taxes and incentives.

(9) Environmental and Ecological Considerations: environmental constraints and protection required: air and water pollution.

(10) Financing: availability and cost of short- and long-term capital, return on investment, buy versus lease.

With so many factors to consider, it is difficult to identify just what is a "best" site. Trying to choose between only two sites with different amounts of land, different measures of labor availability and productivity, different tax structures and rates, and varying descriptions of other factors can be extremely difficult, unless one site clearly dominates the other site (is better for at least one factor and equal for all other factors). As more factors and sites are considered, the choice becomes even more complex. A systematic approach to resolving this problem involves the establishment of quantitative measures for all site factors and the incorporation of this information into a composite score or index, which represents the site ratings or rankings.

<u>Site Factor Measures</u>

Once the task of identifying or developing a set of applicable factors is completed, the factors need to be evaluated for a specific site selection project. Measuring or rating the factors requires an assessment of the factors both from the standpoint of what the company needs and what different sites can offer.

Certain types of descriptive data on prospective areas and candidate sites are available from a number of sources. These sources of information can be classified into three main categories: (1) the United States government (as well as the governments of other countries), particularly the Departments of Commerce and Labor, (2) individual states, counties and communities, (3) private and public agencies and companies, such as railroads, airlines, utilities, and banks, and (4) consolidations of site selection data, which may incorporate information from the other major sources. Additional sources and methods of developing required data are shown in Appendix I.

As an example of the types of information available from government sources, the Department of Commerce provides the "Census of the Population" from the Bureau of the Census, "Climatography of the U.S." from the National Climatic Center, and other data for plant location analyses. Other federal sources include the Department of Labor, which provides numerous publications through the Bureau of Labor Statistics, and the Department of the Interior.

As many states, counties and communities jump on the economic development bandwagon, the amount of information available becomes more voluminous and the content more sophisticated. Many states have an agency that specifically deals with economic/business/industrial development and which is designed and staffed to assist companies considering new plant sites. On a smaller scale, regions, counties or communities, frequently through the Chambers of Commerce, also are involved in efforts to attract new industries and jobs.

A third source of information includes the transportation industry, utilities, banks, and other development counselors, such as those available from port districts and foreign trade zones. Many of these organizations have a special department set up to assist in providing information required to help make site location decisions. Publications, such as "The Official Railway Guide" from the National Railway Publication Company and "Electrical World Directory of Electric Utilities" published by McGraw-Hill Book Company, help provide starting points in the data gathering process.

Finally, the consolidated sources of site selection data include the Geo-Life Index from the Site Selection Handbook, information in Plant Location, Places Rated Almanac (Boyer and Savageau, 1985), and Places, U.S.A. (Sperling, 1987). The Places Rated Almanac and Places, U.S.A. use multiple criteria approaches which provide ranked lists of sites. Similarly, the Grant Thorton study identifies the best states for manufacturing, and various other rating studies attempt to identify the "best" locations to live and work.

These references consolidate information from a number of other sources. For example, the Geo-Life Index (which provides information on quality-of-life indicators) incorporates population data from the U.S. Bureau of the Census, health information from the U.S. National Center for Health Statistics and the American Hospital Association, education data from the U.S. Department of Education and the National

Education Association, crime data from the Federal Bureau of Investigation's Uniform Crime Reports, tax and other information from Statistical Abstracts, cost-of-living data from the American Chamber of Commerce, climate information from Conway Publications' Weather Handbook, and unemployment data from the U.S. Bureau of Labor Statistics.

The Places Rated Almanac, published by Rand McNally, is primarily a collection of information of interest to individuals seeking a place to live. It rates, ranks, or describes places according to nine categories of information: climate and terrain, housing, health care and environment, crime, transportation, education, recreation, the arts, and economics. The places included are listed as Metropolitan Statistical Areas (MSA) and Consolidated Metropolitan Statistical Areas (CMSA) as defined by the U.S. Bureau of the Census.

Weather data in the Places Rated Almanac are from the National Oceanic and Atmospheric Administration (NOAA), National Climatic Center and the U.S. Geological Survey; housing information is gathered from the U.S. Bureau of the Census (such as the Census of Housing), the National Association of Realtors and the Federal Energy Regulatory Commission; information on health care and the environment is collected from the National Center for Health

Statistics, the American Dental Association, the Environmental Protection Agency, the U.S. Department of Health and Human Services, the American Hospital Association, the American Heart Association and the American Academy of Allergy; crime data are from the FBI's Uniform Crime Reports, the National Institute for Drug Abuse and the U.S. Department of Justice.

In the Places Rated Almanac, information on transportation is derived from reports from the Federal Aviation Administration, the Civil Aeronautics Board, Amtrak, the U.S. Department of Transportation and various local sources; education data are gathered from the U.S. Bureau of the Census, the National Center for Education Statistics, the U.S. Department of Health and Human Services, the American College Testing Program and the Education Commission of the States; recreation information sources include the U.S Bureau of the Census, the U.S. Department of Commerce, the National Recreation and Parks Association and organizations such as the National Golf Association, the American Association of Zoological Parks and Aquariums, the Thoroughbred Racing Association, Inter-Ski Services and the U.S. Forest Service.

Further sources of information include, for the arts, the National Endowment for the Arts, the American Symphony

Orchestra League, the Central Opera Service, the Public Broadcasting Service, the National Center for Education Statistics and American Library Directory; economic data are collected from the U.S. Bureau of Labor Statistics, U.S. Department of Commerce, U.S. Bureau of the Census and Moody's Investors Service.

Places, U.S.A. appears to be a microcomputer-based software version of the Places Rated Almanac. The program utilizes a self-described "expert system" approach which enables the user to indicate his or her preferences with respect to the site characteristics. Like the Places Rated Almanac, Places, U.S.A. is divided into nine major categories: weather, lack of crime, arts and culture, economics, education, health, housing, leisure activities, and transportation. The program also lists possible locations as defined by the Metropolitan Statistical Areas (MSA) and Consolidated Metropolitan Statistical Areas (CMSA) of the U.S. Bureau of the Census. Although all the sources of the information incorporated into the program's database are not identified, it appears that it uses many of the same sources as the Places Rated Almanac, such as weather data from the National Oceanic and Atmospheric Administration, crime rates from the FBI crime statistics, various publications of the Office of Management and Budget and other governmental agencies, and state and local Chambers of Commerce.

The description of these references gives an indication of the vast amounts of data available from a variety of sources. From such sources, relevant information is collected and used to develop measures for the factors that are important to a specific site selection project. Typically, however, the readily available information that describes candidate sites is not necessarily in a form which can be readily used to evaluate the site selection factors of interest for a particular location project. Thus, the information will have to be modified or adapted before it can be used. In addition, other required information may have to be acquired or developed through direct measurement or evaluation during visits to the candidate sites.

Evaluation of the site factors may involve objective (quantitative) or subjective (qualitative) assessments. Quantitative measures for some of the factors, such as acreage or square feet of existing buildings on a site, are usually easily obtainable. If it is possible to quantify the factors in monetary terms, an economic comparison can be made, based on net present value calculations or other financial indicators. Since some costs are one-time, upfront costs (for example, land and construction costs) while other costs are periodic, on-going expenses (power costs and taxes, for instance), care must be taken to ensure that costs are compared on an equivalent basis. (Johnson, 1986) (Singhvi, 1987) Numerous examples of cost models can be found in the literature. Stafford (1979) presents an analysis of comparative costs and revenues, and a capital budgeting framework model. Conway and Liston (1976) include descriptions of cost analyses performed by a number of different companies to aid in their site selection decisions.

On the other hand, for certain projects, converting all factors to a common monetary base may not be desirable. Bunn (1984) reports on an airport location study in which cost-benefit-driven planners would prefer an alternative which would save more time for rich people than for poor people, affect the poorer area more, and kill more of the older people. Alternative methods of determining measures for nonmonetary factors, both quantitative and qualitative, may be more appropriate.

While some factors may be measured directly, values for other, more subjective factors are not so easily determined. For example, the amount of land required can be measured in acres and tax rates can be expressed as percentages, but it is more difficult to objectively measure such attributes as community pride and an area's cooperative attitude toward new industry. Although direct quantitative measures may not be obtainable, it still may be desirable to assign numerical values to the factors. Measures can be established by using descriptive groups or classes. (Wardrep, 1985) (Schmenner, 1982) As an illustration, Reed (1961) provides descriptions for levels or classes for twenty-one noncost (qualitative) site factors, for which he also makes point assignments. Table 1 shows the descriptive classes (and Reed's assigned points) used to assess community attitude.

Table 1. Sample Descriptive Classes for Community Attitude

Description	Points
Hostile, bitter, noncooperative	0
Parasitic in nature	15
Noncooperative	30
Cooperative	45
Friendly and more than cooperative	60

As shown above, numerical values can be assigned to each descriptive class. Such assignments can be developed through the application of utility theory. (Objective factor measures can also be translated to a similar scale.) The essence of utility theory is to provide a function (utility function) which transforms the payoffs (or measures of the factors) on to a dimensionless utility scale

(Bunn, 1984). Utility theory assumes that an individual is aware of his or her alternatives, and can evaluate and choose among them so that the satisfaction derived from the selected alternative is maximized. In effect, an individual's utility function is a formal, mathematical representation of his or her preference structure. (Goicoechea, et al, 1982)

The assignment of numerical values requires the selection of a utility scale, such as zero to ten or zero to one hundred, for a range of possible values of the factor, where the low value (zero) represents "horrible" or "unsuitable" and the high value (ten or one hundred) reflects "wonderful" or "the best possible". For both subjective and objective factors, the scale should be realistic, which means that some of the sites being considered realistically could be expected to score at the extremes of the range for each factor. However, rather than assigning a value of zero to the worst site and a value of one hundred (for example) to the best site for a given factor, it is preferable to attempt to assess realistic boundaries on each relevant factor, without specific reference to the actual alternatives available. Such a procedure allows the evaluation scheme to remain the same as the alternative set changes, which is obviously necessary if all the alternative sites have not been completely identified when the measurement scheme is designed. (Edwards and Newman, 1982)

For subjective factors, the descriptive classes are assigned values along the selected utility scale, following two guidelines. First, the classes are intended to differentiate one alternative from another, so the descriptions should represent significant, identifiable differences. Second, the assignments of values, particularly the minimum and maximum, should reflect the actual evaluation in process, rather than the factor in general. (Edwards and Newman, 1982) Classification schemes such as Reed's (1961) may be useful in helping to develop factor descriptions, but the assignment of "points" should be project-specific.

For objective factors, the actual measures can be transformed on to the same scale. All factor measures must be on a common scale for the assessment of weights to be meaningful. Utility functions, which can take any form, are developed and the measurements for alternatives are then converted to the utility scale. These functions are often assumed to be linear for ease of calculation. (Edwards and Newman (1982) argue that the use of linearity is well justified, since curved functions seldom make any difference to the decision.) Three situations exist for transforming actual measures to a dimensionless scale:

(1) more is preferable to less (continuously increasing linear function), (2) less is preferable to more (continuously decreasing linear function), and (3) an intermediate measure is preferable to either extreme (bilinear function). Equations for each of these cases are given below, using a zero to one hundred scale for illustration purposes. These equations are adapted from Edwards and Newman (1982).

When more is preferable to less, as could be the case for a preference for a large site, then the size of a particular site could be translated using the following equation:

$$V_A = 100 * (M_A - M_{min})/(M_{max} - M_{min}) \qquad [1]$$

where V_A is the value assigned on the utility scale, M_A represents the actual measure for the site, M_{min} is the minimum plausible measure, corresponding to zero on the utility scale, and M_{max} is the maximum plausible measure, corresponding to one hundred. For example, the value of a site measuring 280 acres would be

$$100 * (280 - 150)/(300 - 150) = 87$$

where 150 acres is the minimum feasible size and 300 is the maximum feasible size. Figure 3 presents the same solution in graphical form.

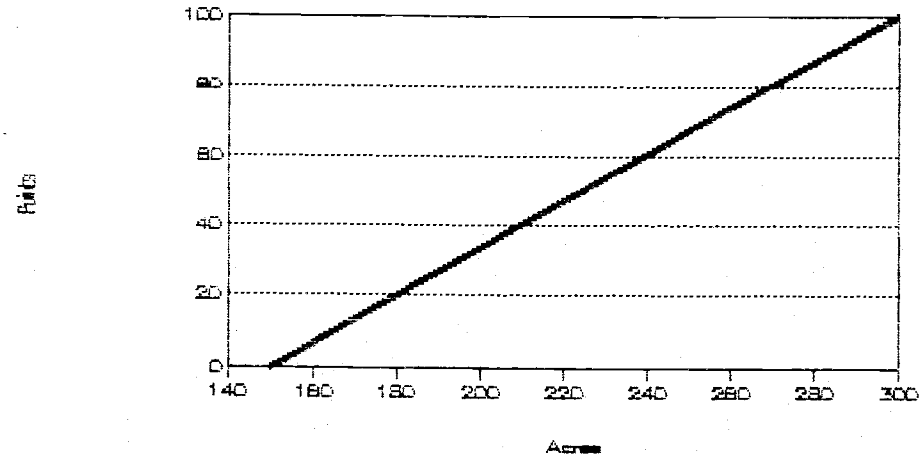

Figure 3. Linear Utility Function: More is Preferred

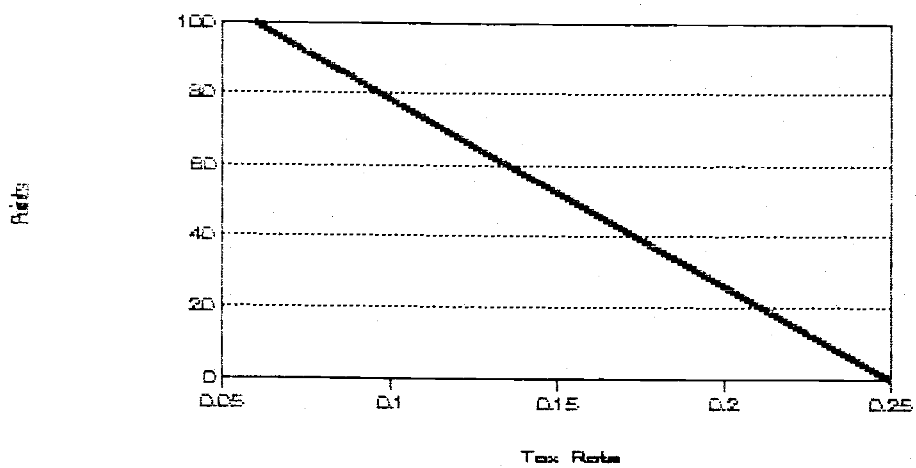

Figure 4. Linear Utility Function: Less is Preferred

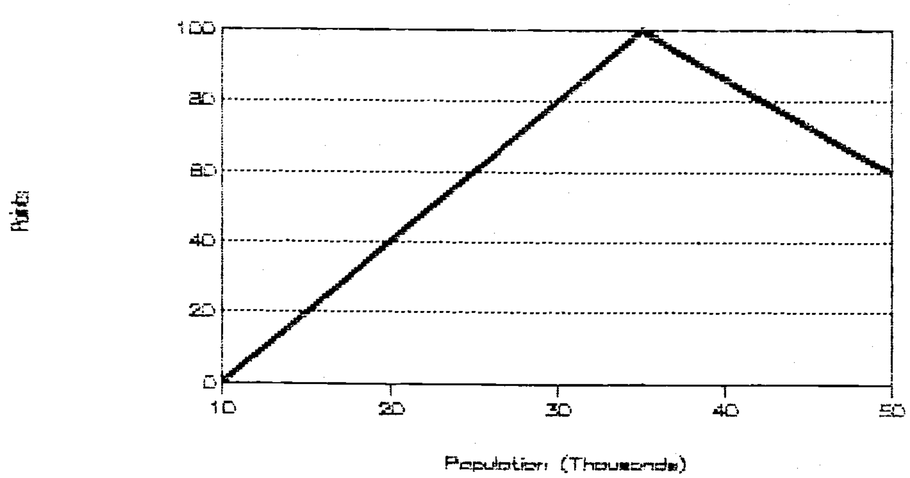

Figure 5. Bilinear Utility Function: Intermediate is Preferred

When less is preferable to more, such as with tax rates, then the value for an actual site is calculated by:

$$V_A = 100 * (M_{max} - M_A)/(M_{max} - M_{min}) \quad [2]$$

where V_A is the value assigned on the utility scale, M_A is again the actual measure for a particular site, M_{min} is the minimum plausible measure, in this case corresponding to one hundred, and M_{max} is the maximum plausible measure, corresponding to zero. For example, a site with a tax rate of 12 percent would have a value of

$$100 * (25\% - 12\%)/(25\% - 6\%) = 68$$

where the plausible tax rates range from 6 to 25 percent. This can be seen graphically in Figure 4.

More complicated calculations are required when an intermediate measure is preferred. Such functions can be approximated by two lines rather than one. One line will run from zero at either the minimum or maximum value to one hundred at the optimal (intermediate) value. The other line ordinarily will not descend from the optimal value all the way back to zero. Two possibilities exist: (a) the upper branch of the bilinear function does not hit zero, or (b) the lower branch does not descend to zero. In the first case, the value for an actual site is calculated by:

$$V_A = V_{max} + (100 - V_{max}) * (M_{max} - M_A)/(M_{max} - M_i) \quad [3]$$

where V_A is the value assigned on the utility scale, M_A represents the actual measure for a particular site, M_i is the optimal (intermediate value), corresponding to the peak, and M_{max} is the maximum plausible measure, corresponding to V_{max}. For example, if plausible area population measures range from 10,000 to 50,000 with a preferred value of 35,000, then the value for an area with a population of 42,000 would be

$$60 + (100 - 60) * (50{,}000 - 42{,}000)/(50{,}000 - 35{,}000) = 81$$

when V_{max} is assigned the value of 60. Figure 5 displays this bilinear function. Similarly, for the second case described above, the equation would be:

$$V_A = V_{min} + (100 - V_{min}) * (M_A - M_{min})/(M_i - M_{min}) \quad [4]$$

where V_A is the value assigned on the utility scale, M_A represents the actual measure for a particular site, M_i is the optimal (intermediate value), corresponding to the peak, and M_{min} is the minimum plausible measure, corresponding to V_{min}.

If the minimum and maximum plausible or feasible measures are chosen carefully, the actual measures should, in most cases, fall within the range. It is possible, however, to encounter a measure that is outside its particular range. There are two solutions to this problem: (1) treat the measure as though it fell at the range boundary and assign it the maximum or minimum value, as appropriate, or (2) use a number less than the minimum or more than the maximum, as calculated. The decision depends of whether the difference between the boundary value and the calculated value is expected to make any meaningful difference to the attractiveness of the alternative. (Edwards and Newman, 1962)

Other methods could also be used to assign numerical values to represent the evaluation of a site for a particular factor. One quite simple method used for both quantitative and qualitative factors involves the assignment of a relative rank to each site for each factor. For example, if five sites were under consideration, then each factor would have the sites ranked from 1 (worst) to 5 (best). The site with the lowest cost would receive the highest rank and the highest cost would be ranked the lowest with appropriate ranks given for the intermediate values of the costs. Similar rankings would be assigned for each factor. While this method is quite simple to apply, one obvious disadvantage is that the identification of an additional site could require reassignment of the ranks for each factor. Another disadvantage is the linear proportionality of the ranking scale (sites are ranked equal distances apart). Thus, it is not possible to represent the situation where two sites are very similar to each other but quite different from other sites.

Whatever method is used, it is important to maintain consistency among the ratings used for different factors, which would be assured using the formulas given. Desirable characteristics (high or low) should always be rated at the same end of the scale of values. For example, low costs would generally be very desirable as would a high level of community support. Either maximum or minimum scores could be used as long as they were used consistently.

Whether objective measures are possible or subjective assessments are required, the evaluation of a factor may be certain or uncertain. If there is no uncertainty surrounding the measurements, then deterministic calculations can be made. If, however, values for the factors cannot be known with certainty, then probabilistic calculations will be required. Some range of probable values is specified by defining a probability distribution. For example, a triangular distribution could be defined by specifying minimum, mode and maximum values. Similarly, a normal approximation could be used to provide values in a distribution with a specified mean and standard deviation. In order to accommodate uncertainty in a decision model, simulation can be used to determine expected values for the factors.

Site Factor Weights

In addition to identifying the applicable site factors and establishing measurement scales, a relative importance weight must be developed for each factor. In the simplest case, all factors are considered to be equally important; thus, all weights have the same value.

Weights are usually developed by an organization specifically for a particular project. Typically, decision makers within the organization identify those factors which they believe will have the most impact on the facility to be sited. Although a single decision maker may have the responsibility for assigning importance weights, for most large projects, input will be obtained from a number of stakeholders: those who have an interest or stake in the decision. In some cases, people outside the organization may also be stakeholders. The public's concern with the location of nuclear power plants is a good example.

The relative importance of the factors varies depending on the firm itself, the type of industry, the kind of facility, the magnitude of the investment required, and the level of analysis. While the same basic factors may apply in each case, they can vary widely in their relative importance and their potential impact on the decision. (Schmenner, 1982)

Different types of industries will view the factors as having varying amounts of importance. For example, the availability of a large, semi-skilled labor force would be more important to a labor-intensive industry than to a research and development laboratory, which might be much more concerned about the quality and availability of institutions of higher education as a source of scientists and engineers. While this proximity to a university may be important for a research and development laboratory, transportation costs may be a more critical consideration for the location of a finished goods warehouse. The producer of heavy equipment would be expected to be much more concerned with transportation availability and costs than a software design firm, which could utilize mail services to ship its lightweight products. A food processing company would likely have different factor priorities than an electronics firm.

Just as factors will have different importance weights for different industries, at different levels or stages of the process of selecting a site, the factors that are important to consider may also vary. Although the same general list of factors may apply, the factors will have different importance weights, with some being inconsequential at a particular level (and therefore, effectively receiving zero weight). As a firm moves through the site selection process, the relative importance of the factors and the level of detail required to describe and evaluate them will change.

With so many diverse and shifting factors to consider, determining which are the most important can be a complex process. The literature on site selection includes studies that have been conducted to attempt to identify the most important factors and to compare the relative importance of different factors for different types of industries and facilities.

Goldstein (1985) reported on an Industry Week survey of 1,000 executives who were asked to rate site selection factors. Table 2 presents the list of factors which were rated as "vitally important" by this group, along with the percentages of this response that each factor received.

Levine (1986) classified factors as pivotal, vital, important, and secondary. His list of factors with their classification was given earlier in the Site Factors section. Also presented in that section was Schmenner's priority list of factors. Schmenner provided additional information with the inclusion of percentages indicating that a particular factor was "desirable, if available".

Table 2. Vitally Important Site Selection Factors

Factor	Percentage
Geographical location	64
High worker productivity	59
Land transportation	54
Low union profile	49
Stable state government	38
Skilled-labor availability	32
Long-term financing	32
Energy/energy sources	30
Raw-materials availability	28
Tax exemptions	27
Tax credits	26
Unskilled-labor availability	22
Air transportation	21
Ample fresh water	17
Rail transportation	16
Worker-training programs	10
Sea transportation	5

His study presented these data for two groups: new plants (159 respondents) and relocated plants (36 respondents). Table 3 displays his findings and indicates the importance ranking, in parentheses, where (1) = most frequently cited (most important). Schmenner further classified the information on new plants by type of industry and provided percentages of "desirable" ratings for the top thirteen factors. These are shown in Table 4, which also shows the relative importance ranking for each industry.

As can be seen, the first factor listed, a favorable labor climate, was the first or second most important factor for all industry groups. The last factor,

Table 3. Desirable Factors for Site Selection

Factor	New Plants	Relocations
Favorable labor climate	74 (1)	44 (2)
Low land costs	60 (2)	50 (1)
Near markets	42 (3)	22 (7)
Low taxes	35 (4)	19 (9)
On expressway	35 (5)	28 (4)
Rail service	30 (6)	22 (8)
Low construction costs	29 (7)	33 (3)
Low wage rates	28 (8)	25 (5)
College nearby	26 (9)	14 (10)
Low energy costs	25 (10)	14 (11)
Government help with roads, sewerage, water, labor training	25 (11)	3 (14)
Near suppliers	23 (12)	25 (6)
Government financing	13 (13)	6 (13)
Available land/buildings	3 (14)	11 (12)
Near other division facilities	3 (15)	3 (15)
Air transportation	1 (16)	0 (17)
Quality of life	1 (17)	0 (18)
Retain labor force	0 (18)	3 (16)

government financing, was relatively unimportant for all groups. However, other factors ranked quite differently depending on the type of industry. For example, having a college nearby was quite important (ranked second) for high technology industries but much less important for the others (ranked from ninth to twelfth). While the high tech industries considered rail service to be quite unimportant (ranked thirteenth), forest-tied industries ranked it first, heavy metals ranked it second (tied for first), and specialty chemicals and metals ranked it third most important. Other interesting comparisons can be found by examining Table 4.

Table 4. Desirable Factors for Site Selection by Type of Industry

INDUSTRY GROUP

FACTOR	Agriculture Tied	Market Sensitive	Forest Tied	Labor Cost Sensitive	Heavy Chemicals/ Oils/Rubber /Glass	Specialty Chemicals/ Metals	Heavy Metals	Industrial Machinery/ Transport Equipment	High Technology
Favorable labor climate	100.0 (1)	65.0 (1)	62.5 (2)	81.8 (1)	64.3 (1)	85.7 (1)	100.0 (1)	61.9 (2)	79.3 (1)
Low land costs	66.7 (2)	55.0 (3)	50.0 (4)	81.8 (2)	57.1 (3)	42.9 (5)	75.0 (3)	66.7 (1)	41.4 (3)
Near markets	55.6 (3)	60.0 (2)	62.5 (3)	36.4 (5)	64.3 (2)	42.9 (6)	50.0 (5)	28.6 (7)	3.4 (12)
Low taxes	11.1 (10)	35.0 (6)	25.0 (6)	45.5 (4)	28.6 (6)	71.4 (2)	25.0 (7)	35.7 (4)	31.0 (5)
On expressway	11.1 (11)	42.5 (5)	25.0 (7)	36.4 (6)	28.6 (7)	42.9 (7)	50.0 (6)	38.1 (3)	17.2 (8)
Rail service	44.4 (4)	45.0 (4)	75.0 (1)	27.3 (8)	50.0 (4)	57.1 (3)	100.0 (2)	9.5 (12)	0 (13)
Low construction costs	33.3 (5)	17.5 (9)	12.5 (8)	54.5 (3)	28.6 (8)	28.6 (9)	0 (11)	31.0 (5)	27.6 (6)
Low wage rates	22.2 (6)	25.0 (8)	0 (11)	36.4 (7)	14.3 (11)	42.9 (8)	25.0 (8)	26.2 (8)	41.4 (4)
College nearby	11.1 (12)	15.0 (11)	0 (12)	27.3 (9)	21.4 (10)	14.3 (12)	25.0 (9)	26.2 (9)	51.7 (2)
Low energy costs	22.2 (7)	17.5 (10)	12.5 (9)	18.2 (11)	28.6 (9)	57.1 (4)	75.0 (4)	23.8 (10)	20.7 (7)
Government help with roads, sewerage, water	22.2 (8)	32.5 (7)	0 (13)	9.1 (12)	14.3 (12)	28.6 (10)	0 (12)	31.0 (6)	13.8 (9)
Near suppliers	22.2 (9)	15.0 (12)	50.0 (5)	27.3 (10)	50.0 (5)	28.6 (11)	25.0 (10)	16.7 (11)	10.3 (10)
Government financing	0 (13)	15.0 (13)	12.5 (10)	0 (13)	0 (13)	14.3 (13)	0 (13)	11.9 (12)	10.3 (11)
Number of Plants in Group	9	40	8	11	14	7	4	42	29

Percentage (and ranking) of site selection factors perceived as "Desirable, if available"

Browning (1980) identified fourteen major relocation factors and determined their importance by type of facility. Table 5 gives both the rank of the factor and a percentage rate which represents a weighted response. The weighted response was calculated by assigning percentages to the four-point scale used to rate the factors. A "critical rating" (1) by a respondent received 100 percent, a "very important" rating (2) received 75 percent, a "somewhat important" rating (3) received 25 percent, and a "slight" or "of no importance" rating (4) received zero percent. If all respondents rated an item as very important (2), then it would have a 75 percent weighted response. Browning's data was from a 1977 survey conducted by the Market Research Department of the Wall Street Journal, which incorporated responses from 1,200 questionnaires.

Interesting comparisons can also be derived from an examination of the information in Table 5. For example, while manufacturing plants considered the availability of (general) labor to be the most important factor, research and development facilities were most concerned with the specific availability of executive and professional talent. Although corporate headquarters, regional and divisional offices, and R&D facilities ranked air transportation either first or second in importance, it ranked next to last for manufacturing plants, which in turn ranked rail transportation higher (sixth compared to twelfth, thirteenth and fourteenth for the "white-collar" facilities).

Table 5. Factor Importance by Type of Facility

FACTOR	All Company Facilities Rank	All Company Facilities %	Manfg. Plant Rank	Manfg. Plant %	Distrib. Center Rank	Distrib. Center %	Reg./Div. Office Rank	Reg./Div. Office %	R&D Facility Rank	R&D Facility %	Corporate HQ Rank	Corporate HQ %
Availability of labor	1	93	1	79	4	43	6	31	4	18	5	18
Tax abatements/incentives	12	56	10	49	9	33	9	20	8	13	6	17
Transportation facilities												
Air	7	64	13	41	7	34	1	38	2	20	1	26
Highway	3	90	3	75	1	60	2	37	3	19	2	24
Rail	6	66	6	59	6	43	13	14	14	8	12	10
Water	14	39	14	34	14	23	14	13	13	8	13	9
Raw materials availability	8	63	5	61	13	23	12	14	12	11	14	8
Accessibility to markets												
Established	4	85	4	65	2	58	4	33	10	11	10	13
New	5	77	7	55	3	53	5	31	11	11	11	12
Availability of financing	13	51	12	46	11	31	10	20	9	13	7	16
Large land area	9	63	9	53	10	32	11	18	6	13	8	14
"Right to work" laws	11	58	8	54	8	34	8	20	7	13	9	14
Availability of executive/ professional talent	10	62	11	46	12	29	3	34	1	22	3	22
Energy/fuel availability	2	91	2	78	5	43	7	29	5	18	4	20

Weighted Response: On a four-point scale, a critical rating (1) received 100%, a very important rating (2) received 75%, a somewhat important rating (3) received 25%, and a slight or of no importance rating received 0%.

Seldom are all factors considered to be equally important. (If they are, the weight for each factor would be equal to the reciprocal of the number of factors.) The purpose of weights is to express the importance of each factor relative to all others. Weights capture the essence of value judgments and represent the relative preferences of different stakeholders -- their particular preference structures. Weights, therefore, can be expected to vary from stakeholder to stakeholder.

There are numerous methods for developing weights. Several of these will be described in this section. They include (1) ranking, both rank sum and rank reciprocal, (2) rating and relative point assignments, (3) paired comparisons, partial and complete, (4) ratio, and (5) simplified rank scaling. Generally, knowledge about the ranges (maximums and minimums) of the measures of the factors to be weighted is required in order to assess the weights, although knowledge of the actual measures or values for candidate sites should not be given as it may bias the evaluator. (Edwards and Newman, 1982) (Battelle, 1975)

Ranking. In ranking the importance of factors, the evaluator simply assigns a numerical rank to each factor, using a "1" to indicate the most important factor, a "2" to indicate the next most important and so on through to the least important factor, which is ranked "m" where m is the total number of factors. Weights can then be calculated using either the rank sum or the rank reciprocal method.

With the rank sum method, the weights for the factors are calculated by first converting the ranks assigned to their reverse ranks. For example, the most important factor, assigned rank (1), will have reverse rank "m". Then the reverse rank for each factor is divided by the sum of the reverse ranks for all factors. This division normalizes the weights so that they sum to unity. (Eckenrode, 1965) Symbolically:

$$w_j = R_j / \sum_j R_j \qquad [5]$$

where w_j = weight for factor j, for j = 1 to m

R_j = reverse rank for factor j
= m + 1 - (assigned rank for factor j)

m = number of factors

The rank reciprocal method is similar except that the assigned ranks are first converted to their reciprocals (1/assigned rank). The reciprocals are then used to calculate normalized weights as in the rank sum method. (Edwards and Newman, 1982)

For either of these methods, ties in importance ranking are assigned the average rank. For example, if after identifying the second most important factor, the next two factors are felt to be equally important, then they would both receive the rank of 3.5 (the average of ranks 3 and 4). Use of the rank sum method typically results in weights which are "flatter" than those derived using the rank reciprocal method. A numerical example is provided in Table 6.

Table 6. Weights Calculated Using Ranking Methods

Assigned Rank	Rank Sum Weight	Rank Reciprocal	Rank Reciprocal Weight
1	0.286	1.00	0.410
2	0.238	0.50	0.205
3	0.190	0.33	0.135
4.5	0.119	0.22	0.090
4.5	0.119	0.22	0.090
6	0.048	0.17	0.070
-----	-----	----	-----
21	1.000	2.44	1.000

<u>Rating</u>. The rating method assigns to each factor an assessment of its importance along a continuous scale. For example, a scale from zero to ten could be used with ten representing the maximum value (greatest importance) and zero indicating no value (not important or not applicable). The evaluator may select points between numbers and assign more than one factor to the same numerical value, if they are equal in importance. (Eckenrode, 1965) (Moore, 1969)

(West, 1977) Figure 6 shows an example format that could be used to assign ratings, where the evaluator draws a line from each factor to the appropriate point on the scale. The assigned ratings can be normalized to sum to unity.

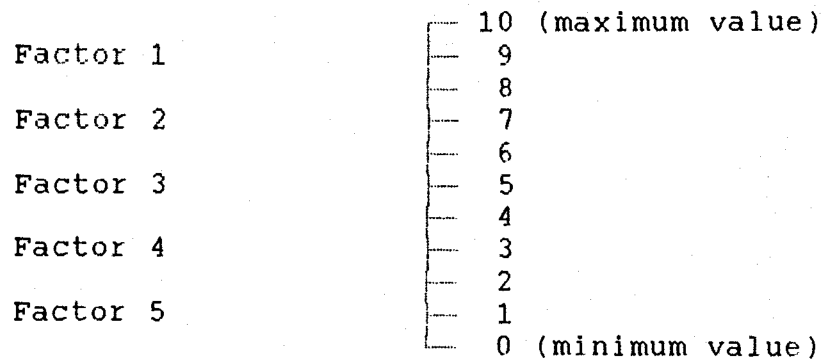

Figure 6. Factor Rating Form

Rating scales can create problems in interpretation. The use of a numerical scale implies a ratio scale, with a true zero. Thus, a factor given a rating of 4 would be twice as important as a factor rated 2. A factor rated 9 would be three times as important as a factor given a rating of 3. If these mental comparison are made during the rating, then reasonable weights will result from the ratings. Unfortunately, however, the evaluator doing the rating often treats the scale as an ordinal scale and, therefore, really only orders the factors to positions on the scale relative to the other factors.

A variation of rating is accomplished by assigning a number of points to each factor to represent its relative importance. To illustrate, Conway and Liston (1976) describe the weighted criteria approach used by the Gates Rubber Company's Site Selection Group. This method utilizes a total of 10,000 points, which are distributed on the basis of the perceived relative importance of the factors. The first distribution is made for major factor categories. The points assigned to each major category are then distributed to the next level of factors and so on until points have been assigned to each factor for which a measurable value will be collected for each site under consideration. Figure 7 presents a portion of the point assignment scheme, showing the distribution of 25 percent of the total 10,000 points to the Labor factor.

LABOR (25% of total)	2500 pts.
A. Climate (50% of 25%) Strike History, Community Involvement, Union Domination	1250 pts.
B. Rates and Benefits (40% of 25%)	1000 pts.
C. Availability (5% of 25%)	125 pts.
D. Maturity (3% of 25%) Absenteeism, Turnover, Management Potential	75 pts.
E. Unemployment (2% of 25%)	50 pts.

Figure 7. Point Assignment Scheme

Paired Comparisons. Paired comparisons of the factors provide another method to determine weights. Using this method, each factor is paired with every other factor and the more important of the two factors is indicated. Partial paired comparisons evaluate each pair of factors only once while complete paired comparisons evaluate each pair twice, reversing the listed order of the factors. Complete paired comparisons thus provide consistency checks to eliminate any position bias. (Eckenrode, 1965)

The pairs for comparison can be presented in list or matrix format. Using the list format, each pair is presented as:

Factor 1 versus Factor 2

Factor 1 versus Factor 3

etc.

and the evaluator is asked to indicate the more important factor by circling or otherwise indicating it. The matrix format arrays the factors in rows and columns as shown in Figure 8.

Preferences can be indicated by (a) recording a "1" in the cell if the column factor is preferred to the row factor and a "0" otherwise or (b) recording the number of the factor that is preferred. For partial paired comparisons, only the top half of the matrix is filled in, while completed paired comparisons use the entire matrix. Paired comparisons should be checked for consistency of rankings (circularity). For example, if Factor 1 is considered more important than Factor 2 and Factor 2 is more important than Factor 3, then Factor 1 should be more important than Factor 3.

Factor	1	2	3	4	5	6
1	0					
2		0				
3			0			
4				0		
5					0	
6						0

Figure 8. Paired Comparisons Matrix

Weights are then developed from the sums of the number of "more important" ratings given to each factor. Weights may be normalized to sum to unity. An example is shown in Figure 9, using a partial matrix and indicating the preferred factor by listing its number in the cell.

Factor	1	2	3	4	5	6	"More Important" Ratings	Weights
1	0	1	3	1	1	6	3	0.200
2		0	3	2	2	6	2	0.133
3			0	3	3	6	4	0.267
4				0	5	6	0	0.000
5					0	6	1	0.067
6						0	5	0.333

Figure 9. Sample Paired Comparisons Weight Calculations

A weakness of weights developed from paired comparisons is obvious from the example. The weights developed are multiples of the same value and are spaced at even intervals. The results in Figure 9 imply that Factor 6 is five times as important as Factor 5, when in fact the perceived weight could be considerably different from that.

<u>Ratio</u>. The ratio method begins by ranking the factors in order of importance. The least important factor is assigned a value of ten (for example). The evaluator then assigns a numerical value to the next least important to reflect how much more important that factor is relative to the least important factor. For example, if a value of 20 is assigned, it indicated that that factor is twice as important as the least important. The evaluator continues

up the list assigning values in a similar fashion. A factor that receives a value of 40 is considered four times as important as the least important factor and twice as important as a factor that receives a value of 20. Ties are permitted if two or more factors are considered to be equal in importance. These weights can also be normalized. An example is given in Table 7. Consistency checks for the ratio method can be made by using the triangular table procedure, as described by Edwards and Newman (1982).

Table 7. Ratio Method

	Rank	Value Assigned	Weight
Factor 1	3	45	0.180
Factor 2	4	30	0.120
Factor 3	2	60	0.240
Factor 4	6	10	0.040
Factor 5	5	15	0.060
Factor 6	1	90	0.360

Simplified Rank Scaling. Another method applicable to the development of factor weights is the Simplified Rank Method of Scaling, developed by Dunn-Rankin and King (1969), and primarily designed for use in assessing the differences between stimuli for psychological tests. This method, which specifically requires a number of evaluators, starts with an ordering of the factors using ranking or paired comparisons. Rank totals for all the evaluators are determined and the minimum and maximum possible rank totals are determined. The rank totals are then transformed on to an appropriately selected scale, such as zero to one hundred. Significance tests can be performed to determine the potential for discrimination among the factors. Despite its name, it requires more detailed calculations that the other methods presented here.

Descriptions of various other weighting methodologies, including combinations and modifications of the methods described above, can be found in the literature. Brown and Gibson (1971) utilized a paired comparisons method of calculating weights in their geometric-weighted site selection model, which is presented in the next section. Hicks and Kumtha (1971) developed a methodology which asserts that the correct weight of a plant location factor, tangible or intangible, is directly related to the likely variability of its cost effect compared to the relative variability of all other factors. The weights are calculated as:

$$w_j = \sigma_j / \sum_j \sigma_j$$

[6]

where w_j = weight for factor j, for j = 1 to m

σ_j = standard deviation in equivalent annual cost effect for all locations for factor j

m = number of factors

Studies comparing the results of using various weighting methods, such as those described above, have been performed and have generally found that the results are quite consistent. Eckenrode (1965) based his conclusions of the use of Kendall's Coefficient of Concordance, which is used to measure consistency among sets of weights produced using various methods, as well as consistency among evaluators in assessing a set of factors and consistency within each evaluator using each of the various methods. Kendall's Coefficient of Concordance is a nonparametric statistic which tests for differences in order, but not differences in the magnitude of intervals between factor weights. Dunn-Rankin and King (1969) compared methods using absolute differences and correlation coefficients.

The nature of most site selection problems will require input from a number of stakeholders in assessing the relative importance of the site factors. Such group participation in the decision process can be accommodated by considering the responses of a number of evaluators. Weights determined by management preferences must have the support of the users of the facility. Any of the methods of developing weights described above could be used to develop individual sets of weights for the various evaluators.

While the responses from a number of evaluators could be consolidated into a single set of weights (with accompanying variances), it may be preferable to use separate sets of weights to perform the site evaluations, particularly if there is much variability in the weights. (The calculated averages could be used as another set of weights.) A modification of the Delphi technique[10] could also be used to arrive at a final set of importance weights for the site factors, if circumstances warrant.

The amount of variability in the weights assigned might be partly a function of the differences in evaluators. For example, if all the evaluators were from within a company and had very similar backgrounds and goals, then variability in the weights should be reduced. However, if some of the evaluators had different goals, such as might occur when the public is involved in a controversial type of project, then less agreement on the important factors would be likely. Weight discrimination analyses, using variances, could be conducted to determine if the variability among weights for the same factor from different evaluators (within-factor variability) is greater than the differences between weights for different factors (between-factor variability). Highly variable weights can obscure the factor differences between sites so that a preference cannot be clearly identified. Then additional efforts must be made to reach a consensus on weights or to identify and evaluate factors that differ sufficiently to discriminate among the sites.

Site Evaluation (Ratings or Rankings)

Candidate sites are evaluated by determining a site rating or ranking for each alternative using the factor measures and weights developed for the specific project. An overall or total "score" for each site is calculated by combining these measures and weights according to some method. The scores have no absolute meaning but rather serve as relative figures of merit, comparing one site to another with respect to multiple objectives. When high values are used to reflect desirable characteristics, then the higher the total score, the "better" the alternative. The recommended decision would be to select the site with the highest total score.

One type of site evaluation method, as described by Moore (1969), is factor analysis. The factor analysis technique uses a ranking procedure with the pertinent factors weighted according to their importance. The factor considered the most important is given a weight of one, while less important factors are weighted based on their relative importance compared to the most important factor. A factor felt to be only one-third as important would receive a weight of three. Factors with equivalent importance would receive equal weights.

Rather than utilizing measurement or descriptive scales for the factors, in this method, the factors are ranked relative to each other for each site under consideration. Taking one factor at a time, each alternative site is ranked, with numerical rankings given from "1" for the most favorable alternative to "N" for the least favorable, where N is the number of alternatives being evaluated. The ranking for each factor for each alternative is multiplied by the factor weight. The weighted ranks are totaled for each alternative, and the alternative with the smallest total is considered to be the preferred alternative.

Numerous applications of the factor analysis technique and modifications to the basic technique are described in the literature, including Reed (1961 and 1967), Hicks (1971), Stafford (1979), Tompkins and White (1984), and Johnson (1986). A recent application of a detailed factor analysis was developed by Bernier and Long (1987) to perform operations assessments of factories.

Possibly the most commonly used method of calculating total scores is the additive-weighted technique. Weighted values for each factor are calculated by multiplying the factor value by the factor weight. The additive-weighted model then simply adds up the weighted values. The site rating (SR_i) for site i (i = 1 to n) is calculated as:

$$SR_i = \sum_j w_j a_{ij} \qquad [7]$$

where w_j = weight for factor j, for j = 1 to m

a_{ij} = value of factor (attribute) j for site i

m = number of factors

If the weights, w_j, have been normalized to sum to unity, then the site ratings, SR_i, represent weighted averages and are comparable on the same scale as the factor measures.

Other weighted-factor methods may involve multiplicative or geometric calculations. For example, a procedure developed by Brown and Gibson (1971) involves a scoring method based on geometric averages. The general model is based on a combination of critical factors, objective factors and subjective factors. For each site i, a location measure (or site rating) LM_i is calculated as shown below.

$$LM_i = CFM_i * [X * OFM_i + (1 - X) * SFM_i] \qquad [8]$$

where CFM_i = critical factor measure for site i (CFM_i = 0 or 1),

OFM_i = objective factor measure for site i ($0 \leq OFM_i \leq 1$ and $\sum_i OFM_i = 1$),

SFM_i = subjective factor measure for site i

($0 \leq SFM_i \leq 1$ and $\sum_i SFM_i = 1$), and

X = objective factor decision weight

($0 \leq X \leq 1$).

The critical factor measure is the product of the critical factor indices for site i with respect to critical factor j. The critical factor index for each site is either one or zero depending on whether the site meets the minimum requirement for the critical factor. If any critical factor index is zero, then CFM_i and LM_i are zero, thus indicating that the site should be excluded from further consideration.

The OFM_i and SFM_i are calculated for each site by evaluating the appropriate factors and converting to normalized measures. The objective factor measure for site i is defined as:

$$OFM_i = [OFC_i * \sum_i (1/OFC_i)]^{-1} \quad [9]$$

where OFC_i = total objective factor cost for site i.

The subjective factor measure for site i is defined as:

$$SFM_i = \sum_k (SFW_k * SW_{ik}) \quad [10]$$

where SFW_k = weight for subjective factor k relative to all subjective factors and

SW_{ik} = weight of site i relative to all potential sites for subjective factor k.

A few more words should be said regarding the treatment of costs. The Brown and Gibson model and the Gates Rubber Company example described by Conway and Liston (1976), as well as others, specifically incorporate cost considerations into the multi-criteria model. Others (Edwards and Newman, 1982) (West, et al, 1986) handle costs separately from the nonmonetary factors and utilize both the cost figures and the weighted scores to select the preferred site alternative.

Sensitivity Analysis

In almost any decision environment, at least some of the parameter values are based on the best guess of experienced personnel or on estimates derived from limited analyses of minimal data. It is, therefore, extremely important to determine the degree of sensitivity of the results to the values used.

Sensitivity analysis consists of varying some of the values over a range of interest and observing the effect upon the final ranking or ordering of alternatives. If the final ordering of alternatives changes greatly with slight variations in some of these values, this may provide the motivation and justification for the expenditure of more time and money to obtain more accurate estimates. On the other hand, if the results do not change over wide fluctuations in the values, no further effort is really needed or justified, and the results will help reassure the decision maker of the thoroughness of the study and the validity of the results.

In the multi-criteria site selection problem, the parameters which could be varied in a sensitivity analysis are the individual factor measurement values and the factor weights. Factor measures are determined from either objective measurements, such as acres of land or distances, or subjective assessments of how a site rates with respect to a set of descriptive classes. These measures may represent point estimates or probability distributions, or may be subjective evaluations reflecting the judgment of experts. Hence, the measures may not be known with complete precision. Also uncertain may be the components of the utility functions that are used to assign dimensionless values to the measures: the maximum and minimum plausible values and the shape of the function.

A full sensitivity analysis of factor measures requires a complete solution of the decision problem for different values of each factor. With a large number of factors, this may involve quite a few iterations, and the results may not be easy to interpret. In actual practice, the extent of the analysis can be reduced by concentrating on key factors. Those factor values which involve a high degree of uncertainty and subjectivity in estimation should be varied to investigate the effect of their variation on the ranking of alternatives. Also, values associated with factors with high importance weights are likely candidates for sensitivity analysis. Since the weights of the associated factors are high, even slight changes in the values may result in a change in the ranking of alternatives. Site selection projects have frequently tended to emphasize changes to factor values, rather than importance weights, in checking for sensitivities.

Probably more important, however, is the sensitivity to weights. Since weights are entirely subjective numbers, developed from the value judgments of stakeholders who may disagree, they are more likely to be in dispute than factor measures (Edwards and Newman, 1982). Hence, the defensibility of the decision may depend on a thorough analysis of the weights.

A sensitivity analysis involving weights consists of investigating the sensitivity of the rankings or orderings of the alternatives to changes in factor weights. If the rankings remain the same as the weights are changed by small amounts, then small errors in the estimation of the factors weights will not be critical. If the choice is sensitive to one or more of the weights, the analysis will indicate the effects of the weights by the instability in the ranking of alternatives. Typically, for a given alternative, the larger the range of variation in the factor measures, the greater will be its sensitivity to weights.

Strengths and Weaknesses of Multi-Criteria Site Selection Models

The weighted-factor, multi-criteria approach to site selection, as described here, entails gathering the necessary data, structuring the model, and identifying the needs of the firm for a specific location project, which typically requires a large amount of time and other resources. All inputs, subjective as well as objective, must be assigned numerical values in order to use the evaluation models. The efforts expended are valuable in clarifying the needs of the firm and in identifying the key factors that affect the decision.

One major advantage of such site evaluation methodologies is that they enable the comparison of sites on the basis of a single composite "score", which represents each site. However, this same advantage provides a corresponding disadvantage. By relying on a single value, detail about the site is lost. If two or more sites score close together, a single value does not provide a view of where the differences occur.

Furthermore, the results of the analysis are often not fully explained. Choosing the highest rated or ranked site may be appropriate only if there is a significant difference between it and the next highest rated site. Even in this case, such a decision may be incorrect if costs have not been considered. Frequently, there will be trade-offs between alternatives with high nonmonetary-factors scores and alternatives that score lower on the nonmonetary factors but also have lower costs. The decision makers should be provided with guidelines on conducting additional analyses to help them make a satisfactory selection.

In developing the model, appropriate efforts should be expended to determine the appropriate factors to consider in the decision process. Although it is probably not feasible for most problems to consider every conceivable factor that might affect the decision, failing to include important factors can adversely affect the analysis. (Identifying too few factors is more of a problem in application than in theory.) Alternatively, including unnecessary factors wastes time and money in data collection and analysis. Sometimes factors are chosen based on ease of measurability, where the data are readily available, even though the factor may not be that important to the decision. Similarly, if the measures for a particular factor are essentially the same for all alternatives, there is no point in including it in the analysis.

When a large number of factors and subfactors are considered, clear definitions are required to prevent confusion, particularly with respect to possible overlap or duplication of subfactors in different categories. When designing a model, independence among the factors selected for inclusion must be carefully evaluated. If weights are developed using relative preferences, mutual preferential independence is required to ensure consistency among the rankings of the factors and separability of the joint utility function. (Bunn, 1984) (Keeney and Raiffa, 1976)

Furthermore, when using a large number of factors and subfactors, there is a tendency to lose sight of the relative importance that should be placed on each. For example, assume that the objective of proximity to labor is considered to be twice as important as adequate community facilities, such as schools and churches. If eight factors or subfactors are used to measure adequacy of community facilities and only two factors to measure proximity to labor, then care must be taken in assigning weights to ensure that community facilities do not overly influence the overall weighted site rating. (Muther and Hales, 1980)

Other concerns involve variability. Variability can arise from the differences among types of companies or facilities, and the kinds of areas and sites under consideration. Further variability is introduced through the identification and measurement of factors and the transformation of factor measures to a common, dimension-less scale, as well as interactions among factors. Weights are frequently treated as if their values were completely certain, although they actually have distributions associated with them. This variability can arise from the use of different methods in developing the weights, from differences in weights assigned by different evaluators (representing various stakeholders), and/or from uncertainty in the minds of individual evaluators regarding the assignment of weights which reflect the relative importance of different factors. Sensitivity analyses, if performed, seldom attempt to account for all the sources of variability or even identify the most critical components in the decision.

Although the use of multi-criteria decision models greatly aids in the selection of sites, there is room for improvement. A methodology which attempts to address some of the weaknesses described above is presented in the next chapter.

CHAPTER 3.

DEVELOPMENT OF THE METHODOLOGY

The primary objective of this work is to improve the decision maker's understanding of the multi-criteria site selection process through a rigorous analysis of alternatives. The methodology presented will assist the decision maker in making critical discriminations among the alternatives based on the composite site ratings and on the weighted values for individual factors. Special emphasis is placed on an assessment of the importance weights utilized in the model and the sensitivity of the results to variability in these weights.

The procedures presented here assume that the decision to search for a new site for a company facility has been justified, that the selection task is complex enough to require consideration of multiple criteria, and that sufficient resources exist to conduct a thorough analysis. Alternative regions, areas, or sites have been or can be identified, as appropriate to the present level of analysis. The methodology is composed of eight basic steps, described below. Additional explanation is provided in the following sections and an application of the methodology is presented in Chapter 4.

1. <u>Screening of Site Factors</u>. From a comprehensive list of site factors, presented in Appendix II, identify those that are most applicable to the present site selection project by initially classifying the factors as:

   a. Critical or essential

   b. Important

   c. Not important/not applicable

   At this phase, the classification should be done at the first subfactor level below the major factor categories. Sub-levels below this level should be used to provide descriptive information with regards to the nature of the factors.

2. <u>Refining the Site Factors List</u>. Specify the factors in the critical and important classes by refining the descriptions to best express the considerations that are important to the decision process. Only certain subfactors will apply. Maintain the structure of major factors, subfactors, and sub-subfactors, and attempt to maintain as much independence as possible between factors. Consideration should be given to the efforts required to develop the objective measurements (including costs) and subjective descriptive classes, and to specifying the minimum and maximum plausible or feasible values.

3. Developing Importance Weights. Applying an appropriate weighting method, develop an initial set (or sets) of weights for the factors. Continuing to maintain the factor level structure should simplify the process by reducing the number of factors that must be compared at a particular level. Use multiple evaluators, if possible, representing key stakeholders in the decision. Analyze the variability of the weights (within-factor and between-factor), using appropriate statistical measures (Eckenrode, 1965) (Dunn-Rankin and King, 1969) (Edwards and Newman, 1982).

4. Finalizing the Site Factors List. Utilizing the weights assigned, prune the factors that are determined to be less important to the decision process and those that are not expected to differ for the candidate sites. Even an otherwise important factor will not affect the decision unless it contributes to the discrimination among sites. Continue to strive for independence among the factors. Reassign weights, if necessary.

5. Measuring the Site Factors. Collect data on the selected factors for the previously identified alternative sites. The degree of detail appropriate for the collection of data for individual factors depends on the cost of collecting the data, the

expected accuracy or reliability and the related variability in the measures, the desired confidence level, the importance weights applied to the factors, and the variability in the weights. The data are then transformed to a common, dimensionless scale using appropriate utility functions.

6. Rating the Sites. Utilizing the site factor values and weights developed in the previous steps, calculate weighted values for each factor for each alternative site and total or composite site scores for the candidate sites. An additive-weighted model, which is simple to apply and understand as well as commonly employed in practice, will be used in this analysis, although other scoring techniques could be applied.

7. Analyzing the Results. Rather than assuming that the highest scoring site is the best and recommending its selection, rigorously analyze the results with respect to:

   a. Cost considerations and dominance, if costs were not included in the factors used in the multi-criteria model. If certain sites are dominated by other sites with respect to costs and nonmonetary scores, then they can probably be eliminated from further consideration. Those remaining will still be contenders. If one site is obviously (and consistently) much better than all others, then the analysis can end with its recommendation. Cost versus nonmonetary factor trade-offs should be considered and indifference points identified.

b. Significance of the differences among the rating scores. The significance can be measured in various ways, such as the amount of the differences or the percentage variation. Each alternative should be compared to every other alternative. For example, the top two rated sites may not be significantly different, while the difference between the first and third may be considerable.

c. Non-discriminatory factors. If the values or weighted values for certain factors are equal (or nearly equal) for all sites under consideration, then these factors could be eliminated, at least temporarily. If factors are removed from the analysis, it may be desirable to revise the weights. While this creates additional work, it may be worth while if the factor list is very long or there are many non-discriminatory factors apparent in the analysis or the decision is particularly critical.

d. Subaggregation analysis. Operating at the weighted factor value level, the contribution of each factor to the total score can be examined. The best and worst sites can be identified and the range of the weighted values calculated.

8. <u>Sensitivity of Factor Weights</u>. Develop alternative sets of weights, using statistical averages of the previously developed weights, equal weights for all factors, or some alternative weighting method. Using the alternative weights, recalculate the weighted values and total scores as in Step 6. Repeat the analysis of the results as in Step 7, with the addition of:

    e. Changes in rank order of the sites due to different weighting schemes. Determine a composite measure for each site, such as average total score or weighted-average total score (with variances, if applicable). Identify weight indifference points. Perform additional analyses, including:

        i. Sensitivity analyses of scores to changes in factor weights, starting with the highest weight(s), and observing the impacts.

        ii. Sensitivity analysis at weighted factor value level. Determine the percentage of the total score that each factor contributes and vary the weights (and/or factor values), starting with the largest contributor, and observing the impacts.

The steps described above are presented in flowchart format in Figure 10 and discussed in more detail in the following sections.

Step 1. Screening of Site Factors

The review and evaluation of the previously described lists of site factors resulted in a comprehensive set of factors and subfactors to be considered in the site selection process (Appendix II). This list is structured along the guidelines developed earlier, using ten major categories as the basis for factor classification. The major categories are (1) Land, (2) Utilities, (3) Transportation, (4) Markets, (5) Material, Supplies and Services, (6) Labor, (7) Community Characteristics, (8) Government and Legislative, (9) Environmental and Ecological Considerations, and (10) Financing.

A key consideration in the development of such a listing is the overlap or duplication of factors. In order to minimize the resulting problems of inconsistency in rating the factors, this list has been developed with the goal of avoiding overlap. Cross-references are used from sections of the list where certain considerations might be

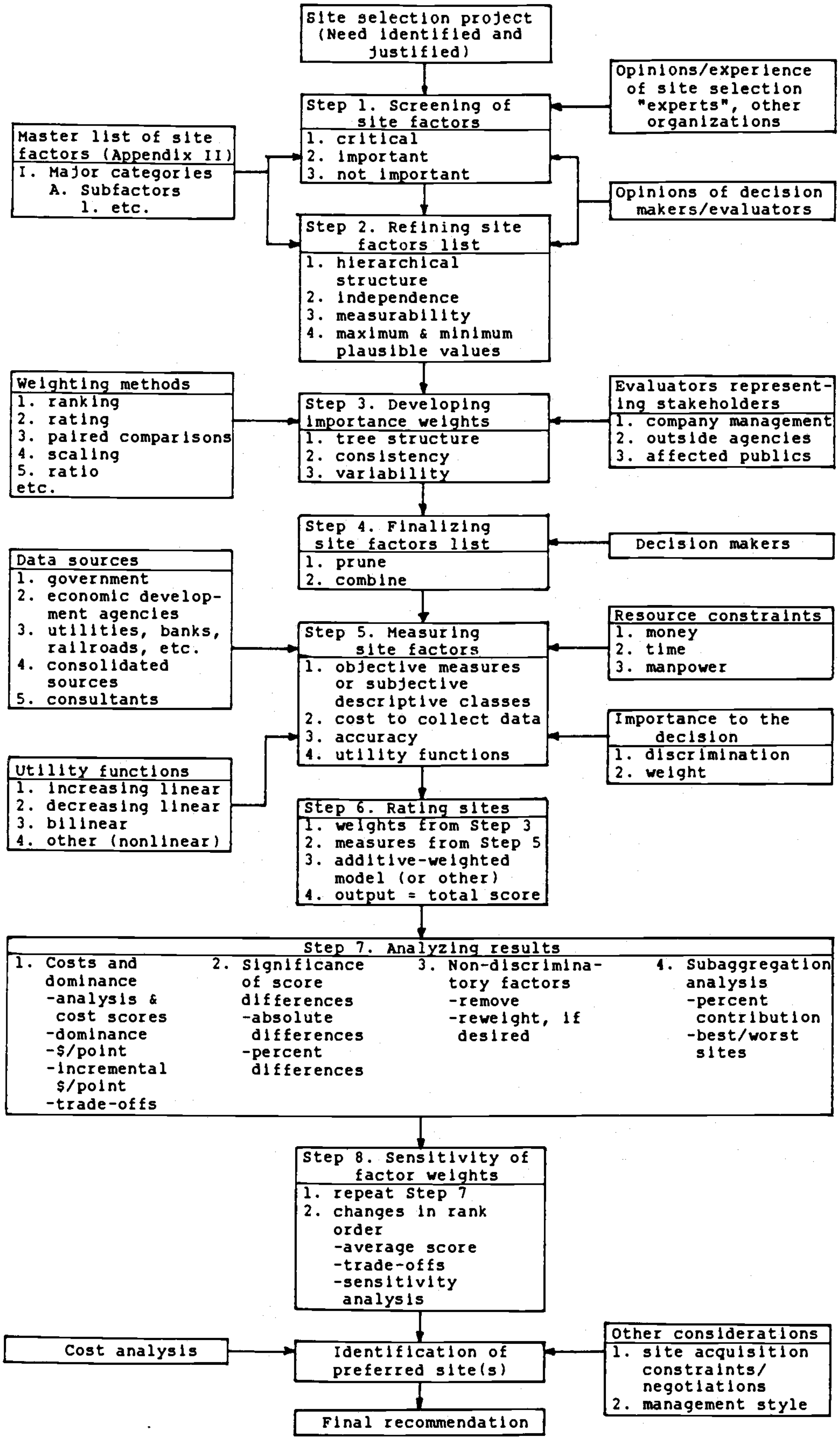

Figure 10. Site Selection Methodology

expected to the section where such factors are included. For example, information related to union activities and labor laws might be addressed under the Labor section or under the Government and Legislative section. In this list, such issues are included under Labor and referenced from the appropriate subsection of Government and Legislative. Similarly, taxes and tax incentives could be included under Government and Legislative (as is done here) or under Financing (with reference to Government and Legislative).

A separate list of factors of particular interest in international location decisions is included in Appendix III. These factors apply both to domestic firms considering locations in foreign countries and to foreign firms considering locations in the United States. While this area of study is not of primary consideration in this work, the increasing competitiveness of world markets and the trend towards more overseas plants should provide fruitful grounds for future research.

The site selection factors list is structured in a hierarchical fashion. Each major factor category is disaggregated into subfactors, which are further subdivided into more detailed descriptions of the characteristics that apply to each factor. Depending on the factor, the subfactors can become quite detailed. For example, Figure 11 shows an excerpt from the list of subfactors that apply to the major factor of Transportation.

C. Air
1. Airlines, air taxis and commuter service (national, regional, feeder, all-freight)
2. Passenger and freight schedules and transit times
3. Fares and rates
4. Air charter and rental
5. Helicopter-shuttle service (including costs to set up, if not available)
6. International service
7. Pickup and delivery zones and services
8. Distance and travel time from plant site to airports (scheduled-service or municipal)
9. Service to plant/supplier and market areas (direct route, by interline routes, by air/truck routes)
10. On-time-performance record, claims record and customer-service record of air carriers
11. Airport facilities
    a. Terminal
    b. Runway (length, surfacing, lighting)
    c. Radio and radar
    d. Instrument approaches
    e. Availability of gas, jet fuel
    f. Repair services
12. Airfields used by executive aircraft
13. Hangar and office facilities
14. Taxiway access to plant sites
15. Air freight (See also Section V. MATERIALS, SUPPLIES AND SERVICES: D.8.)
    a. Sizes and types of containers
    b. Air cargo forwarders
    c. Density of average shipment
    d. Bulk or quantity rates
    e. Shipment or delivery minimums
16. Weather closures of airport (frequency and duration)
17. Planned or proposed new airports
18. Planned or proposed legislation (noise control, approach or takeoff patterns) that would affect operations at the airport

Figure 11. Subfactors under Transportation Category

It is recommended that the entire list be reviewed to develop an understanding of the many factors that could potentially affect the selection of a site before beginning to classify the factors as (1) critical or essential, (2) important, or (3) not important or not applicable. (Other descriptions can be used if they seem more suitable; the major requirement is to reduce the length of the list by identifying those factors that are not important.) The factors should be rated at the first subfactor level below the major factor level, as designated by capital letters, such as C in Figure 11. While not every level below this will apply to the specific project, these levels will be specified later and should be viewed as providing explanatory information at this point.

Step 2. Refining the Site Factors List

After eliminating those factors that are judged to be not important or not applicable to the specific location project, the remaining critical and important factors should be further defined to best represent the issues relevant to the decision. It is quite possible that not all of the items listed at the lower levels of a particular factor will be applicable. It is also possible that special factors not on the original list will need to be added for certain projects. Whether cost considerations will be included in the weighted model or handled separately should be determined.

While editing the list, consideration should be given to the types of measures (objective or subjective) that will be required and how they can be obtained (actual measurements, subjective evaluations from experts). Measurements or evaluations will be made at the lowest factor level. The descriptive classes for subjectively assessed factors and the minimum and maximum plausible or feasible measures for each factor should be given some thought during this step.

Maintaining the hierarchical structure of major factors, subfactors and sub-subfactors can greatly assist later in assigning weights, although the outline format is not intended to necessarily imply equivalent levels of detail. For example, if Air Transportation was considered to be an important factor in the first screening, then the list of subfactors, as shown in Figure 11, could be further refined to yield the list in Figure 12. In this illustration, the only air transportation needs are for passenger travel on commercial airlines. The list could be further reduced if, for example, weather closures were not a major issue depending on the area(s) under consideration. Furthermore, although air travel might be considered an important factor, it might not need to be included in the evaluation if the factor measures were essentially the same for all sites (all sites to be considered used the same airport).

C. Air
1. Airlines and commuter service (national, regional, feeder)
2. Passenger schedules and transit times
3. Fares
4. Distance and travel time from plant site to airports
5. Service to plant/supplier and market areas
6. On-time-performance record, claims record and customer-service record of air carriers
7. Airport facilities (terminal)
8. Weather closures of airport (frequency and duration)
9. Planned or proposed new airports
10. Planned or proposed legislation (noise control, approach or takeoff patterns) that would affect operations at the airport

Figure 12. Reduced Factor List for Air Transportation

As a final list of factors is developed, care should be taken to ensure that there is no overlap or duplication of factors and the factors are as independent as possible. For factors to be independent, the measure of one factor should not depend on the measure for another and changes in the measure or value of one factor should not affect other factors. The inclusion of dependent factors can result in more weight effectively being placed on a particular factor than is expressed through the process of developing weights, which generally assumes independence. For example, factors to measure the quality of the educational system in an area might include (1) high school grade point averages, and (2) the percentage of high school graduates who go to college. If Factor 1 is high, it is quite likely that Factor 2 will also be high. If Factor 1 increases, then Factor 2 can be expected to increase. If a site scores high with respect to one of these factors, then it will likely also score high on the other, with a combined contribution to the total score that is larger than would otherwise be expected based on the individual factors' weights. Dependencies can be avoided by dropping one (or both) of the factors or by combining factors into a single measure.

Step 3. Developing Importance Weights

Using multiple evaluators, if possible, who represent the interested stakeholders, weights should be developed for each of the factors at each of the levels. Alternative techniques for developing weights were discussed in the previous chapter. The method selected may be partly determined by the evaluators: they may have experience with one method or seem more receptive to one method than another. Any of the methods should provide satisfactory results as long as the appropriate cautions are recognized (i.e., ratings should represent ratios of relative importance and paired comparisons should be checked for circularity). The evaluators should be aware of the plausible range of values for each factor.

By continuing to utilize the hierarchy of factors, the task of developing weights is simplified by reducing the number of factors that must be compared or contrasted at any one level. For example, at the major factor level, there will be at most ten factors to evaluate (fewer if one or more of these levels have been determined to be unimportant to the decision). Then the subfactors under each of these major factors will be evaluated for each remaining level. For example, the major factor of Transportation would be weighted relative to the importance of the other major categories (Land, Utilities, etc.), then within the Transportation category, the importance of Air Transportation would be weighted in relation to Rail, Highway and Street (Motor), and Water Transportation. Finally, within the Air factor, subfactors such as those shown in Figure 12 would be evaluated.

A set of normalized weights is calculated for each level. The final weight for each of the lowest level factors is determined by multiplying together the appropriate weights from each level. Edwards and Newman (1982) describe this approach as value tree development. The procedure is similar to that employed in calculating probabilities using decision trees.

For example, if Transportation is given a weight of 0.40, relative to the other major factors, and Air is weighted 0.25 with respect to the other Transportation factors, and the Airport Terminal is assigned a weight of 0.25 with respect to the other Air Transportation factors, then the final overall weight for the Airport Terminal would be 0.40 * 0.25 * 0.25 = 0.025, relative to all the lowest level factors under consideration in the decision model. (This is the level at which measurements, objective and subjective, will be made.) The tree structure and a simplified example set of calculations is shown in Figure 13. The weights developed at each level are shown in parentheses and the final weights at the ends of the branches of the tree.

When multiple evaluators have been used to develop weights, achieving consensus may be extremely difficult. Analyses of the weights can be used to assess the extent of the differences and the potential impact on the decision. The means and variances can be calculated and the significance of the differences among sets of weights tested statistically. Edwards and Newman (1982) recommend calculating an average of the weights obtained from

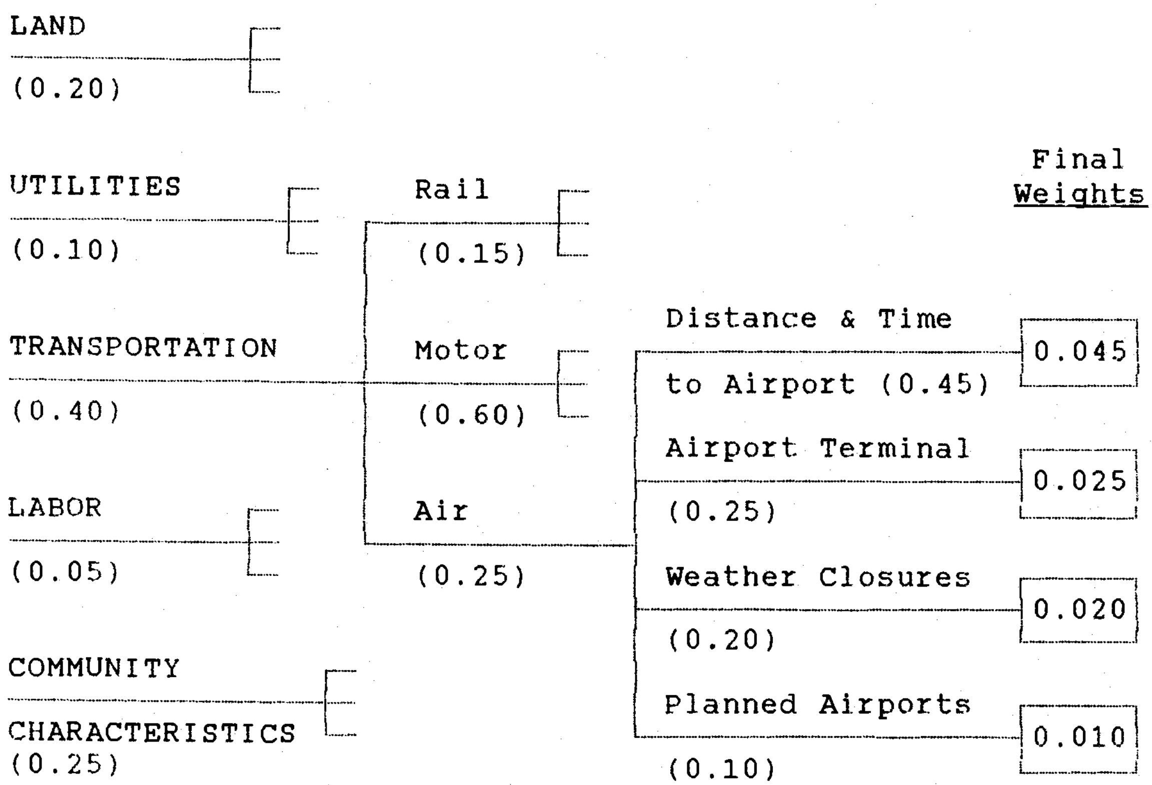

Figure 13. Calculation of Final Weights Using Tree Structure

different evaluators but using it only as an alternative set. This set, as well as the individual evaluators' original sets, should be used to determine site scores. Then the differences in the scores resulting from different weights can be evaluated. Dunn-Rankin and King (1969) reference work done in investigating the distribution of the differences in a two-way analysis of variance where the classification was by evaluators (judges) and by factors (items), yielding measures of variability both within-factor and between-factor. Eckenrode (1965) examined the consistency among sets of weights developed using different methods. He used concordance tests and correlations to determine the significance of the differences in the weights. He also tested the amount of time required to assign weights and the ease of use of different weighting methods. A thorough analysis of the weights is vitally important for the defensibility of the decision.

<u>Step 4. Finalizing the Site Factors List</u>

The list of lowest level factors should be reviewed with the purpose of pruning the factors that will have minimal effect on the decision, based on the final weights assigned at the ends of the "branches". It may be desirable to combine low weighted factors, particularly those that will be subjectively assessed, into a single factor that will have greater impact. Factors whose measures are not likely to differ much for the candidate sites can also be removed from the list, as their contribution will not help to discriminate among the sites. Weights may be reassigned as necessary.

Referring back to the example presented in Figure 13, it may be determined that, relative to the other factors under consideration, Planned Airports, with a final weight of 0.01, is not of enough interest to remain on the list. Possibly this factor is not expected to differ for the candidate sites or the effort required to gather data to assess it may be excessive for the weight applied. By redistributing its weight proportionally to the remaining factors, the final weights would increase to 0.05 for Distance and Time to Airport, 0.028 for Airport Terminal, and 0.022 for Weather Closures. (It may even be decided to eliminate the entire Air Transportation branch, with its combined weight of 0.10, depending upon the relative weights of the other factors.)

Step 5. Measuring the Site Factors

Data on the final set of factors are collected for the previously identified candidate sites. The data will be a combination of objective measures, such as distances in miles and travel times in minutes, and subjective evaluations, such as the adequacy of terminal facilities, which could be an overall assessment, based, at least partially, on objective measures, such as size in square feet and baggage handling capacity.

The amount of effort expended to collect the required data will vary depending on the cost of collecting the data, the importance of the factor being measured, and the desired accuracy of the measures. The cost of collecting the data depends on its availability. As discussed in Chapter 2, there are many sources of information to assist in site searches. Readily available information, such as from documents published by governmental agencies, can be obtained at a relatively low cost and is usually quite accurate (although data from state or area economic development agencies can be expected to shown that state or area in the best possible light). The acquisition of other information may require visits to the sites and direct measurements.

The importance of this information, as reflected in the weights assigned to the factors, must be compared to the cost of acquiring it. It generally does not make good sense to spend large amounts of time and money to collect information that will have only a minor impact on the decision. (This is an advantage of this methodology, which differs from most in that weights are assigned and their importance to the decision evaluated prior to the data collection phase.)

In addition, the desired accuracy or confidence in the measures must be determined. Decisions as to the appropriate degree of detail in data collection are largely judgment-based and are a function of the resources available to the firm: time, money and manpower. Risk can be handled statistically by utilizing expected values and standard deviations, and confidence intervals can be calculated. Alternatively, the desired confidence levels can be specified and steps taken to attain them. Less precise estimates may be good enough if the extra effort required to refine a measure is not worth the cost.

Once a preliminary set of data has been collected, the measures or assessments are transformed to a common, dimensionless scale using utility functions. The end points for the range of measures (the maximum and minimum plausible values) are used to structure the utility functions (increasing linear, decreasing linear, or bilinear) for both the objective and subjective factors. Values which fall outside the limits can be dealt with as described in Chapter 2.

Step 6. Rating the Sites

With the factor values and weights for each site, the sites can be rated or scored. The weighted values for each factor are obtained by multiplying each factor value times its weight. The summation of these weighted values provides the composite or total score for each site. The formulation for such an additive-weighted model was discussed in the previous chapter. The additive-weighted model is simple to apply and to interpret. If modifications are made (factors eliminated or added, or weights changed), its simple structure makes it easy to rerun.

Although the factor measurement and weighting methods may differ, the additive-weighted model is the most commonly used scoring technique in site selection and many other multi-criteria analyses.

The basic output from an additive-weighted model is a composite score (single value) for each site. Generally, the higher the score, the "better" the site, assuming that "less is better" factors, such as costs, have been adjusted so that low measures are assigned high point values. Therefore, the highest scoring site should be selected. This recommendation is where many site analyses end. However, without further evaluation, the decision should not just be based on the composite scores.

Step 7. Analyzing the Results

The results of the application of the additive-weighted model should be rigorously analyzed in order to provide the decision maker with the most relevant information possible. Rather than identifying the "best" site, this procedure attempts to provide a recommendation for action through a process which includes reducing the number of alternatives by eliminating sites from further consideration, identifying where significant differences do and do not occur, simplifying further analyses by reducing the factor list, performing subaggregation analyses at the weighted factor value level, and assessing the certainty of the rankings of sites due to changes in importance weights. This last aspect will be discussed in Step 8.

To illustrate the analysis of the results, an example site selection project is developed and presented in Table 8. This example evaluates five sites with respect to both costs and nonmonetary factors. The applicable costs are determined and converted to equivalent uniform annual costs (EUAC). These values are then transformed to a "less is better" linear utility scale, where 70 represents the maximum plausible cost and 45 equals the minimum plausible cost (in thousands of dollars). Five nonmonetary factors are included in the multi-criteria analysis, using the weights and factor values shown. The composite scores are calculated, and the rankings of the sites with respect to both monetary and nonmonetary values are indicated.

Cost Considerations and Dominance. Cost considerations may be included as factors in the multi-criteria model or they may be treated separately. If costs are analyzed separately and a composite cost figure (such as an equivalent uniform annual cost) for each site is developed, then the sites can be compared with respect to both the costs and the nonmonetary scores. If a site has the lowest costs (assuming that lower costs are preferred) and the

Table 8. Data for Example Sites

	Weight	Site 1 Value	Site 1 Wtd.Value	Site 2 Value	Site 2 Wtd.Value	Site 3 Value	Site 3 Wtd.Value	Site 4 Value	Site 4 Wtd.Value	Site 5 Value	Site 5 Wtd.Value
Factor 1	0.20	10	2.00	6	1.20	3	0.60	7	1.40	4	0.80
Factor 2	0.10	4	0.40	8	0.80	6	0.60	5	0.50	2	0.20
Factor 3	0.40	8	3.20	5	2.00	9	3.60	3	1.20	3	1.20
Factor 4	0.05	5	0.25	3	0.15	8	0.40	9	0.45	7	0.35
Factor 5	0.25	4	1.00	5	1.25	7	1.75	6	1.50	9	2.25
Total Score			6.85		5.40		6.95		5.05		4.80
Rank			2		3		1		4		5
EUAC (thousands $)			58.90		52.50		62.60		56.20		54.70
Cost Score *			4.44		7.00		2.96		5.52		6.12
Rank			4		1		5		3		2

* Cost Score = 10 * (70 - EUAC)/(70 - 45)
where 70 = maximum plausible cost ($000)
45 = mimimum plausible cost ($000)

highest nonmonetary score (dominant in two parameters), it would be a most desirable site. However, based on the adage, "the more you pay, the more you get", some correlation between high costs and high scores can be expected. If a site has the highest cost but the lowest score, it can probably be eliminated from further evaluations. Consideration should also be given to the significance of the differences of the costs and the scores among sites before discarding what might actually be a close competitor. In any event, the lowest cost site should probably be kept in the analysis for the time being even if it scores rather low on the nonmonetary factors.

When two measures of desirability are available, such as costs and nonmonetary composite scores, the sites under consideration can be examined for dominance. Dominance can be identified using the rankings of the sites or the actual values for the costs and nonmonetary scores. The five example sites can be ranked in order of 2-5-4-1-3 from lowest to highest cost and 3-1-2-4-5 from highest to lowest scores. Sites 4 and 5 are both dominated by (always ranked lower in desirability than) Site 2. The feasible solution space and the dominating sites can be viewed graphically by plotting the points representing the costs and nonmonetary scores for the sites, as shown in Figure 14.

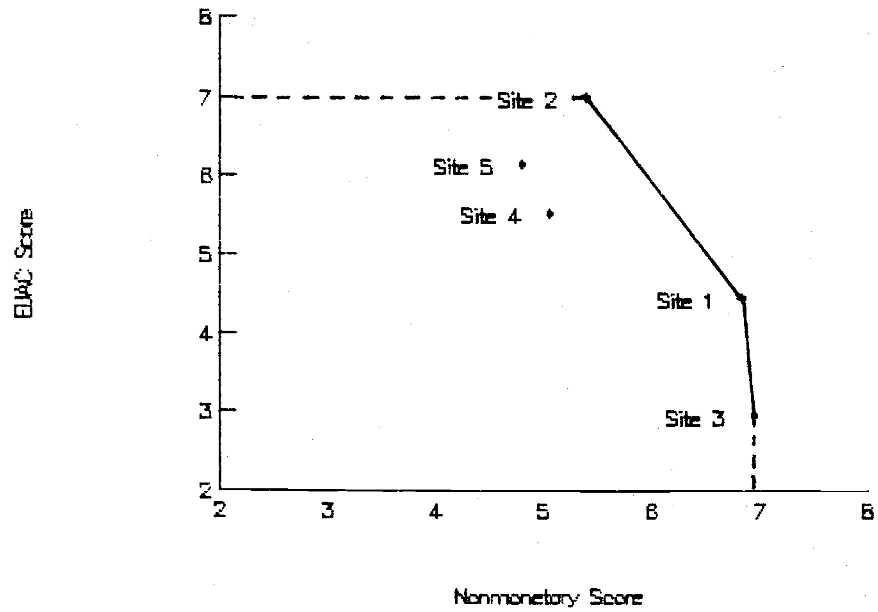

Figure 14. Dominance Graph for Example Sites

The sites on the interior of the indicated region are dominated by the sites on the perimeter. Since the lines connecting Sites 1, 2 and 3 form the boundary, Sites 4 and 5 are clearly less desirable sites. Additional sites which would lie outside (above and to the right of) the perimeter would be preferred to at least one of the sites which currently lies on the boundary.

Dominated sites can be eliminated from further consideration since they will not be preferred to the other sites with respect to either criteria. Thus, Sites 4 and 5 can be removed from the list of candidate sites. Non-dominated sites, in this case, Sites 1, 2 and 3, remain as contenders. Depending on the outcome of the dominance checks (if too many sites are eliminated), it may be desirable to seek additional sites to be included in the analysis. Dominance will be reevaluated in Step 8, when comparing the results obtained from the use of different weights.

The relationship between the costs and nonmonetary scores can be shown by determining a ratio of dollars to nonmonetary "points" for each site, as shown in Table 9. If the decision was based on these ratios, Site 1 would be chosen since it has the lowest ratio. Sites 3 and 2 would be the next most desirable sites, in that order, and Sites 4 and 5 would again be the least preferable sites.

Table 9. Ratios of Dollars to Nonmonetary Points

	Site 1	Site 2	Site 3	Site 4	Site 5
Cost ($000)	58.9	52.5	62.6	56.2	54.7
Nonmonetary Score	6.85	5.40	6.95	5.05	4.80
$/"point"	8.60	9.72	9.01	11.13	11.40

However, rather than basing the decision on these single ratios, incremental ratios of dollars to points can be determined to assess the desirability of investing additional funds and attaining a higher nonmonetary score. Using the lowest cost site as the base, the sites are ranked in increasing order of costs and nonmonetary scores, as shown in Table 10 for Sites 1, 2 and 3. The increments are determined by subtracting the value (cost or nonmonetary score) of the first listed site from the value of the second, and the second from the third. The last column shows the incremental ratios of dollars to nonmonetary points, which represent the value in dollars for a one-point increase in nonmonetary scores.

Table 10. Incremental Ratios of Dollars to Nonmonetary Points

Site	Increase in Costs ($000)	Increase in Scores	Incremental Ratio ($/pt)
2			
	6.40	1.45	4.40
1			
	3.70	0.10	37.00
3			

According to the figures in Table 10, it would "cost" $4,400 per point increase in nonmonetary value to select Site 1 over Site 2. If dollar values can be assigned for increases in the measures of the nonmonetary factors, then the ratios calculated above can be used to assess the benefits accrued from the larger investment with respect to the gain in nonmonetary score.

To accomplish this, the decision makers could be asked to estimate how much it would be worth to increase the value of one of the factors from the minimum value (zero) to the maximum value (ten). For example, suppose that an increase from zero to ten in Factor 3 would be worth $20,000. Since the weight of Factor 3 is equal to 0.40, the contribution of the increase to the total score would be 10 * 0.40 = 4 (points). The dollar value of a one-point increase in the total nonmonetary score would be equal to $20,000 divided by 4 points or $5,000.

In comparing Site 1 to Site 2, the cost for a one-point increase in the nonmonetary score is $4,400, which is less than the amount the decision maker is willing to pay ($5,000). Hence, the additional investment in Site 1 would be justified. However, in comparing Site 3 to Site 1, the cost of a one-point increase is $37,000, which would not justify the higher cost of Site 3, considering its very small increase in nonmonetary score.

A similar analysis could be conducted using the converted utility cost scores rather than the actual dollar values. In this case, the decision maker would be asked to assess the value of increased factor measures in terms of increases in cost utility values. Such values would be compared to the incremental ratios, which are calculated by dividing the decrease (negative increase) in the cost scores by the increase in the nonmonetary scores. These ratios also represent the slopes of the lines connecting the sites shown in Figure 14.

Depending on the importance or relative weight placed on the costs and nonmonetary factors, the choice of a site may change. The trade-offs between costs and nonmonetary scores can be shown graphically, as in Figure 15. The left axis plots the scores for the sites relative to costs only and the right axis relative to nonmonetary factors only. The lines connecting these points represent the sites for various combinations of costs and nonmonetary scores. The top lines indicate the preferred sites for given ranges of weights, which are determined by the points of intersection of the lines. At these indifference points, the decision maker would not prefer one site to the other but would be satisfied with either. The indifference points can be read off the graph or calculated by setting the equations for the intersecting lines equal to each other and solving simultaneously for the relative weight of the costs.

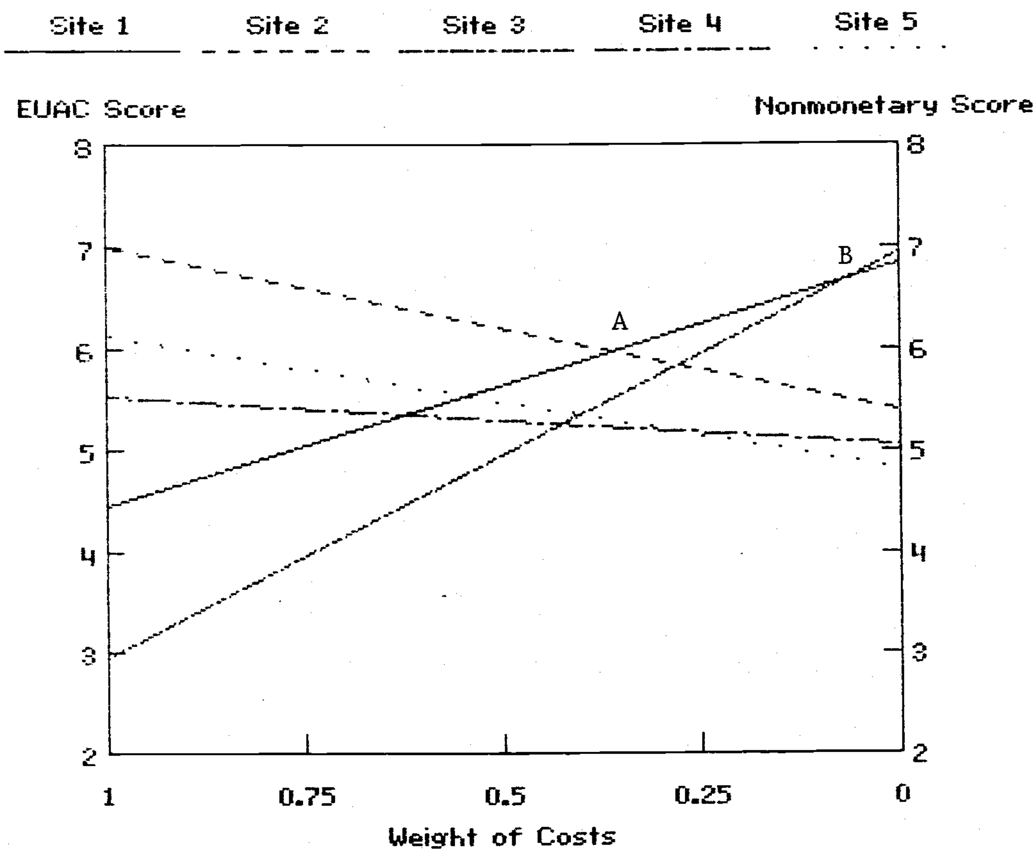

Figure 15. Cost Versus Nonmonetary Trade-Offs: Example Sites

Indifference point A, the intersection of the lines representing Sites 1 and 2, occurs when the relative weight of the costs is approximately equal to 0.36. Thus, if nonmonetary factors are considered to be nearly twice (1.8 times) as important as costs, Site 1 would be preferred, until indifference point B is reached. To the right of indifference point B, where nonmonetary factors almost completely dominate cost considerations (the weight of the costs equals 0.06), Site 3 would be preferred. Site 2 is the preferred site over the widest range of values (weights of the costs greater than 0.36). The sites included in the area under the top lines would not be chosen unless the preferred sites were no longer available. The area above the lines can be viewed as an opportunity zone. Newly identified sites in that area would be superior to the sites currently under consideration for particular ranges of weights. Dominance can also be identified using the preference lines in Figure 15, which shows that the lines representing Sites 4 and 5 are totally contained in the area under the top lines.

Significance of Score Differences. If one site scores 6.95 and another site scores 6.85 on nonmonetary factors, it is difficult to tell whether the higher rated site is really significantly better than the other. Recall that the scores have no real meaning in themselves, but rather serve only to compare one alternative to another with respect to multiple criteria. Assessing the meaning of the differences between scores can be accomplished by looking at the absolute differences between pairs of scores and the percentage variations. If dominance checks have reduced the number of alternatives to be considered, the significance tests are simpler. To illustrate, the nonmonetary scores for the five example sites are shown in Figure 16.

The sites are ranked in order of highest to lowest score and pairwise comparisons are made in the same order until every site is compared once with every other site.

Site	1	2	3	4	5
Score	6.85	5.40	6.95	5.05	4.80
Rank	2	3	1	4	5

Absolute Differences

3 -> 1: 0.10			
3 -> 2: 1.55	1 -> 2: 1.45		
3 -> 4: 1.90	1 -> 4: 1.80	2 -> 4: 0.35	
3 -> 5: 2.15	1 -> 5: 2.05	2 -> 5: 0.60	4 -> 5: 0.25

Percentage Differences

3 -> 1: 1.4			
3 -> 2: 22.3	1 -> 2: 21.2		
3 -> 4: 27.3	1 -> 4: 26.3	2 -> 4: 6.5	
3 -> 5: 30.9	1 -> 5: 29.9	2 -> 5: 11.1	4 -> 5: 5.0

Figure 16. Absolute and Percentage Differences in Scores: Example Sites

As can be seen, the absolute differences range from 0.10 (between Sites 1 and 3) to 2.15 (between 3 and 5). Four of the differences are less than 1.0 (10 percent of the zero to ten scale). Using this as the criteria for significance would mean that there is no significant difference between Sites 1 and 3, 2 and 4, 2 and 5, and 4 and 5.

Analyzing the percentage differences (the absolute difference divided by the base alternative) indicates there are two sets of sites with percentage differences that are less than or equal to 5 percent, plus one additional set less than 10 percent. Considering these criteria, 1 and 3, and 4 and 5 would not be significantly different in the first case, and 2 and 4 would be added at the 10 percent level. Sites 2 and 5 have an 11.1 percent difference and all other pairs have differences greater than 20 percent.

The results of the above analysis generally indicate that the selection of Site 1 or 3 would be approximately equally satisfactory. Either of these two sites would be preferred to 2, 4 or 5, since both 1 and 3 score significantly higher. However, additional analysis would be required to choose between Sites 1 and 3.

The tests described are simple, although some judgment is required to set a desired level at which to test the differences. The analysis demonstrated above assumes that the scores are known with certainty. If the scores are uncertain due to variability in the factor measures and/or the weights, and the variances of the scores can be determined, then additional statistical tests can be applied. For example, hypothesis tests could be used to determine the significance of the differences between the mean scores for pairs of alternatives.

Such analyses enable more meaningful interpretations of the composite scores. Their primary value is in demonstrating that the highest rated site is not necessarily the only (or "best") choice. Other criteria, such as differences in costs, could be used to make a final choice from among those sites which do not score differently with respect to the nonmonetary factors.

Non-Discriminatory Factors. If the list of factors is long and the contribution of some of the factors to the total score is the same for all candidate sites (the weighted factor values are equal), it may be desirable to eliminate these factors from the model. The inclusion of fewer factors will reduce the number of calculations required during sensitivity analyses. If there are many non-discriminatory factors present, their removal, accompanied by a reassignment of weights to the remaining factors, may help "spread out" the resulting scores when the analysis is rerun with the new weights. Thus, a clearer decision among the sites may be apparent.

Subaggregation Analysis. A further aid to discriminating among the alternative sites is subaggregation analysis (Edwards and Newman, 1982). Although the terminology used here is similar to that used by Edwards and Newman, the meanings differ somewhat. In sub-aggregation analysis, the weighted values at sublevels in the analysis are calculated and examined for the extent of their potential impact of the results. Subaggregated values could be calculated at any level of the "tree" and the method is appropriately applied where uncertainty exists with respect to the weights assigned at that level. For this work, weighted factor values will be used to illustrate how the process is conducted. The dominated sites, 4 and 5, will not be included in this analysis.

The percentage that each weighted factor value contributes to the total score is calculated for each site. As can be seen in the example presented in Table 11, Factor 3 makes the largest contribution for all sites. Factor 5 is the second largest contributor for Sites 2 and 3 but third for Site 1, which gains more from Factor 1. Factor 4 is relatively unimportant for all sites and could be dropped from the analysis. Factors 1 and 2 have very little impact on the score for Site 3, but contribute much more to Sites 1 and 2. Reviewing the impact of the different factors on the total score provides an indication of where additional efforts should be expended to refine weights or factor measures.

Table 11. Example Subaggregation Analysis

Data for Three Contender Sites

	Weight	Site 1 Value	Site 1 Wtd.Value	Site 2 Value	Site 2 Wtd.Value	Site 3 Value	Site 3 Wtd.Value
Factor 1	0.20	10	2.00	6	1.20	3	0.60
Factor 2	0.10	4	0.40	8	0.80	6	0.60
Factor 3	0.40	8	3.20	5	2.00	9	3.60
Factor 4	0.05	5	0.25	3	0.15	8	0.40
Factor 5	0.25	4	1.00	5	1.25	7	1.75
Total Score			6.85		5.40		6.95
Rank			2		3		1

Percentage of Weighted Factor Value Contribution to Total Scores

	Site 1	Site 2	Site 3
Factor 1	29.2%	22.2%	8.6%
Factor 2	5.8%	14.8%	8.6%
Factor 3	46.7%	37.0%	51.8%
Factor 4	3.6%	2.8%	5.8%
Factor 5	14.6%	23.1%	25.2%

Ranking of Sites Using Weighted Factor Values

	Best Site	Weighted Value	Worst Site	Weighted Value	Value Range	Rank of Range
Factor 1	1	2.00	3	0.60	1.40	3
Factor 2	2	0.80	1	0.40	0.40	4
Factor 3	3	3.60	2	2.00	1.60	1
Factor 4	3	0.45	2	0.15	0.30	5
Factor 5	3	2.00	1	0.50	1.50	2

An identification of the best and worst sites with respect to the weighted factor values is also included in Table 11. The range of values from the best to the worst and an ordering by magnitude of the value is also shown. As can be seen from this listing, Site 3 is the best site for three out of the five factors, but worst with respect to one factor. Sites 1 and 2 are each best for one factor but worst for two others.

Aids such as those described here can be particularly helpful in analyses that consider a large number of factors and/or a large number of alternative sites. These techniques are useful in identifying where the major impacts occur and how the sites compare with respect to subaggregated values.

Step 8. Sensitivity of Factor Weights

Since the factor weights are the components of the model most likely to be subject to disagreement, the impact of different weights on the analysis should be examined. Alternative weights could be calculated as an average of the weights developed in the earlier analysis or by using an alternative method from Chapter 2. Another option would be to assume all factors at each level are equally important and thus all weights would be equal (at each level). Equal weights could be considered the "base case scenario":

a compromise position from which to explore the impacts of major disagreements among evaluators as to which are the important factors. The differences between the sets of weights should be examined for the extent of the variability, as discussed earlier.

Using the alternative weights, the multi-criteria model is rerun as described in Step 6. The analysis of the results using the new weights follows Step 7. In addition, dominance checks can be performed on the rankings from the original and new weights. If the ranked order does not change, even with significantly different weights, then the analysis is not sensitive to changes in weights. If this occurs, it is probably because one site is considerably better than any of the others in a number of the factors. If, however, the order does change, then the alternatives should be explored in more detail.

Changes in Rank Order. Alternative rank orders using different weights can be translated into a combined score for each site. The combined score may be determined by calculating an average total score or a weighted total score. An example best serves to illustrate these options, as shown in Table 12.

Table 12. Combined Scores and Ranks Developed from Alternative Weights

Site	1	2	3	4	5
Weight Set I	(Corporate Management)				
Score	5.9	5.6	7.1	5.3	5.1
Rank	2	3	1	4	5
Weight Set II	(Regional Management)				
Score	5.5	6.5	6.6	5.3	3.6
Rank	3	2	1	4	5
Weight Set III	(Operating Personnel)				
Score	6.4	6.0	6.3	5.8	4.4
Rank	1	3	2	4	5
Average Score	5.93	6.03	6.67	5.47	4.37
Rank	3	2	1	4	5
Weighted (Set I = 0.45, Set II = 0.30, Set III = 0.25)					
Average Score	5.91	5.97	6.75	5.43	4.48
Rank	3	2	1	4	5

In this example, three alternative sets of weights have been used to calculate scores for the five candidate sites. The weight sets might have been developed by different groups within an organization, such as corporate management, regional management, and operating personnel. The site selection analyst, with input from the key decision makers, has determined that the opinions of corporate management should weigh most heavily, followed by regional management and then operating personnel. A set of relative weightings was developed which is used to calculate a weighted-average score. Assigning such weights can involve the same techniques as described previously and the same difficulties. The sensitivity of the rankings to these weights can also be determined and may be an important part of the analysis if there is great variation in the results.

As can be seen in Table 12 and graphically in Figure 17, the scores and some of the ranks differ for the different weighting schemes. By combining the results into averages, an overall ordering can be developed, taking into consideration the different weights. Again, significance of the differences of the averages could be evaluated.

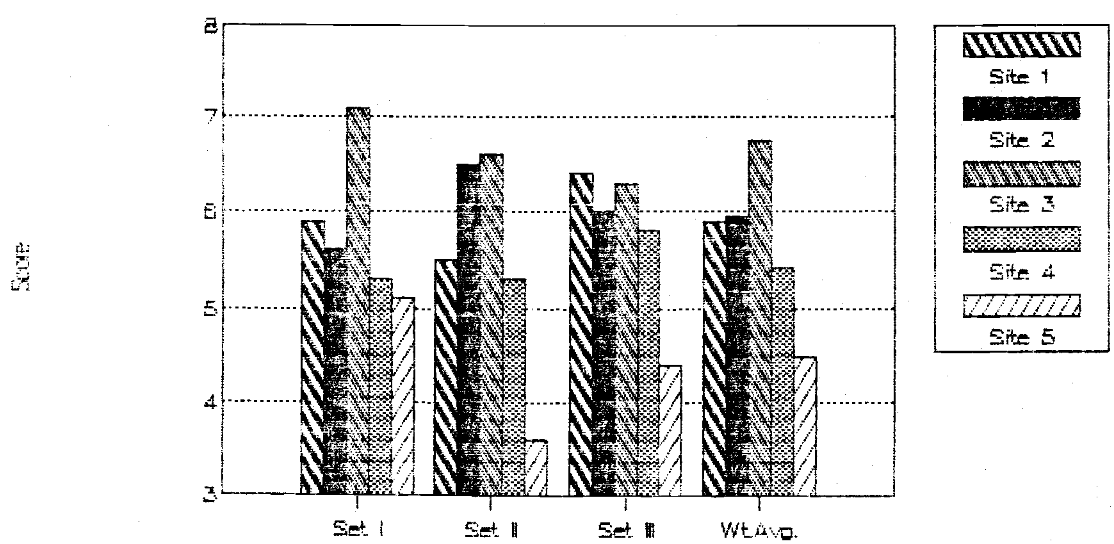

Figure 17. Scores for Example Sites Using Alternative Weights

Trade-offs between alternative sets of weights can be examined in a manner similar to the cost and nonmonetary factors comparisons described previously. Indifference points between alternative sites can be found for sets of weights which represents mixes of other weights. For example, as shown in Table 12, there is a disagreement between corporate management's highest ranked site (Site 3) and that ranked first by operating personnel (Site 1). The weight which must be applied for one opinion to prevail over the other can be found by the solution of simultaneous equations for the lines representing the sites. The solution is shown graphically in Figure 18. Only the top two ranked sites (1 and 3) are considered since there is no difference in rankings for the other three sites. As can be seen, Site 3 would be preferred unless the opinions of corporate management are nearly ignored (the weight of corporate management at the indifference point is equal to 0.08).

When changes in scores and rank orders occur with different weighting schemes and there is considerable uncertainty as to the extent of the influence of weights on the results of the analysis, additional investigations can be conducted. These include sensitivity analyses based on (a) incremental variations in certain weights with emphasis on the highest weights and (b) extreme changes in weights with emphasis on the largest weighted factor values.

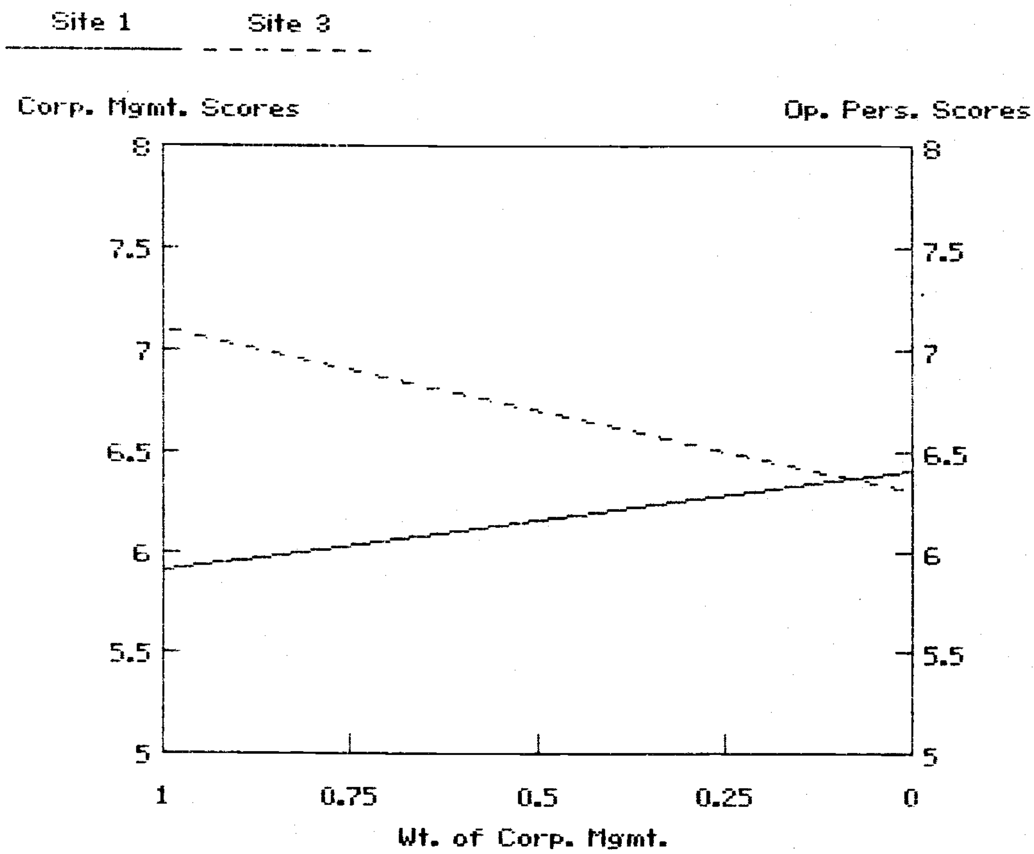

Figure 18. Trade-Offs Between Alternative Sets of Weights: Example Sites

Starting with the highest weight first (generally referring to the original set or sets of weights or a consensus set developed during prior analyses), that weight is varied by certain increments and the effects on the composite scores and ranks observed. Depending on the number of factors, and therefore, the relative size of the weights, desirable increments might be +/-10 percent, +/-20 percent, +/-30 percent, and so on. The objective is to determine if and when a significant change occurs and to identify those weights for which the results appear to be sensitive. If normalized weights are used (the assumption generally made in this work), then at least two weights have to be changed in order to maintain the sum equal to unity. To more easily gauge the effects of incremental changes in one weight, the offsetting adjustment can be spread proportionally over all the other weights, maintaining their relative levels. To illustrate this procedure, an example using Sites 1, 2 and 3 is presented in Table 13. Figure 19 displays the results of the sensitivity analysis in graphical form.

Examining the original set of weights indicates that Factor 3, which has the highest weight (0.40), is a likely candidate for changes. The weight of Factor 3 is first increased by 30 percent. The other weights are reduced proportionally to their original weights so that the weights sum to unity. As a result, the scores and the differences in the scores change, although the ranking of the sites does not. Using the original weights, the difference between the scores for Site 3 and Site 1 is only

Table 13. Incremental Weight Sensitivity Analysis

	Weight	Site 1 Value	Site 1 Wtd.Value	Site 2 Value	Site 2 Wtd.Value	Site 3 Value	Site 3 Wtd.Value
Factor 1	0.20	10	2.00	6	1.20	3	0.60
Factor 2	0.10	4	0.40	8	0.80	6	0.60
Factor 3	0.40	8	3.20	5	2.00	9	3.60
Factor 4	0.05	5	0.25	3	0.15	8	0.40
Factor 5	0.25	4	1.00	5	1.25	7	1.75
Total Score			6.85		5.40		6.95
Rank			2		3		1

30% Increase in Factor 3 Weight

	Weight	Site 1 Value	Site 1 Wtd.Value	Site 2 Value	Site 2 Wtd.Value	Site 3 Value	Site 3 Wtd.Value
Factor 1	0.16	10	1.60	6	0.96	3	0.48
Factor 2	0.08	4	0.32	8	0.64	6	0.48
Factor 3	0.52	8	4.16	5	2.60	9	4.68
Factor 4	0.04	5	0.20	3	0.12	8	0.32
Factor 5	0.20	4	0.80	5	1.00	7	1.40
Total Score			7.08		5.32		7.36
Rank			2		3		1

30% Decrease in Factor 3 Weight

	Weight	Site 1 Value	Site 1 Wtd.Value	Site 2 Value	Site 2 Wtd.Value	Site 3 Value	Site 3 Wtd.Value
Factor 1	0.24	10	2.40	6	1.44	3	0.72
Factor 2	0.12	4	0.48	8	0.96	6	0.72
Factor 3	0.28	8	2.24	5	1.40	9	2.52
Factor 4	0.06	5	0.30	3	0.18	8	0.48
Factor 5	0.30	4	1.20	5	1.50	7	2.10
Total Score			6.62		5.48		6.54
Rank			1		3		2

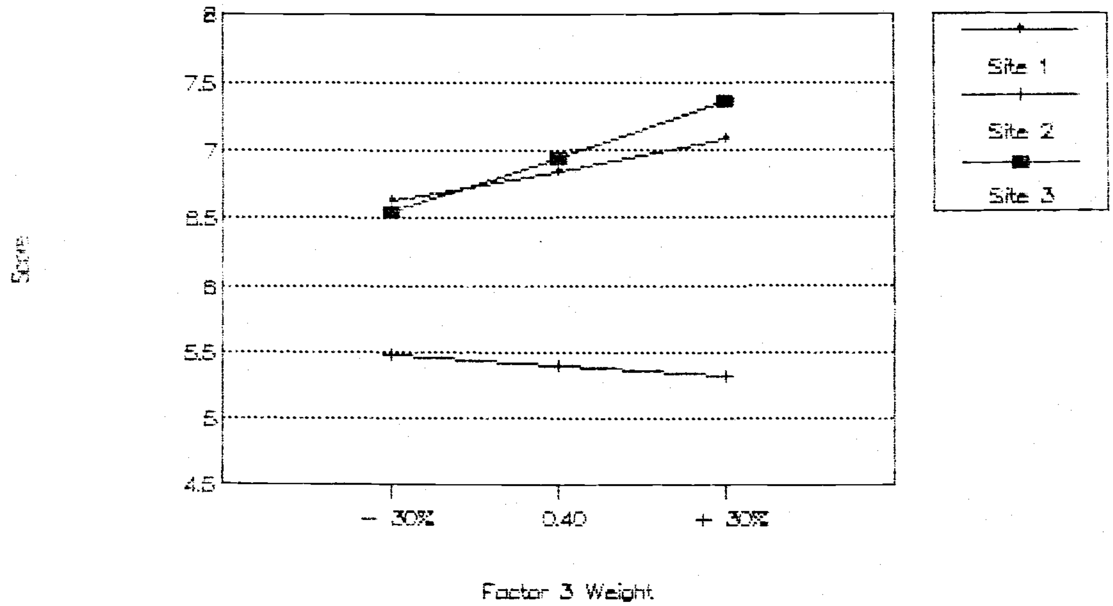

Figure 19. Sensitivity to Changes in Weight for Factor 3

0.10 or 1.4 percent. By increasing the weight of Factor 3, the difference increases to 0.28 or 3.8 percent. Next, the weight of Factor 3 is decreased by 30 percent, with appropriate adjustments to the other factor weights. Now the ranking of the sites also changes, although the difference between Site 1, the highest ranked, and Site 3 is only 0.08 or 1.2 percent. This analysis shows that, while the results do appear to be sensitive to the weight of Factor 3, Sites 1 and 3 are close enough in composite scores that either would be an acceptable site. Further analysis could be conducted to investigate the effects of incremental changes to other factor weights. If certain weights are felt to be highly uncertain or have high standard errors of the estimates (standard deviations), then they are likely candidates for sensitivity analyses. Furthermore, two or more weights could be varied at one time to observe the results.

A similar sensitivity analysis is conducted, using the highest weighted factor values as the "trigger". A high weight coupled with low factor measures may not contribute as much to the composite score as a factor with a lower weight but high values for the factor measures. By looking at the weighted values, the largest contributing factors can be identified and examined for weight sensitivity. The factor values could also be varied, either independently or in conjunction with variations in weights. Extreme changes to the weights may be examined to observe the effects. For example, the weight for a factor could be set at 1.0, 0.5, and 0, and the composite scores recalculated for each site.

By examining the weighted values shown in Table 13, it can be seen that Factor 3 has the greatest impact for all three sites, with Factors 1 and 5 also having a fairly large effect. Each of these factors are assigned weights of 1.0, 0.5 and 0, in turn, and the effects on the results examined. The remaining factors in each case are weighted equally. As can be seen in Figure 20, the changes to

Factor 3 had no effect on the ranking of the sites, although the scores for Sites 1 and 3 decreased significantly. However, the ranking was sensitive to the changes in the weights for Factor 1 and 5. Sites 1 and 3 showed considerable (and opposite) sensitivities to the changes in Factor 1. Site 1 also showed significant sensitivity to the changes in Factor 5. Use of these extreme values and observation of the resulting impacts can help refine the decision maker's thought processes with respect to reasonable weights and the choice of a preferred alternative or alternatives.

Selected components of the methodology described here will be further illustrated in the next chapter. The application presented involves the selection of a site for a small, biomass-fueled electrical generating plant.

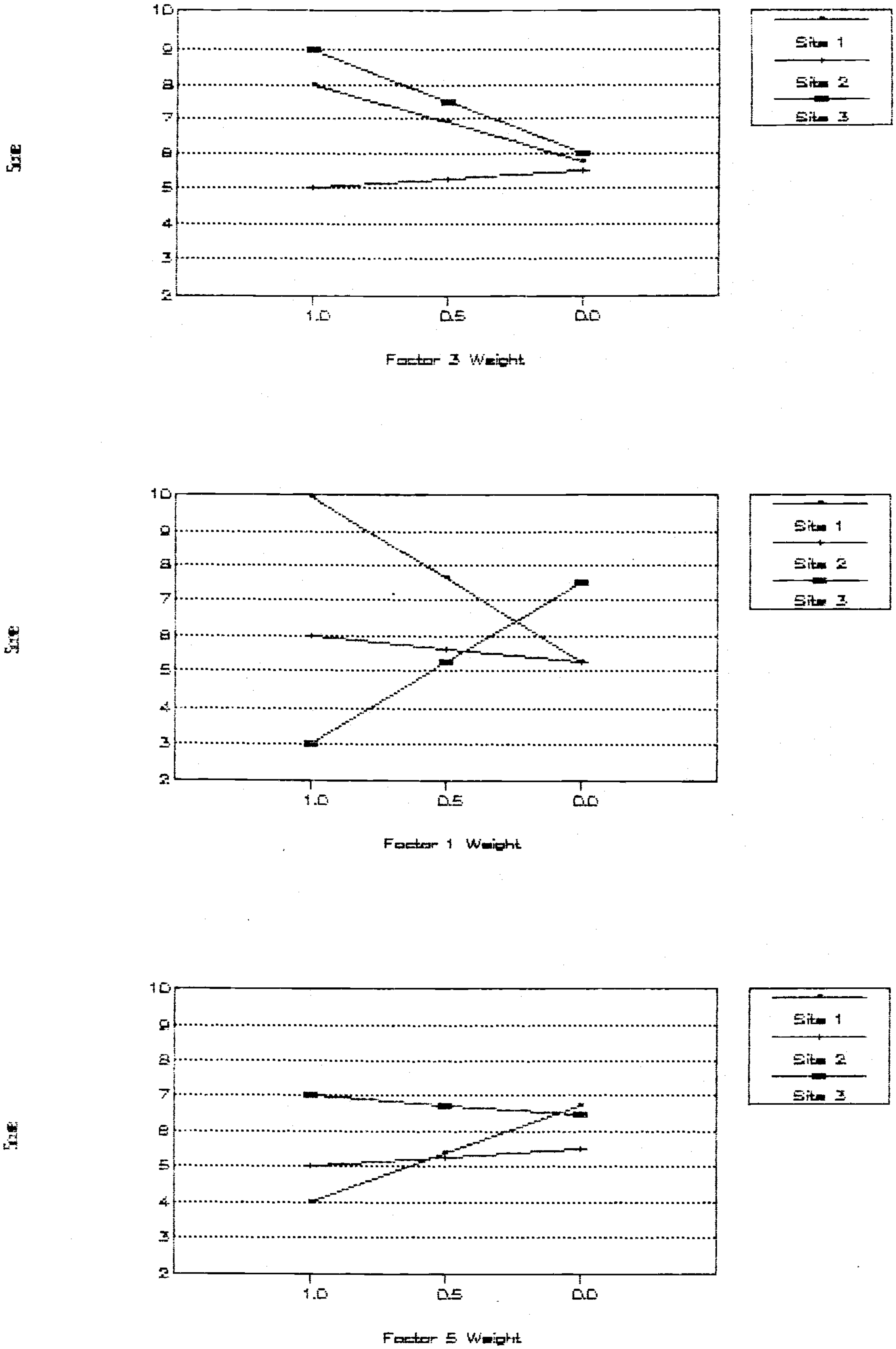

Figure 20. Sensitivity Analysis for Extreme Weight Changes

CHAPTER 4.

APPLICATION OF THE METHODOLOGY

The selection of a site for a small, biomass-fueled electrical generating plant is used to illustrate the methodology described in the preceding chapter. The initial study of this location problem was part of the Combined Cycle Biomass Energy Research Project, conducted at Oregon State University for the U.S. Department of Agriculture. The location analysis was included in Task 7: Economic and Marketing Analysis (West, et al, 1986). Provided here will be a more in-depth analysis of the site selection methodology, with emphasis on the factor importance weights, as outlined in Chapter 3. This project has the advantages of being relatively simple, yet flexible enough to adequately illustrate the concepts described earlier.

Background on the Project

The biomass plant described in this section is a small (approximately 10 megawatt) electrical generating plant that uses "biomass" as fuel. The fuel material, in this case, would be primarily waste wood products. The wood products are potentially available from a number of sources, including residues from logging, sawmills and other wood products manufacturing operations, and silviculture. Silvicultural residue includes hardwoods, pre-commercial thinnings, beetle-kill material, and residue from stand improvement operations. These wood fuels are then used to generate electricity, which could provide power at the same or a nearby site or could be sold to commercial customers or a local utility.

A major portion of the project cited above involved the mechanical design for the generating unit. The final design selected was a combined cycle system with a ceramic heat exchanger and an air heater. This plant has an expected net output of 9,504 kilowatts with a net efficiency of 21.63 percent. It consumes 170 million Btu's per hour and has an availability factor of 85 percent. The minimum fuel requirement is approximately 110,000 dry tons per year. The plant requires a water source which is capable of supplying water for the plant and absorbing the plant's discharge. The minimum requirement for this plant, including cooling tower make-up, is approximately 6,000 gallons per hour. Table 14 displays the financial data used in the Biomass Project Economic and Marketing Analysis (West, et al, 1986). This data will provide the basis for estimates of costs for the candidate sites to be considered in this evaluation.

Table 14. Basic Data for Economic Analysis

Project construction cost	$22,855*
Project first cost	$25,253
Project life	20 years
Operation and maintenance (O&M) (salaries, maintenance, etc.)	$ 710/yr
Operation and maintenance (fuel at $2.25/million Btu's)	$ 2,513/yr
Escalation rate, per year	5%
Amount of loan taken at time of project start	$25,253
Loan interest rate	10%
Depreciation	
equipment, yrs 1-5	$ 3,197/yr
facilities, yrs 1-18	$ 222/yr
Tax rate	33%
Investment tax credit	None
Discount rate	10%
Plant availability rate	85%
Generated power, per year	70,767 MW
Levelized cost of electricity (after-tax breakeven value over 20 yr period)	$0.102/kWh

* All costs except the levelized cost of electricity are in thousands of 1988 dollars.

The selection of a site for such a plant involves the levels of analysis presented earlier. For this study, the assumed general region for the plant is the Pacific Northwest. Within a particular area in the general region (in this case, western Oregon), the justification of the economic feasibility of the plant is also assumed. What remains is to select from among a set of technically feasible sites within this area. Technically feasible sites are those which meet the critical requirements for the plant, although some modifications either at the site or in the plant design may be required before a plant could be located there.

Developing and Refining the Site Factors List

A list of twelve site factors that were considered pertinent to the biomass plant site selection project was developed. To develop this list, input was solicited from individuals who had some knowledge of and familiarity with power generation, particularly using alternative fuels, and/or forestry operations. They included personnel from the OSU Forest Research Laboratory, the OSU Colleges of Engineering and Forestry, the Oregon State Department of Energy, and representatives from public utilities. The factors identified include:

* Volume of wood supply
* Competition for the wood supply
* Air quality standards at the location
* Distance from the wood supply (maximum haul distance)
* Volume and quality of water supply
* Distance from power transmission lines
* Distance from a road network
* Current zoning of the available land
* Site preparation required
* Total amount of land available
* Topography and soil conditions
* Labor availability

Twelve is a manageable number of factors that still provides adequate coverage of the important considerations.

In identifying minimum and maximum plausible values for these factors for the plant under consideration, certain factors were determined to have critical or mandatory values. Failure to meet any one of these critical requirements would remove a site from further consideration. The critical factors with their limits are:

* Volume of wood supply (110,000 tons per year minimum)
* Air quality standards at the location (cannot be in a restricted area)

* Distance from the wood supply (60 miles maximum haul distance from farthest unit of fuel)
* Volume and quality of water supply (6,000 gallons per hour minimum)
* Total amount of land available (30 acres minimum)

The current zoning of the available land may also eliminate a site, depending on the difficulty of rezoning.

Restructuring the identified factors within the major categories in the master site factors list (Appendix II) yields the following classification. This order will be used in the remainder of the chapter.

I. LAND

1. Current zoning of the available land
2. Site preparation required
3. Total amount of land available
4. Topography and soil conditions

II. UTILITIES

5. Volume and quality of water supply

III. TRANSPORTATION

6. Distance from a road network

IV. MARKETS

7. Distance from power transmission lines

V. MATERIALS, SUPPLIES AND SERVICES

8. Volume of wood supply

9. Competition for the wood supply

10. Distance from the wood supply

VI. LABOR

11. Labor availability

IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS

12. Air quality standards at the location

These factors are all nonmonetary and will require both objective measurements and subjective assessments. Cost considerations are not incorporated into the factor list but will be discussed later in the analysis.

Assigning Importance Weights and Finalizing the Factors List

In order to develop importance weights for the twelve site factors, evaluators were selected from local utilities and industries that had experience with cogeneration. The weights were developed using a paired-comparisons survey. Each factor was paired once with every other factor (partial paired comparisons) and the respondents were asked to identify which factor in each pair was felt to be more important. A copy of the survey form is included in Appendix IV.

The number of times each factor was ranked as more important were summed up for all the evaluators. This subtotal for each factor was then divided by the total of all responses from all evaluators to calculate a normalized weight. The results of the survey and the calculated weights are shown in Table 15.

Table 15. "More Important" Subtotals and Resulting Weights

Factor	Subtotal	Weight
1. Current zoning of the available land	45	0.0734
2. Site preparation required	33	0.0538
3. Total amount of land available	30	0.0489
4. Topography and soil conditions	28	0.0457
5. Volume and quality of water supply	57	0.0930
6. Distance from a road network	47	0.0767
7. Distance from power transmission lines	50	0.0816
8. Volume of wood supply	88	0.1436
9. Competition for the wood supply	87	0.1419
10. Distance from the wood supply	57	0.0930
11. Labor availability	18	0.0294
12. Air quality standards at the location	73	0.1191
	---	------
Totals	613	1.0000

As can be seen from the above calculations, the highest weighted factors are the volume of wood supply (Factor 8) and the competition for the wood supply (Factor 9) at 0.1436 and 0.1419, respectively. These are both included under Materials, Supplies and Services. The third most important factor belongs to the Environmental and Ecological Considerations category: the air quality standards at the location, with a weight of 0.1191. The lowest weighted factor, at 0.0293, is labor availability, a Labor factor. At this time, no factors will be removed from the list.

Using the paired comparisons method, all weights are multiples of the reciprocal of the total number of responses, which is 0.00163 for the biomass project. The weight calculated for the highest weighted factor (0.1436) is less than five times the weight for the lowest weighted factor (0.0294). However, the evaluators may well feel that the volume of wood supply is much more than five times as important as labor availability in selecting a site for the biomass plant. This is a weakness of the paired comparisons weighting method; it does not reflect the perceived ratios of importance among the factors. Furthermore, because of the way that the weights are derived, the maximum weight from partial paired comparisons is equal to 2/n, where n is the number of factors. For the biomass project, the maximum weight would be 2/12 or 0.1667.

Measuring the Site Factors

The factors selected for evaluation are a combination of objective and subjective factors, and for both, a zero-to-ten utility scale is used. For the objective factors, there are both "more is better" factors, for which an increasing linear utility function is used, and "less is better" factors, for which a decreasing linear function is used. There are no factors for which an intermediate value between the minimum and maximum plausible values was considered to be preferable, which would be represented by a bilinear function.

Where a higher measure is more desirable, Equation [1] (from Chapter 2) applies, with a multiplier of 10 instead of 100. These factors and their applicable equations, with the appropriate numbers for the maximum and minimum plausible measures, are listed below. Calculated values outside the range from zero to ten are assigned the corresponding endpoint values.

3. Total amount of land available (30 acres minimum)

   $V_A = 10 * (M_A - 30)/(60 - 30)$

5. Volume and quality of water supply (6,000 gallons/hour minimum)

   $V_A = 10 * (M_A - 6,000)/(12,000 - 6,000)$

8. Volume of wood supply (110,000 tons/year minimum)

   $V_A = 10 * (M_A - 110,000)/(220,000 - 110,000)$

These factors are all critical factors for which the minimum value must be available or the site will be eliminated from consideration.

Where a lower measure is more desirable, Equation [2] (Chapter 2) applies, with the multiplier again changed to

10. The calculations are handled similarly to the previous set, using the following equations.

6. Distance from a road network (2 miles maximum)

$V_A = 10 * (2 - M_A)/(2 - 0)$

7. Distance from power transmission lines (5 miles maximum)

$V_A = 10 * (5 - M_A)/(5 - 0)$

10. Distance from the wood supply (60 miles maximum haul distance)

$V_A = 10 * (60 - M_A)/(60 - 0)$

11. Labor availability (measured as distance in miles to a minor population center, with 15 miles maximum)

$V_A = 10 * (15 - M_A)/(15 - 0)$

The distance from the wood supply is considered a critical factor which would disqualify a site from further consideration if it failed to meet the stipulated requirement.

The subjectively assessed factors are evaluated against descriptive classes which are assigned values from zero to ten. These factors, their descriptive classes and assigned values are shown in Table 16. Values between the numbers shown can also be used to reflect intermediate assessment levels. The air quality standards at the location is a critical factor. Under certain circumstances, the current zoning of the site could also effectively eliminate an alternative.

Table 16. Descriptions and Values for Subjective Factors

Factor	Value
1. Current zoning of the available land	
Rural-residential	1
Farm use	3
Forest management	5
Other agricultural	7
Industrial	9
2. Site preparation required	
Extensive earthwork	1
Moderate earthwork	5
Little or no earthwork	9
4. Topography and soil conditions	
Extensive stabilizing material required	1
Moderate stabilizing material required	5
Little or no stabilizing material required	9
9. Competition for the wood supply	
More than 3 competitors	1
3 competitors	3
2 competitors	5
1 competitor	7
No competitors	9
12. Air quality standards at the location	
In a non-attainment area	0
Near the boundary of a non-attainment area	5
In an attainment area	9

Using the equations and descriptive classes given above, each factor can be evaluated for each candidate site. Generally, the data required to adequately measure these factors are easily obtainable without expending excessive amounts of time and money. Estimates for most of the values will be adequate although judgment will be required to assess the appropriate subjective class (and corresponding numerical value) for each site.

For this analysis, six candidate sites will be evaluated. Their utility values for each of the factors have been assessed using the appropriate equations or descriptions. These values for each site are shown in Table 17, along with the factor weights previously assigned.

Table 17. Weights and Measures for Six Alternative Biomass Plant Sites

		Weights	Site A	Site B	Site C	Site D	Site E	Site F
Factor 1	Current zoning of land	0.0734	4.0	6.0	8.0	4.0	9.0	6.0
Factor 2	Site preparation required	0.0538	3.0	7.0	6.0	3.0	8.0	7.0
Factor 3	Amount of land available	0.0489	2.0	3.0	1.0	7.0	0.0	7.0
Factor 4	Topography & soil conditions	0.0457	1.0	9.0	3.0	8.0	2.0	5.0
Factor 5	Volume of water supply	0.0930	6.0	4.0	2.0	2.0	10.0	6.0
Factor 6	Distance from roads	0.0767	5.0	5.0	7.0	4.0	7.0	5.0
Factor 7	Distance from power lines	0.0816	5.0	5.0	4.0	3.0	8.0	6.0
Factor 8	Volume of wood supply	0.1436	10.0	0.0	9.0	5.0	2.0	5.0
Factor 9	Competition for wood	0.1419	9.0	1.0	9.0	7.0	3.0	5.0
Factor 10	Distance from wood supply	0.0930	7.0	3.0	2.0	2.0	9.0	7.0
Factor 11	Labor availability	0.0294	0.0	10.0	1.0	6.0	3.0	7.0
Factor 12	Air quality standards	0.1191	8.0	2.0	8.0	8.0	1.0	6.0

Rating the Sites

The candidate sites described above are evaluated using an additive-weighted model. The weighted factor values are calculated by multiplying the factor values by the appropriate weights. These weighted values are summed to arrive at a final composite score for each site. These calculations are shown in Table 18. The use of a micro-computer spreadsheet program greatly simplifies calculations and will be very helpful in analyzing the results.

As can be seen in Table 18, the composite scores range from a high of 6.264 for Site A to a low of 3.736 for Site B. The difference between high and low is 2.528. The second highest rated site is Site C with a composite score of 5.883, followed by Site F at 5.817. The next section will analyze these results in more detail.

Analyzing the Results

Although Site A appears to be the preferred site based on the calculated scores, a more thorough analysis should be performed before recommending its selection. This evaluation will consider costs, dominance, and the significance of the differences in the scores. Since there are no non-discriminatory factors for the six sites under

Table 18. Site Evaluations Using Paired Comparisons Weights

Factor	Site A Meas	Site A Wtd Val	Site B Meas	Site B Wtd Val
1. Current zoning of land	4.0	0.294	6.0	0.440
2. Site preparation required	3.0	0.162	7.0	0.377
3. Amount of land available	2.0	0.098	8.0	0.392
4. Topography/soil conditions	1.0	0.046	9.0	0.411
5. Volume of water supply	6.0	0.558	4.0	0.372
6. Distance from roads	5.0	0.383	5.0	0.383
7. Distance from power lines	5.0	0.408	5.0	0.408
8. Volume of wood supply	10.0	1.436	0.0	0.000
9. Competition for wood	9.0	1.277	1.0	0.142
10. Distance from wood supply	7.0	0.651	3.0	0.279
11. Labor availability	0.0	0.000	10.0	0.294
12. Air quality standards	8.0	0.953	2.0	0.238
TOTAL SCORE		6.264		3.736
RANK		1		6

Factor	Site C Meas	Site C Wtd Val	Site D Meas	Site D Wtd Val
1. Current zoning of land	8.0	0.587	4.0	0.294
2. Site preparation required	6.0	0.323	3.0	0.162
3. Amount of land available	1.0	0.049	7.0	0.343
4. Topography/soil conditions	3.0	0.137	8.0	0.365
5. Volume of water supply	2.0	0.186	2.0	0.186
6. Distance from roads	7.0	0.537	4.0	0.307
7. Distance from power lines	4.0	0.326	3.0	0.245
8. Volume of wood supply	9.0	1.292	5.0	0.718
9. Competition for wood	9.0	1.277	7.0	0.993
10. Distance from wood supply	2.0	0.186	2.0	0.186
11. Labor availability	1.0	0.029	6.0	0.176
12. Air quality standards	8.0	0.953	8.0	0.953
TOTAL SCORE		5.883		4.927
RANK		2		5

Factor	Site E Meas	Site E Wtd Val	Site F Meas	Site F Wtd Val
1. Current zoning of land	9.0	0.661	6.0	0.440
2. Site preparation required	8.0	0.431	7.0	0.377
3. Amount of land available	0.0	0.000	7.0	0.343
4. Topography/soil conditions	2.0	0.091	5.0	0.228
5. Volume of water supply	10.0	0.930	6.0	0.558
6. Distance from roads	7.0	0.537	5.0	0.383
7. Distance from power lines	8.0	0.653	6.0	0.489
8. Volume of wood supply	2.0	0.287	5.0	0.718
9. Competition for wood	3.0	0.426	5.0	0.710
10. Distance from wood supply	9.0	0.837	7.0	0.651
11. Labor availability	3.0	0.088	7.0	0.206
12. Air quality standards	1.0	0.119	6.0	0.715
TOTAL SCORE		5.059		5.817
RANK		4		3

consideration, that aspect of the methodology will not be demonstrated in this analysis.

Cost Considerations and Dominance. Since costs have not been included in the multi-criteria model, they can be evaluated separately and in conjunction with the composite nonmonetary scores. A comprehensive cost analysis would include consideration of the costs of building and operating the biomass plant, plus the costs that would influence the selection of a particular site. The investment (or first) cost and annual operating and maintenance expenses for the plant alone are shown in Table 14. Also given are the parameters needed for the cost analysis, such as the useful life of the project, the discount rate, tax rate, escalation rate and depreciation charges.

The site-specific costs would include the initial cost of the land, financing costs for the purchase of the land, site improvements required (such as site preparation and the building of roads, transmission lines and water supply systems), and the annual property and other taxes on the land. Certain operating expenses for the plant, such as fuel costs, can also be expected to differ as a result of the location. Estimates of these costs for the six candidate sites have been coupled with the facility costs to yield an overall figure representing the total cost for the biomass plant at each of the six locations. These cost figures, shown in Table 19, are given in dollars per kilowatt-hour ($/kWh), assuming the generation of 70,767 megawatts per year. The costs are also transformed to a zero-to-ten scale, using the "less is better" formulation, and values of $0.200/kWh and $0.100/kWh for the maximum and minimum plausible values, respectively.

Table 19. Costs for Alternative Sites: Biomass Plant

	Site A	Site B	Site C	Site D	Site E	Site F
Costs ($/kWh)	0.140	0.131	0.134	0.148	0.159	0.126
Monetary Score	6.0	6.9	6.6	5.2	4.1	7.4

As can be seen in Table 19, the rank order of preference from lowest to highest cost is F-B-C-A-D-E, where F has the lowest cost and E the highest. The ranking by nonmonetary score is A-C-F-E-D-B, from Table 18. The lowest cost site (F) is third in the nonmonetary ranking. Similarly, the highest scoring site on nonmonetary factors (Site A) is fourth in the cost ranking. Site B, which scores the lowest on nonmonetary factors, is the second best (lowest cost) site. Unfortunately, no clear favorite can be found based on this comparison of monetary and nonmonetary rankings.

However, using the relative rankings for cost and noncost scores, the list of candidate sites can be checked for dominance. If a particular site is lower than another site (or sites) on both rankings, then it can be dropped from further consideration. This can be especially helpful when the list of candidate sites is long and the analysis is time-consuming. For example, in the rankings given above (and shown graphically in Figure 21), it can be seen that Site B is dominated by Site F. Site D is dominated by Sites A, C and F, and Site E is dominated by Sites A and C. These three sites, B, D and E, could be removed from the analysis. Sites A, C and F then remain as contenders. By pruning the list of alternative sites, the time and money spent on the analysis can be reduced or the remaining contenders can be evaluated in more detail for the same expenditure of resources.

To further assess the cost versus nonmonetary factor trade-offs, a graphical analysis can be used, as shown in Figure 21. Each site is graphed by plotting the cost score on the left axis and the nonmonetary score on the right axis. The line connecting these two endpoints represents an average of the two values for various relative weightings of costs to nonmonetary factors. At the left or cost endpoint, the cost considerations have a

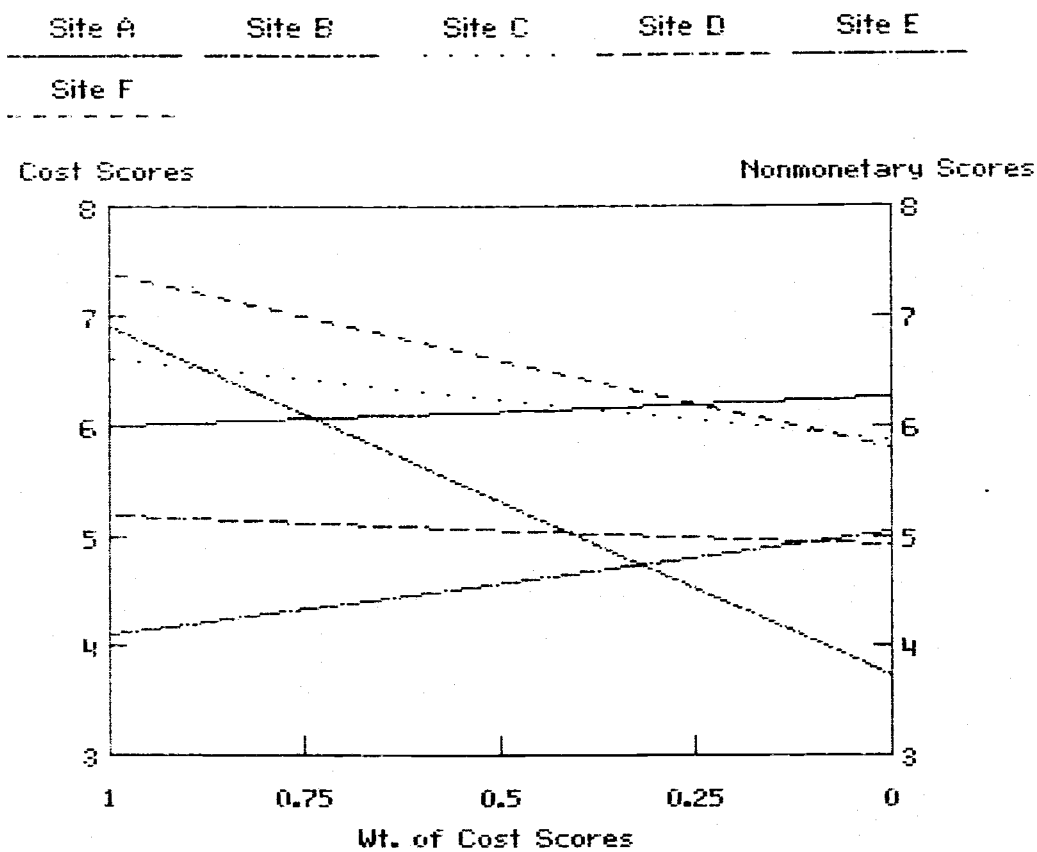

Figure 21. Cost Versus Nonmonetary Score Trade-Offs: Biomass Plant

weight of 1.0, while the nonmonetary scores have a weight of zero. The opposite is true at the right endpoint, where costs have zero weight and nonmonetary scores have a weight of 1.0. The top line in the figure represents the preferred site. Sites whose lines are always below the top line are dominated sites, which can be removed from the analysis.

On the top line in Figure 21, there is an intersection point for Sites A and F. To the left of this point, Site F would be preferred; to the right, Site A is higher. This is the indifference point; for this combination of costs and nonmonetary considerations, the decision makers would be indifferent about a choice of Site A or F. The point of intersection can be read off the graph or calculated by solving simultaneous equations. The indifference point is 0.24. In other words, if the nonmonetary factors are considered to be approximately three times as important as costs, then Site A would be preferred, on the basis of this analysis. Otherwise, Site F would be preferred. Sites B, D and E are clearly dominated by the other sites. Site C, although it is not dominated by a single other site, is always below either A or F, and hence, would be less desirable.

A combined monetary and nonmonetary score could be developed by calculating a weighted average, using the cost and nonmonetary scores, for a given set of importance assessments. For example, costs could be weighted relative to nonmonetary factors according to a 65:35 ratio. Then a combined score for each site could be calculated as shown:

Site A: $(0.65)(6.0) + (0.35)(6.264) = 6.09$

Site B: $(0.65)(6.9) + (0.35)(3.736) = 5.79$

Site C: $(0.65)(6.6) + (0.35)(5.883) = 6.35$

Site D: (0.65)(5.2) + (0.35)(4.927) = 5.10

Site E: (0.65)(4.1) + (0.35)(5.059) = 4.44

Site F: (0.65)(7.4) + (0.35)(5.817) = 6.85

These values demonstrate that, as expected, Site F would be the preferred choice, followed by Sites C and A. These positions can also be observed on the graphical display. Other weights could be used to investigate their effects.

Further information could be obtained through the performance of an incremental cost analysis. The three contending sites are listed in Table 20 in order of increasing costs and nonmonetary scores. The increase in costs (in $/kWh) and nonmonetary scores (in "points") are shown and the incremental ratios of dollars to points calculated. These ratios represent the dollar per kilowatt-hour value of a one-point increase in the nonmonetary score.

If dollar amounts can be developed to reflect the worth of an increase in a factor from the minimum to maximum plausible values, then the incremental ratios can be used to assist in the choice of site. For example, assume the decision makers would be willing to pay $3 million for a ten-point increase in the value of Factor 8, the volume of wood supply. A ten-point increase in Factor 8 would translate to a 1.436 point increase in the total nonmonetary score (10 times the weight of Factor 8, which is 0.1436). Thus the value of a one-point increase in the total score would be $3,000,000/1.436 = $1,754,875 per year or $0.0295/kWh, based on 70,767,000 kWh per year power generation.

Table 20. Incremental Cost Analysis

Site	Increase in Costs ($/kWh)	Increase in Scores	Incremental Ratio ($/kWh/pt)
F			
	0.008	0.066	0.1212
C			
	0.006	0.381	0.0158
A			
F			
	0.014	0.447	0.0313
A			

This value of $0.0295/kWh is below the incremental cost that would be incurred in selecting Site C over Site F, as shown in Table 20. Therefore, the additional cost for Site C would not justify the increase in the nonmonetary score. It might appear that the additional cost for Site A would be justified if its incremental cost is only $0.0158/kWh. However, this figure represents the incremental cost over Site C. The decision should be based on the incremental cost for Site A over Site F, which is also shown in Table 20. Since this cost is still higher than the amount that the decision makers are willing to pay (based on the evaluation of Factor 8), Site A would not be justified. On the basis of this incremental cost analysis, Site F would be the preferred site.

Significance of Score Differences. If costs are unknown or not significantly different (assumed to be equal) for all alternatives, then a decision must be based only on the nonmonetary factors. Examining the scores for the significance of their differences can assist in choosing among the alternatives. The significance of the differences among the scores for the six biomass alternatives can be examined by calculating the absolute and percentage differences between each pair of scores. Differences less than 10 percent will be viewed as being equally satisfactory sites (not significantly different). Figure 22 shows the sites listed in rank order with their scores and the calculated differences.

As can be seen, there is less than a 10 percent difference between Sites A and C, A and F, C and F, and E and D. This can be shown from the ranking by designating with an underline those sites that are not significantly different according to the selected criteria.

A C F E D B

The message to the decision maker is that, considering only the nonmonetary scores, the selection of any of the top three ranking sites (A, C or F) would be satisfactory.

SITE	SCORE	ABSOLUTE DIFFERENCES				
A	6.264	(A->)				
C	5.883	0.382	(C->)			
F	5.817	0.447	0.065	(F->)		
E	5.059	1.206	0.824	0.759	(E->)	
D	4.927	1.338	0.956	0.891	0.132	(D->)
B	3.736	2.529	2.147	2.082	1.323	1.191

SITE	SCORE	PERCENTAGE DIFFERENCES				
A	6.264	(A->)				
C	5.883	6.1%	(C->)			
F	5.817	7.1%	1.1%	(F->)		
E	5.059	19.2%	14.0%	13.0%	(E->)	
D	4.927	21.4%	16.3%	15.3%	2.6%	(D->)
B	3.736	40.4%	36.5%	35.8%	26.2%	24.2%

Figure 22. Absolute and Percentage Differences in Scores: Biomass Plant

<u>Subaggregation Analysis</u>. By reviewing the alternatives at the weighted factor value level, additional information can be obtained to aid in the analysis. The percentage contribution of each factor to the total score can be determined. As can be seen in Table 21, the major contribution varies depending on the site.

Table 21. Percentage of Weighted Factor Value Contribution to Total Score

		Site A	Site B	Site C	Site D	Site E	Site F
Factor 1	Current zoning of land	4.7%	11.8%	10.0%	6.0%	13.1%	7.6%
Factor 2	Site preparation required	2.6%	10.1%	5.5%	3.3%	8.5%	6.5%
Factor 3	Amount of land available	1.6%	10.5%	0.8%	7.0%	0.0%	5.9%
Factor 4	Topography & soil conditions	0.7%	11.0%	2.3%	7.4%	1.8%	3.9%
Factor 5	Volume of water supply	8.9%	10.0%	3.2%	3.8%	18.4%	9.6%
Factor 6	Distance from roads	6.1%	10.3%	9.1%	6.2%	10.6%	6.6%
Factor 7	Distance from power lines	6.5%	10.9%	5.5%	5.0%	12.9%	8.4%
Factor 8	Volume of wood supply	22.9%	0.0%	22.0%	14.6%	5.7%	12.3%
Factor 9	Competition for wood	20.4%	3.8%	21.7%	20.2%	8.4%	12.2%
Factor 10	Distance from wood supply	10.4%	7.5%	3.2%	3.8%	16.5%	11.2%
Factor 11	Labor availability	0.0%	7.9%	0.5%	3.6%	1.7%	3.5%
Factor 12	Air quality standards	15.2%	6.4%	16.2%	19.3%	2.4%	12.3%

Sites A, C, D and F generally have their largest contribution from Factors 8, 9, 10 and 12, which are among the highest weighted factors. Sites B and E have larger contributions in other factors. This analysis provides an indication of where sensitivities to changes in weights might have the greatest impact. For example, changes in the weights for Factors 8, 9, 10 and 12 can be expected to affect the results more for Sites A, C, D and F than for Sites B and E. Figure 23 shows, for each site, the contribution to the total score of the top five highest weighted factors. The percentage of the total score accounted for by the five factors ranges from less than 30 percent to nearly 80 percent.

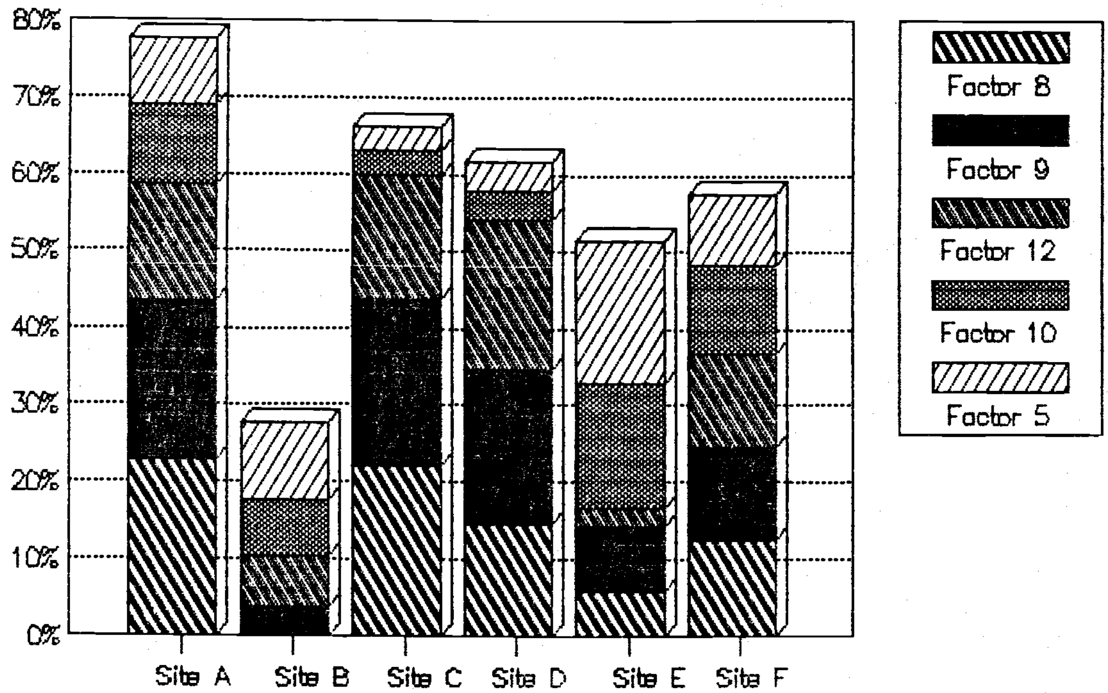

Figure 23. Contribution of Top Five Factors

The best and worst sites for each factor, based on the weighted factor values, are shown in Table 22. The range of the values from best to worst indicates where the greatest differences occur and which factors have the greatest impact on the scores. Other interesting information can be derived from this table. For example, although Site E is the best site for half of the factors, these factors are generally lower in weight. Site E is also the worst site for two of the factors. Site A is the worst site for four of the factors, although it scores highest overall based on total scores. Site F is neither best nor worst for any of the factors, but it ranks third highest on total scores. This analysis can help identify particular strengths and weaknesses of individual sites and also gives an indication of the impact of the best or worst position on the overall results.

Table 22. Best and Worst Sites Based on Weighted Factor Values

		Best Site	Weighted Value	Worst Site	Weighted Value	Value Range
Factor 1	Current zoning of land	E	0.661	A	0.294	0.367
Factor 2	Site preparation required	E	0.431	A	0.162	0.269
Factor 3	Amount of land available	B	0.392	E	0.000	0.392
Factor 4	Topography & soil conditions	B	0.411	A	0.046	0.365
Factor 5	Volume of water supply	E	0.930	C	0.186	0.744
Factor 6	Distance from roads	C, E	0.537	D	0.307	0.230
Factor 7	Distance from power lines	E	0.653	D	0.245	0.408
Factor 8	Volume of wood supply	A	1.436	B	0.000	1.436
Factor 9	Competition for wood	A, C	1.277	B	0.142	1.135
Factor 10	Distance from wood supply	E	0.837	C	0.186	0.651
Factor 11	Labor availability	B	0.294	A	0.000	0.294
Factor 12	Air quality standards	A, C, D	0.953	E	0.119	0.834

The subaggregation analysis is not intended to provide a specific recommendation of which site to select. However, it can assist in determining where additional effort should be expended in exploring the problem, such as an examination of weight sensitivities.

Sensitivity of Factor Weights

Although the factor weights used in the previous section were developed by a group of "experts", it may be desirable to examine the sensitivity of the decision to alternative sets of weights. Four other sets of weights were developed to use in analyzing the biomass site as described below. Explanations of the calculations used and the weaknesses of the methods can be found in Chapter 3.

Alternative Sets of Weights. The first alternative set of weights uses the ranking method and the opinions of the previous evaluators. Essentially, the preferences expressed in the paired comparisons were used to assign ranks to the same twelve factors. The rank sum method was then used to calculate weights. Table 23 shows the factors with their ranks and corresponding weights. Factors 5 (Volume and quality of water supply) and 10 (Distance from the wood supply) were felt to be equally important and thus both received a rank of 4.5 and a weight of 0.1090. Factor 8 (Volume of wood supply) is again the highest weighted factor with a weight of 0.1538, compared to 0.1436 from the paired comparisons.

Table 23. Alternative Weights Using Ranking

Factors	Rank	Weight
1. Current zoning of the available land	8	0.0641
2. Site preparation required	9	0.0513
3. Total amount of land available	10	0.0385
4. Topography and soil conditions	11	0.0256
5. Volume and quality of water supply	4.5	0.1090
6. Distance from a road network	7	0.0769
7. Distance from power transmission lines	6	0.0897
8. Volume of wood supply	1	0.1538
9. Competition for the wood supply	2	0.1410
10. Distance from the wood supply	4.5	0.1090
11. Labor availability	12	0.0128
12. Air quality standards at the location	3	0.1282
Total		1.0000

The next alternative weighting scheme uses a combination of rankings and the hierarchical structure discussed earlier. Each of the major factor categories is ranked relative to the other major categories. Under each major category, the factors are ranked relative to the other factors in that category. Weights are calculated at each level using the rank sum method. Then final weights are calculated using the tree structure and multiplying through the tree. Ranks and weights at each level are shown in parentheses. The final weight is shown in the last column in Table 24. Where only one subfactor is included within a major category, that factor is, of course, ranked number 1, with a weight of 1.0, and thus has the same weight as that shown for its major category.

Table 24. Alternative Weights Using Hierarchical Structure with Ranking

Factors			Final Weight
I.	LAND (6;0.07143)		
1.	Current zoning of the available land	(1;0.4)	0.0286
2.	Site preparation required	(2;0.3)	0.0214
3.	Total amount of land available	(3;0.2)	0.0143
4.	Topography and soil conditions	(4;0.1)	0.0071
II.	UTILITIES (3;0.1786)		
5.	Volume and quality of water supply		0.1786
III.	TRANSPORTATION (5;0.1071)		
6.	Distance from a road network		0.1071
IV.	MARKETS (4;0.1429)		
7.	Distance from power transmission lines		0.1429
V.	MATERIALS, SUPPLIES AND SERVICES (1;0.250)		
8.	Volume of wood supply	(1.5;0.4167)	0.1042
9.	Competition for the wood supply	(1.5;0.4167)	0.1042
10.	Distance from the wood supply	(3;0.1667)	0.0417
VI.	LABOR (7;0.0357)		
11.	Labor availability		0.0357
IX.	ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS (2;0.2143)		
12.	Air quality standards at the location		0.2143
Totals			1.0000

The combined hierarchical/ranking weighting method results in considerably different weights from those developed using the previously illustrated methods. For example, the highest weighted factor in this scheme is Factor 12 (Air quality standards at the location) with a weight of 0.2143. Use of the hierarchical structure creates the differences, particularly since several of the major factors have only a single subfactor, which, as a result, is weighted more heavily. One advantage of the hierarchical structure is that the evaluator, at each level, has fewer factors to compare to one another, thus simplifying the assignment of ranks. For the biomass project with only twelve factors, this may not prove a major benefit.

The third alternative weighting scheme again uses the hierarchical structure as shown above but assigns equal weights to each factor within a given level. The resulting final weights are shown in Table 25. The hierarchical structure results in the highest weights (0.1429) for the factors which have only one subfactor under the major category. The other major categories divide this weight equally among the subfactors.

The final alternative weighting scheme returns to the original list of twelve factors, without the hierarchical structure, and weights each factor equally. Each factor is assigned a weight equal to the reciprocal of the number of factors. In this case, the weight is equal to 0.0833. An equal weights assignment can be considered the "no information" option. It could be helpful in an analysis where there is considerable disagreement over the importance of the factors. Table 26 displays the weights for the original paired comparisons method and the alternatives just discussed.

Table 25. Alternative Weights Using Hierarchical Structure with Equal Weights

	Final Factors	Weight
I.	LAND	
1.	Current zoning of the available land	0.0357
2.	Site preparation required	0.0357
3.	Total amount of land available	0.0357
4.	Topography and soil conditions	0.0357
II.	UTILITIES	
5.	Volume and quality of water supply	0.1429
III.	TRANSPORTATION	
6.	Distance from a road network	0.1429
IV.	MARKETS	
7.	Distance from power transmission lines	0.1429
V.	MATERIALS, SUPPLIES AND SERVICES	
8.	Volume of wood supply	0.0476
9.	Competition for the wood supply	0.0476
10.	Distance from the wood supply	0.0476
VI.	LABOR	
11.	Labor availability	0.1429
IX.	ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS	
12.	Air quality standards at the location	0.1429
Totals		1.0000

Table 26. Alternative Sets of Weights

		Prd.Comp. Weights	Ranking Weights	Hr/Rank Weights	Hr/Equal Weights	Equal Weights
Factor 1	Current zoning of land	0.0734	0.0641	0.0286	0.0357	0.0833
Factor 2	Site preparation required	0.0538	0.0513	0.0214	0.0357	0.0833
Factor 3	Amount of land available	0.0489	0.0385	0.0143	0.0357	0.0833
Factor 4	Topography & soil conditions	0.0457	0.0256	0.0071	0.0357	0.0833
Factor 5	Volume of water supply	0.0930	0.1090	0.1786	0.1429	0.0833
Factor 6	Distance from roads	0.0767	0.0769	0.1071	0.1429	0.0833
Factor 7	Distance from power lines	0.0816	0.0897	0.1429	0.1429	0.0833
Factor 8	Volume of wood supply	0.1436	0.1538	0.1042	0.0476	0.0833
Factor 9	Competition for wood	0.1419	0.1410	0.1042	0.0476	0.0833
Factor 10	Distance from wood supply	0.0930	0.1090	0.0417	0.0476	0.0833
Factor 11	Labor availability	0.0294	0.0128	0.0357	0.1429	0.0833
Factor 12	Air quality standards	0.1191	0.1282	0.2143	0.1429	0.0833

Calculation of Composite Scores. For each of the alternative sets of weights in turn, the model is rerun using the same factor measures for the six candidate sites. The results are summarized in Table 27 and displayed graphically in Figure 24. The spreadsheet calculations for each of the runs are included in Appendix V.

It can be seen that the ranked order of the sites has changed for certain of the weight sets. Notice also that there is considerably less spread in the scores using the two equal-weight-based schemes. The differences in results will be analyzed in more detail in the following sections.

Table 27. Summary of Scores and Ranks for Alternative Weights

	Site A	Site B	Site C	Site D	Site E	Site F
Paired Comparisons						
Score	6.264	3.736	5.883	4.927	5.059	5.817
Rank	1	6	2	5	4	3
Ranking						
Score	6.596	3.404	5.962	4.756	5.263	5.814
Rank	1	6	2	5	4	3
Hierarchical/Ranking						
Score	6.521	3.479	5.780	4.812	5.339	5.791
Rank	1	6	3	5	4	2
Hierarchical/Equal						
Score	5.024	4.976	4.738	4.738	5.488	5.988
Rank	3	4	5 (tie)	6 (tie)	2	1
Equal						
Score	5.000	5.000	5.000	4.916	5.166	6.000
Rank	3 (tie)	4 (tie)	5 (tie)	6	2	1

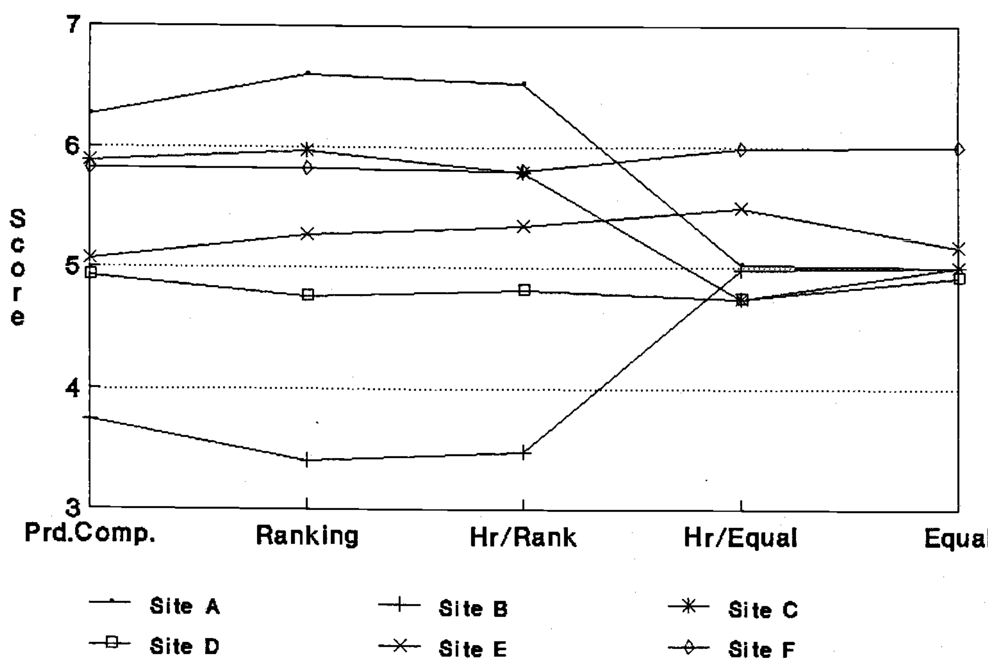

Figure 24. Scores for Alternative Weights

Dominance. By listing the ranked order of the sites for each of the weighting schemes, as shown, checks for dominance can be made. Notice that the ranked order resulting from the use of paired comparison weights is the same as that using ranking, and that the hierarchical structure with ranking differs only in the positions of Sites C and F. Similarly, the hierarchical structure with equal weights and the equal weights provide consistent results, except for the tie scores. These results are to be expected since the same opinions are reflected in each type of weighting scheme.

Weights	Ranked Order
Paired Comparisons	A-C-F-E-D-B
Ranking	A-C-F-E-D-B
Hierarchical/Ranking	A-F-C-E-D-B
Hierarchical/Equal	F-E-A-B-C-D (C-D: tie)
Equal	F-E-A-B-C-D (A-B-C: tie)

Checking for dominance indicates that Site B is dominated by Sites A, E and F, and Site C is dominated by Site A. Site D is dominated by Sites A, C, E and F, and Site E is dominated by Site F. The dominated sites can be easily identified by plotting the scores of the sites for two alternative weighting schemes that provide different results. For example, in Figure 25, the sites are plotted for the scores resulting from the paired comparisons weights versus the scores using the hierarchical/equal weights.

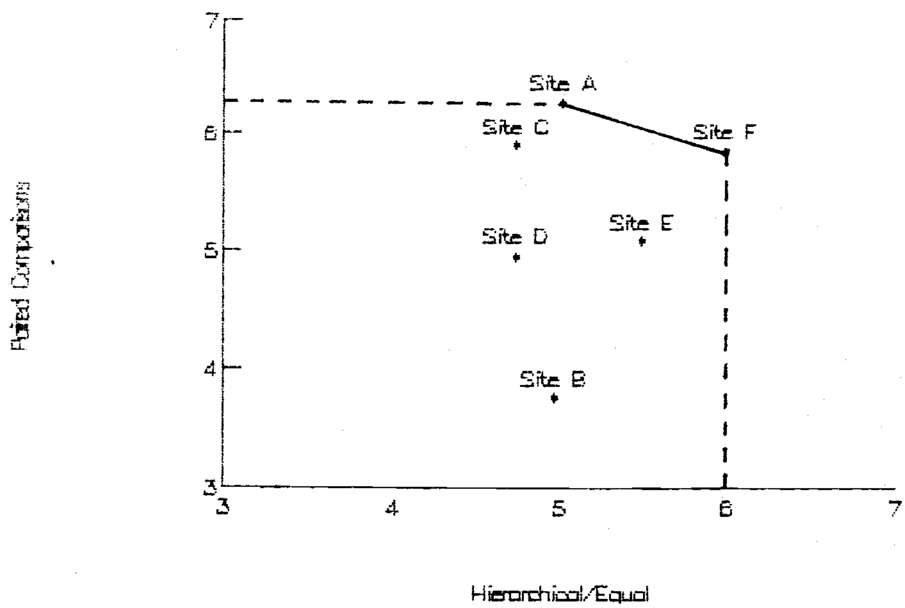

Figure 25. Dominance Graph for Alternative Weights

If the dominated sites are eliminated, only two sites remain as contenders: Sites A and F. However, it may be desirable to keep Sites C and E for further analysis. They are each dominated by only one other site. If the dominating site were removed from consideration for some reason (i.e., no longer on the market), then the dominated site would become a contender. Furthermore, Sites C and E each score fairly high with certain weightings of the factors.

<u>Changes in Rank Order</u>. As was seen above, the ranked order of the sites is sensitive to the weights assigned to each factor. Since the order obtained from the first three sets of weights are essentially the same, as is the order from the last two sets, only two alternatives will be considered here. These are the original paired comparisons weights and the hierarchical structure with equal weight assignments. Sites B and D are eliminated from the following analysis. Figure 26 plots the scores resulting from the use of each of the selected weight sets for the four remaining sites. The left axis shows the paired comparisons weighted scores and the right axis the hierarchical/equal weighted scores. The line connecting the endpoints for each site represents a weighted average of the two weighting schemes.

An examination of Figure 26 indicates that Sites A and F are consistently better than C and E, respectively. The solution of simultaneous equations yields the indifference point on the graphs of Sites A and F, with a relative weight for the paired comparisons of 0.6832 and a weighted average score of 5.871 for these two sites.

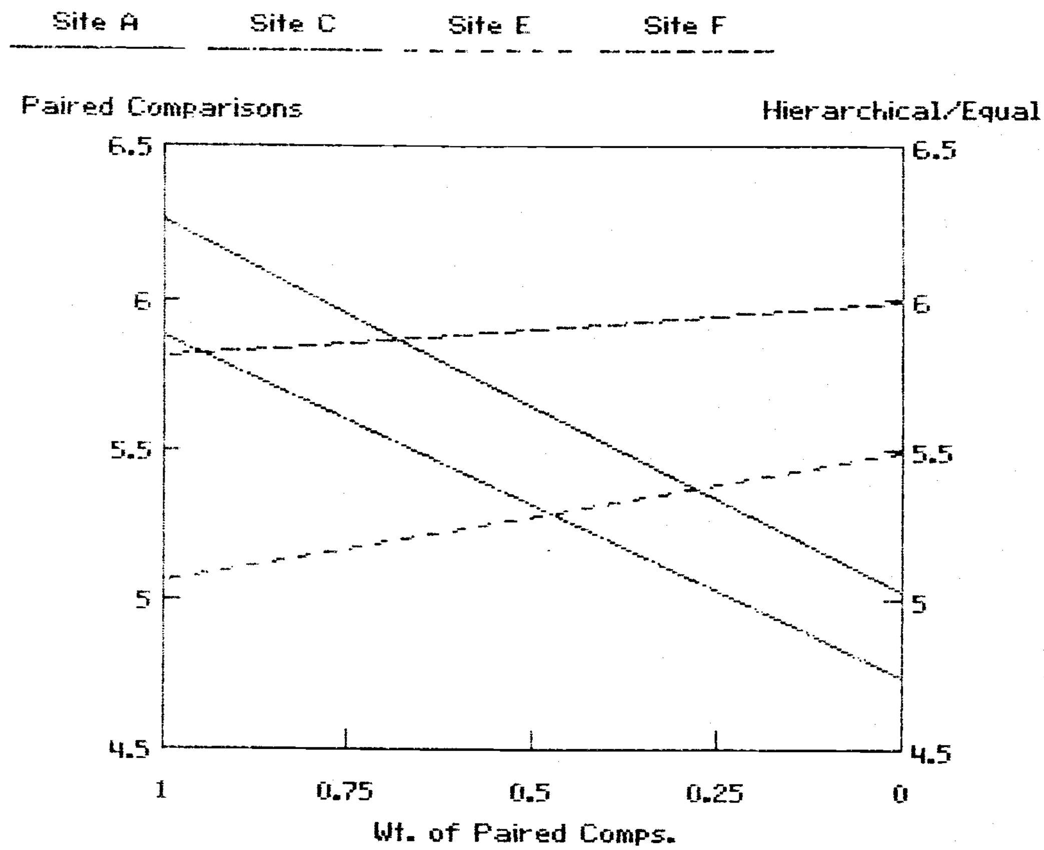

Figure 26. Trade-Offs Between Alternative Sets of Weights: Biomass Plant

Knowing the indifference point can help the decision makers choose a site by analyzing their "confidence" in the alternative sets of weights. If the decision makers are "more than 68 percent sure" that the paired comparisons weights are more realistic than the hierarchical/equal weights, then Site A should be selected. Otherwise, Site F would be preferred. Since the paired comparisons weights were developed using expert opinions collected through the survey process, the decision makers should trust these weights. This analysis provides a "confidence interval" for these weights, upon which the decision makers can base their final decision.

Additional analysis will be conducted in the next section to further examine the sensitivity of the results to the importance weights. Following that, cost considerations will again be incorporated into the decision process and a final recommendation provided.

Sensitivity Analysis of Weights. Using the subaggregation analysis to assist in identifying the factors of interest, a sensitivity analysis can be performed to determine the effects of changes in weights on the total scores. Four factors (Factors 8, 9, 10 and 12) were chosen for variation. Starting from an equal weight assignment, the weights for these factors were then varied by plus and minus 50 percent, with corresponding adjustments to the weights for the other factors to maintain the unity sum. The spreadsheet calculations are included in Appendix VI, and the results summarized in Table 28. This table gives the total scores for the four sites under consideration, using equal weights for each factor, and the revised scores resulting from the adjustments to the weights of the selected factors. The results of this sensitivity analysis are more easily analyzed by using Figures 27 through 30, which show the same information in graphical form.

Table 28. Weight Sensitivity Analysis

Factor		Site A	Site C	Site E	Site F
8. Volume of wood supply:	- 50%	4.773	4.818	5.311	6.045
	Equal	5.000	5.000	5.167	6.000
	+ 50%	5.227	5.182	5.023	5.955
9. Competition for wood supply:	- 50%	4.818	4.818	5.265	6.045
	Equal	5.000	5.000	5.167	6.000
	+ 50%	5.182	5.182	5.068	5.955
10. Distance from wood supply:	- 50%	4.909	5.136	4.992	5.955
	Equal	5.000	5.000	5.167	6.000
	+ 50%	5.091	4.864	5.341	6.045
12. Air quality standards:	- 50%	4.864	4.864	5.356	6.000
	Equal	5.000	5.000	5.167	6.000
	+ 50%	5.136	5.136	4.977	6.000

For all the factors modified in this analysis, changes to the weights caused very little change in the scores for Site F. The scores decreased slightly with increases in Factors 8 and 9, increased slightly with increases in Factor 10, and did not change for changes in Factor 12. Site F scored higher than the other three sites under all of the evaluated circumstances.

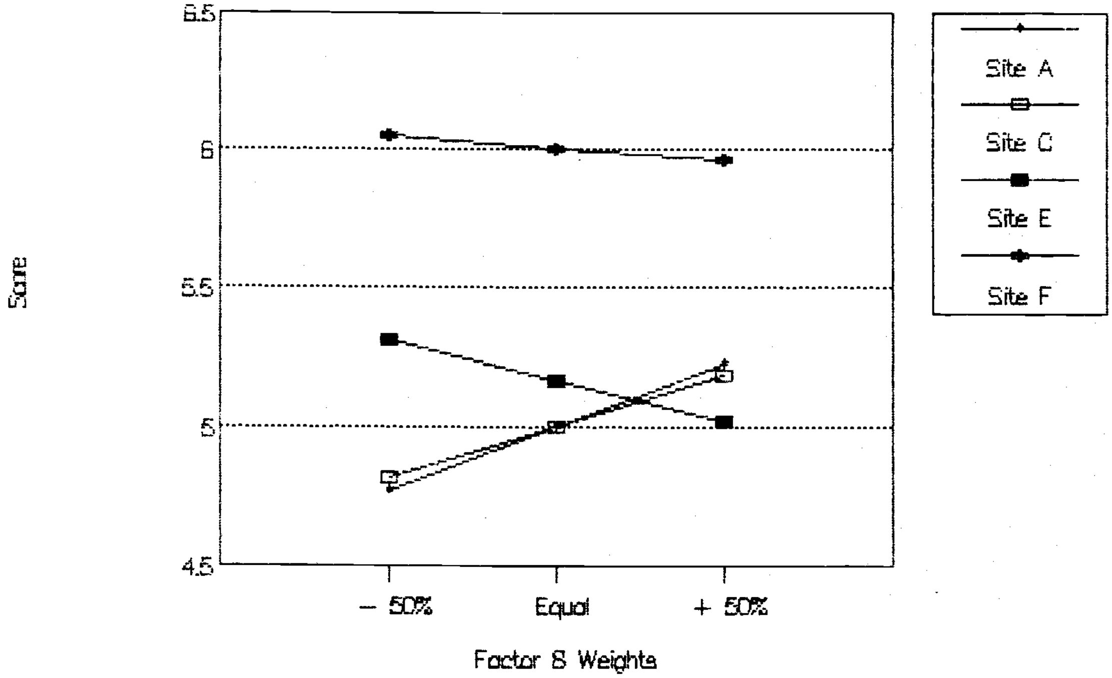

Figure 27. Sensitivity to Changes in Weight for Volume of Wood Supply

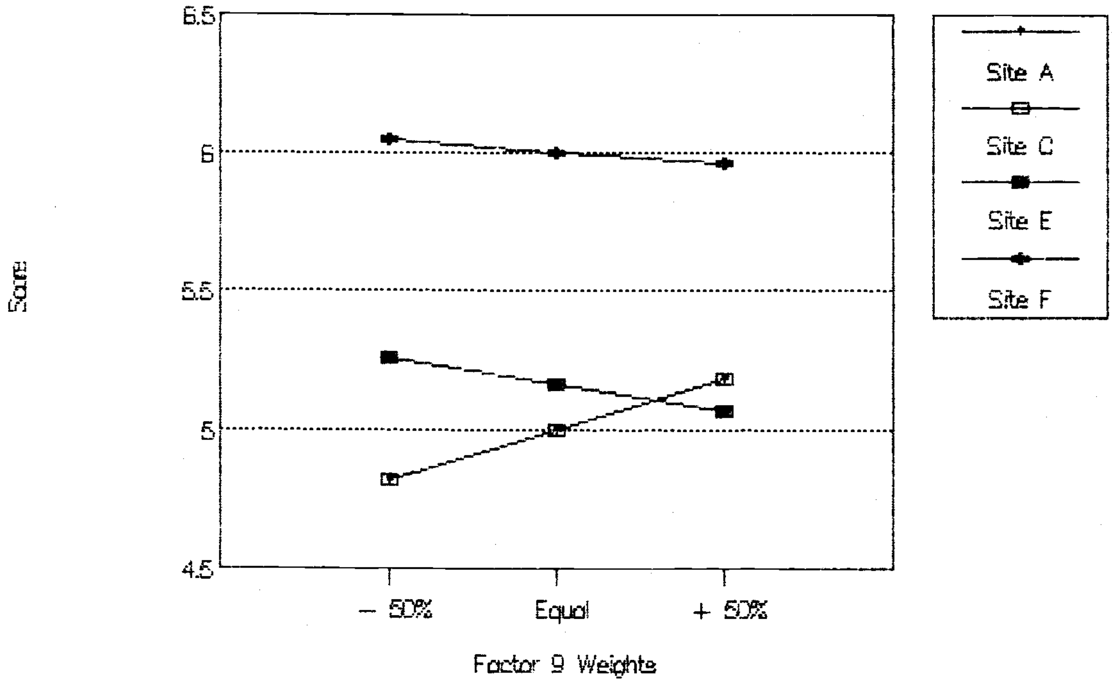

Figure 28. Sensitivity to Changes in Weight for Competition for Wood

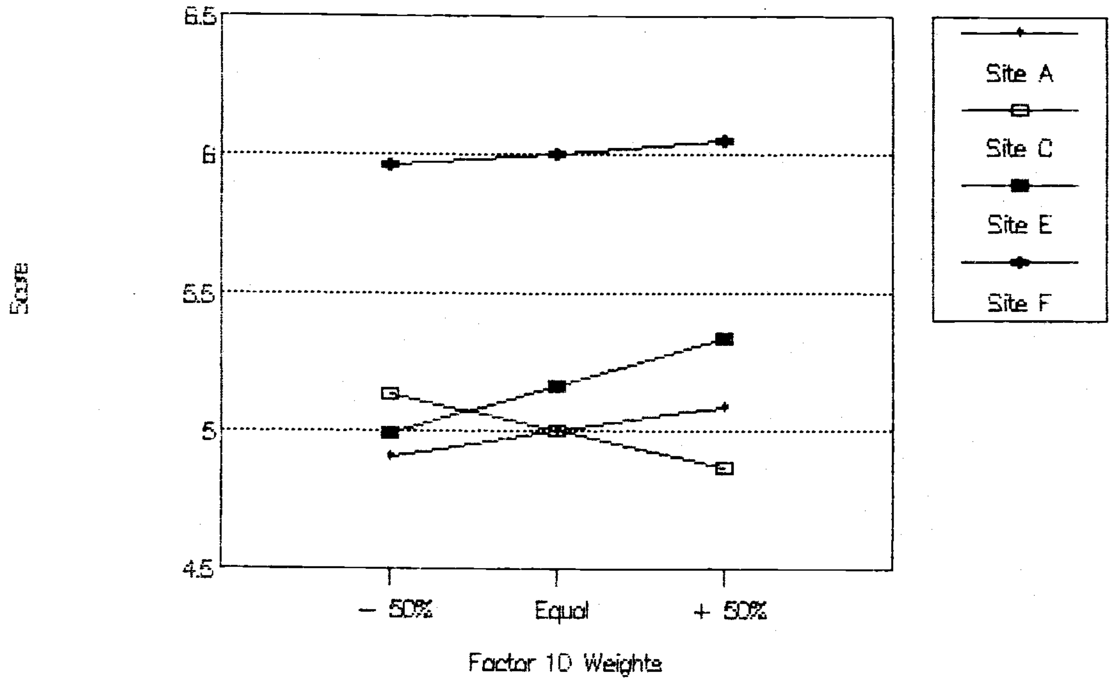

Figure 29. Sensitivity to Changes in Weight for Distance from Wood

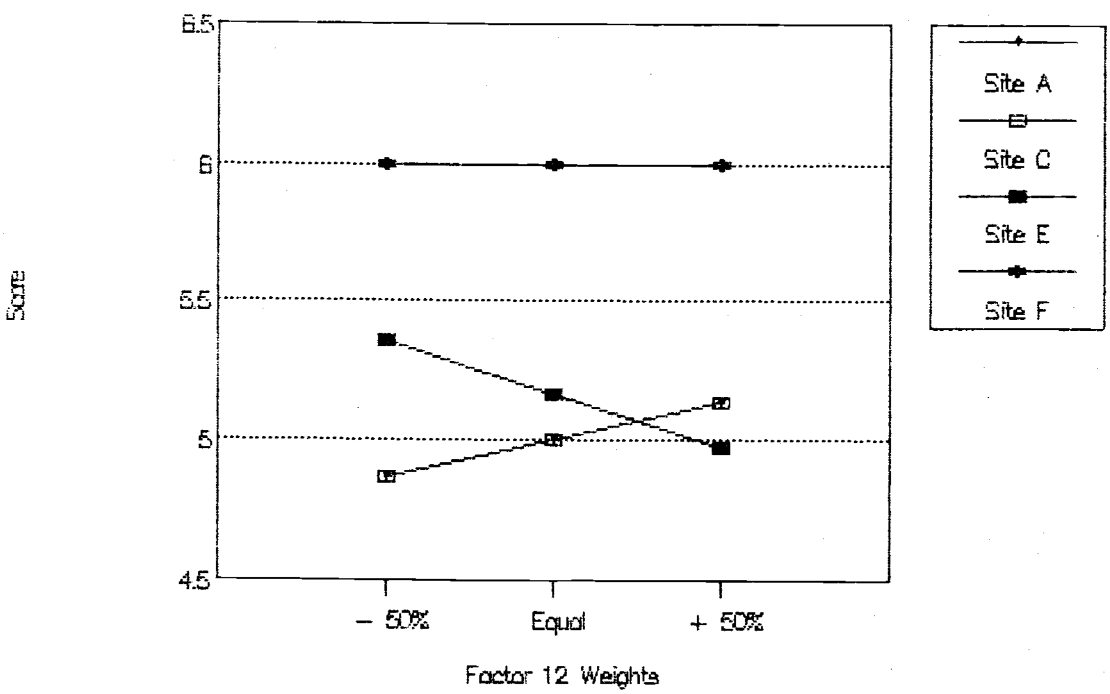

Figure 30. Sensitivity to Changes in Weight for Air Quality Standards

Although at a lower score level, Site E matches the pattern of changes in Site F, except that its score decreased with increases in Factor 12. Thus a selection between these two sites is not sensitive to changes in weights. Site F would be the better choice.

The scores for Site A increased with increases in each of the factors. Site C matches Site A in pattern and very closely in numerical values, except for Factor 10. For changes in the weights for Factor 10, Site C showed decreases in score with increases in weight. Thus a choice between Sites A and C is not quite as straightforward. However, C is better only for lower values of the Factor 10 weight. Since the paired comparisons weights developed using expert input yielded a higher weight for Factor 10, judgment can be applied to conclude that under expected weighting conditions, Site A would score higher than, and therefore, would be preferred to Site C.

Final Cost Considerations and Recommendation

On the basis of the extensive analysis of the nonmonetary factors, the preferred alternatives are Sites A and F. Site A has high factor values for the higher weighted (based on the paired comparisons) factors, and low values for the lower weighted factors. Hence, Site A scores highest using the paired comparisons weights in the model.

Site F, on the other hand, scores highest using the hierarchical/equal weights, which occurs because Site F has values in the middle range for all the site factors. It is neither outstanding nor borderline for any of the factors. A risk-adverse decision maker might prefer Site F, since it is less likely to be unsatisfactory with respect to all of the factors, although it is also not superior for any of them.

Before finalizing a decision strictly on the basis of the nonmonetary evaluation, consideration of applicable costs should again be brought into the analysis. Then the trade-offs between the cost estimates and nonmonetary scores can be reevaluated to aid in making the final decision. For Sites A and F, the costs scores (on a zero to ten scale) are shown in Table 29, along with the nonmonetary scores developed using the paired comparisons weights and the hierarchical/equal weights.

Table 29. Costs and Nonmonetary Scores

	Site A	Site F
Costs Scores	6.000	7.400
Nonmonetary Scores		
Paired Comparisons	6.264	5.817
Hierarchical/Equal	5.024	5.988

If the hierarchical/equal weights are used, then Site F would be the preferred choice because it dominates Site A (is higher in both scores). However, if the paired comparisons weights are used, then the relative importance of costs versus nonmonetary factors affects the decision. Figure 31 displays the graphs of the scores for costs versus nonmonetary factors for the two sites. Only if the nonmonetary factors are considered to be approximately three times as important as costs would Site A would be preferred. Otherwise, Site F would be the choice.

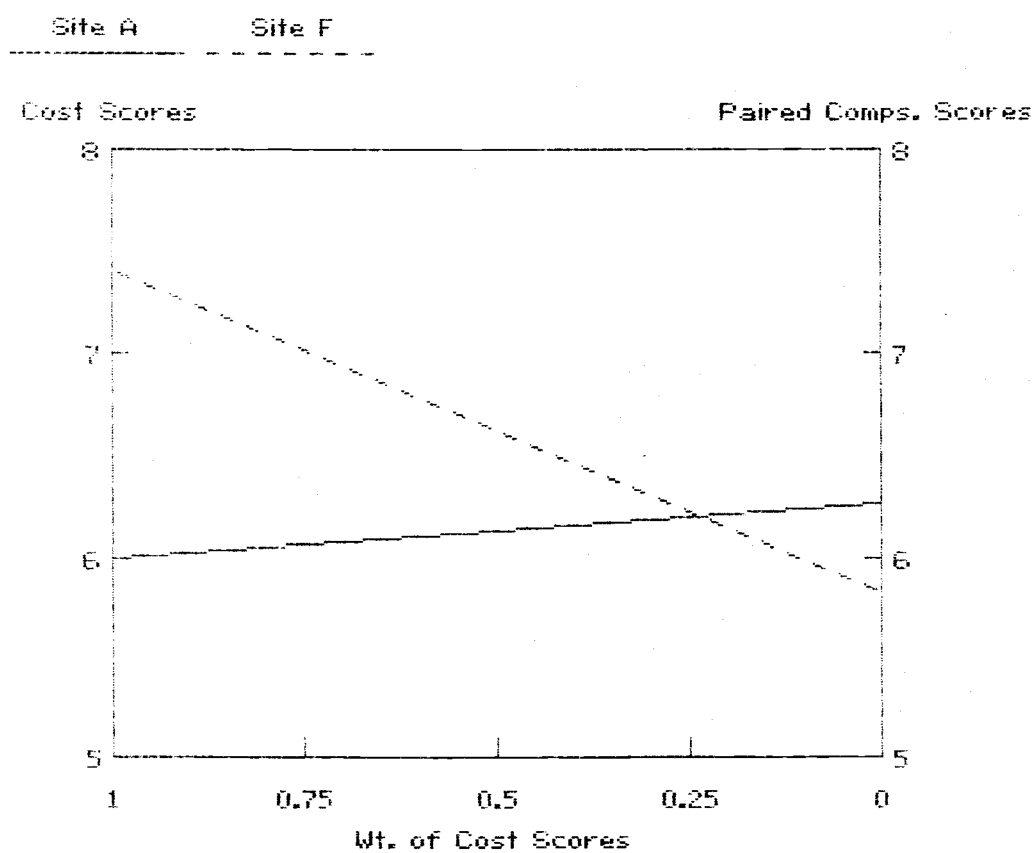

Figure 31. Final Cost Versus Nonmonetary Trade-Offs: Biomass Plant

The final choice depends on the confidence that the decision maker has in the requirements for the facility, the measures for the sites, and the importance weights. Cost differences and the ease of acquiring the sites and preparing for construction of the facility are also important considerations, as is management style. The decision aids provided here will greatly assist in the decision process.

CHAPTER 5.

CONCLUSIONS AND RECOMMENDATIONS

Summary of the Problem

The nature of the site selection problem, with many factors of varying degrees of importance, makes it particularly suitable for the application of the techniques of multi-criteria decision analysis. Basically, structuring the problem involves the identification of the factors of interest and the assignment of relative importance weights for the factors. Appropriate objective measures or subjective assessments of the factors are determined and translated to a common, dimensionless scale through the use of utility functions. Finally, a method of combining the weights and values into a composite score is selected. A specific study is conducted by quantifying the factors which describe the previously identified candidate sites (or areas or regions), calculating a composite score to compare the sites, and performing sensitivity analyses. The advantages and weaknesses of multi-criteria site selection models are briefly described below.

The advantages of this approach include the ability to consider more than one criteria, the quantification of both objective and subjective factors which enables mathematical calculations, and the development of a single number which represents each site under consideration and upon which a decision can be based. The approach is easily customized for individual projects by the selection of the factors which are considered to be the major impactors on the decision, and the assignment of relative importance weights to those factors to reflect the varying degrees of impact.

The studies typically conducted by or for a firm facing a site selection decision may suffer certain weaknesses, such as the use of an incomplete set of factors, improperly defined weights, incomplete analysis of results, and no examination of weight sensitivity. Some of the problems result from failures to properly follow the methodology, others from failures in the design of the methodology.

The incomplete factor list may arise from a lack of awareness of the many different factors which can affect the selection of a location and from undue attention to the latest "critical factor" in site selection. For example, at various times in the past, factors which have received the most attention with respect to site selection have included wage rates, low energy costs (and/or abundant energy supplies), tax rates, and investment incentives. Without considering how important one of these factors really is to an individual firm for a particular type of facility, a decision resulting from overemphasis on such factors can yield a most unsatisfactory location.

The difficulties with improperly defined weights may arise from the perceived implications of the weighting methods. However, the ratios reflected in the normalized weights may not represent the evaluators' actual feelings regarding the relative importance of the factors. For example, one factor may have a weight that is five times the value of another factor, implying that it is five times as important. But, it may actually be felt to be ten times as important or only twice as important. This problem typically arises with the use of rating and paired comparisons methods.

Other problems with weights may result from the failure to make consistency checks on the values assigned. This is particularly likely in paired comparisons, where circularity may arise. Circularity exists when Factor A is judged to be more important than B, B is more important than C, but C is considered more important than A. Other weaknesses may arise from the use of an average of weights from different evaluators without considering the variability of the weights.

Typically, the result of a multi-criteria analysis is the recommendation of the highest scoring site. Unfortunately, however, the pursuit of this site may require the expenditure of more money, time or negotiating efforts than would be required for a lower scoring site that would prove to be just as satisfactory with respect to the facility operation. If the scores for certain sites are not significantly different with respect to the multiple criteria, then any of these sites would be adequate. A final choice should not be made without considering the significance of the differences in scores and other analyses of the results.

The importance weights assigned to the factors are subject to the most disagreement since they are based on value judgments. Hence, the ability to defend the decision depends on a thorough analysis of the weights. Yet, the results of the multi-criteria model are seldom examined for sensitivity to changes in weights. Coupled with the failure to consider the variability in the weights, the lack of a weight sensitivity analysis means that unnecessary uncertainty remains regarding the choice among candidate sites. By viewing the effects of alternative sets of weights, the decision makers can identify if and where additional efforts should be directed to collect and analyze more data to enable further assessments. Sensitivity analyses of weights are particularly important where there is considerable disagreement among the weights that are or would be assigned by different evaluators or interested groups.

Summary of the Recommended Approach

The methodology described here addresses the weaknesses identified above through the development of a systematic approach to the analysis of the multi-criteria site selection process, with an emphasis on investigating the effects of weight sensitivity. In addition to the advantages described above for the general problem, additional advantages of this methodology are summarized below.

Providing a comprehensive list of site factors enables those undertaking site selection projects to benefit from the experience of others' efforts in developing lists of factors. Not only is time saved but potential impactors on the decision are not likely to be inadvertently overlooked. The list provided is quite extensive so some time will still be required to review it.

The hierarchical structure of the list is composed of ten major categories with more detailed levels of subfactors beneath them. The system of rating the factors (at the first level below the major factor categories) as critical, important or not important enables a relatively quick pruning of the list to the factors most likely to affect the selection of a site for a particular project. By eliminating those factors that are judged to be unimportant, the list of factors that must be considered can be reduced substantially.

The list will be further reduced during the development of importance weights. The final list of site factors should number between five and fifteen for most projects. Fewer are unlikely to thoroughly cover the important aspects of the decision. More will require the expenditure of efforts on factors with very little effect on the decision.

In developing importance weights for the site factors, a method that allows expression of ratios of relative importance is preferred. The ratio method and the simplified rank scaling method are recommended, using numerical scales such as from zero to ten or zero to one hundred. Multiple evaluators, representing different stakeholder groups, should be used, if possible. The sets of weights developed by these evaluators should be examined for major disagreements. The extent of the differences can be expected to be a function of the controversial nature of the project and/or the values of the evaluators. Variances can be used to provide confidence intervals for the results developed using different weights. An average of the weights developed by different evaluators can be calculated to use as another alternative set of weights in the sensitivity analysis.

The importance weights should be developed before collecting data to measure or assess the factors. This prevents the expenditure of time and money on factors that are of much lesser importance to the decision and is one of the major differences of this approach from the procedure typically followed by industries.

The data requirements are of two types: objective and subjective. Objective factors can be measured directly (or estimated within specified limits). Uncertainty in the values can be accommodated through the use of probability distributions. Objective measures can be of three basic types: more is better, less is better, and an intermediate value is better, within certain ranges. The actual measures are transformed to a dimensionless scale (such as zero to ten or zero to one hundred) through the use of utility functions. Equations are given for increasing linear functions, decreasing linear functions and bilinear functions.

Subjective factors generally cannot be measured directly but rather must be assessed by expert evaluation. Descriptive classes for different levels of the factors are developed to represent the possible states. These classes are then assigned values on the same scale used for objective measures. A site is assigned numerical values from the descriptions that best match it. Uncertainty in subjective assessments can be treated in a manner similar to the objective measures.

Rather than simply recommending the selection of the highest scoring site, this methodology provides a number of aids to more thoroughly analyze the results of the evaluation of alternative sites. Techniques for combining cost considerations with the scores for nonmonetary factors include the identification of indifference points and incremental cost analysis. Indifference points enable an assessment of the relative importance of costs versus nonmonetary factors. The incremental cost analysis provides a means of determining the costs of improvements to the nonmonetary scores and of justifying increased investments.

Dominance, either through cost trade-offs or arising from the utilization of alternative weights, can reduce the number of sites to consider. The significance of differences in scores can indicate which groups of sites should be considered for selection and which groups can be removed from the analysis since their scores are significantly lower. Insignificant score differences among the top scoring sites indicate that those sites would all provide satisfactory locations with respect to the multiple criteria.

Additional information can be obtained by subaggregation analysis. The identification of the best and worst sites with their respective weighted factor values and corresponding ranges points out the most critical differences and the sites that score the highest and lowest for these factors. This can aid in determining which factors might need additional analysis with respect to weights or factor measures.

Since the importance weights reflect subjective value judgments, they are the component of the multi-criteria model that is most uncertain. Before selecting the preferred site(s), the sensitivity of the results should be evaluated for changes in weights. Alternative sets of weights can be developed using a different method and/or different evaluators, a statistical average of the alternative sets of weights, or equal weights for the factors. The changes in the scores and ranking of the sites can be examined for changes resulting from the different weights. Graphical representations can greatly aid in viewing the results.

Depending on the changes that occur, additional efforts may be required to refine the importance weights or to determine the risks of uncertainty in the weights. The calculation of indifference points assists in identifying the preferred site by helping to assess the decision makers' confidence in the factor weights. The final decision might be affected by differences in costs and the efforts required to acquire the site and begin construction (finalizing the sale, obtaining permits, preparing the site).

Developing and implementing analyses as described in this methodology are aided by the use of a microcomputer-based spreadsheet program with graphics capability. Alternative sets of weights can be calculated using the appropriate equations. The equations for the utility functions used to transform objective measures to a common scale can also be entered into the spreadsheet. The basic structure of the additive-weighted model is well suited to the spreadsheet format with factors as rows and alternative sites as columns. The alternative sets of weights can be copied into the appropriate block and the weighted factor values and total scores calculated quickly. Graphs such as those shown in this paper assist in analyzing the results and would also prove useful in presentations to decision makers and other stakeholders.

One major advantage of using a spreadsheet program is that such software can be expected to be available in nearly every company considering site selection decisions. Spreadsheets offer flexibility and ease of use, which is beneficial since many location problems are one-time projects, with limited time and other resources. For companies that wish to develop an inventory of available sites, a spreadsheet package with database capabilities or one that can link up with database programs can provide extra power in analyzing sites. Some planning needs to go into the design of the database to provide easy transfer of the required information to the desired spreadsheet format.

Recommendations for Future Research

The methodology developed in this research was applied to the site selection process for a small, biomass-fueled electrical generating plant. This was a very specialized type of facility, which had a predetermined location in a particular region of the country, the Pacific Northwest. Twelve specific factors were considered in the evaluation of six candidate sites, which were selected to represent a range of values for the factor measures.

Future applications of the methodology would be desirable for different types of projects. The numbers and types of potential applications is extremely broad. Projects worthy of study include the siting of a private enterprise manufacturing plant, facilities for service industries such as hotels, and public projects, such as convention centers or airports. The process of selecting a site for a more controversial project, such as a nuclear power plant, waste dump, or prison, would provide additional opportunities to more fully test the process of developing and analyzing the effects of weights, since more parties (including the public) are involved and disagreements are likely to be unavoidable. An international site selection decision would also provide an interesting application.

The primary difficulty with further extensions in the application area is identifying companies that are about to embark on site selection projects. Furthermore, these companies must have the time, resources and willingness to be "test subjects": to work with the analyst in applying the methodology to their specific problems. Concerns about confidentiality may preclude the study of certain projects that would otherwise be excellent applications. Involvement in public projects is likely to be difficult due to a lack of authority. Economic development agencies may provide a source of projects, particularly if this methodology is offered as a service of the agency. Obviously, constraints on the geographic area to be considered can be expected, but that should not adversely affect the studies.

In a related area would be the future development of industry-specific importance weights that would reflect, at least in a general sense, the primary factors that impact location decisions for different types of companies. This would assist similar industries in identifying the factors of importance and provide a starting point for the development of their project-specific set of weights. Development of such weights would most likely be accomplished through the use of an industry survey, using Standard Industrial Classification (SIC) Codes to assign companies to the appropriate categories. The SIC system was developed by the federal government to classify establishments by the type of economic activity in which they are engaged. An fairly extensive effort, with the corresponding resource requirements, would be needed to adequately address the issue.

Anticipated difficulties include the identification of specific companies to include in the survey and the size of the sample that would be required, given the number of different types of industries and the expected returns from such survey instruments. Another potential problem is that those surveyed may respond differently to a general or hypothetical situation than they would if they were actually involved in a site selection project. Also many companies operate a variety of different types of facilities (production, distribution, service), for which the important factors are liable to differ, although specification of the applicable SIC Codes should avoid such difficulties. Finally, of course, there is the problem of acquiring the resources that would be required to conduct such a survey and analyze the results.

Opportunities also exist for more, in-depth analysis of the mechanics of the methodology. More complex models could be developed by relaxing or removing the simplifying assumptions used in this paper. For example, non-linear utility functions could be substituted if they provided a more realistic representation of values. An interesting study would compare linear and non-linear functions to determine the effects on the results, and to assess what such complexities add to the value of the analysis. (Edwards and Newman (1982) assert that the only time non-linear functions make a difference is when alternatives are quite similar, and then it does not matter which is chosen since they are equally satisfactory.)

Further work could also be done in incorporating the implications of factor dependence and attendant considerations of covariance among the factors. For the biomass plant application, the twelve factors were assumed to be mutually independent: not an unreasonable assumption. For other sets of factors, this might not be an acceptable assumption. Again, the additional analysis required should be evaluated in light of its contribution to the decision process.

Additional studies in this field will undoubtedly yield further suggestions for future research. Although primarily concentrating on the site selection problem, this work would also benefit applications of multi-criteria decision analysis in other fields.

TEXT NOTES

1. Marketing mix refers to the mixture of controllable marketing variables that a firm uses to pursue a sought level of sales in its target market. Marketing mix elements may be classified as the Four Ps: product, price, place, and promotion. (Kotler, 1984)

2. Johann Heinrich von Thunen, Der Solierte Staat in Beziehung auf Landwirtschaft, 3rd ed. (Berlin: Schumacher-Zarchlin, 1875).

3. Alfred Weber, Uber den Standort der Industrien (Tubingen, 1909) and the translation by C.J. Friedrich, Theory of the Location of Industries (Chicago: University of Chicago Press, 1929).

4. By viewing the supply of land as completely fixed, it can be described as an "original and inexhaustible gift of nature" whose total supply is by definition completely inelastic. The price or return to such a factor is called "rent". (Samuelson, 1967)

5. Agglomerating forces are those forces which tend to cause industry to gather densely in a limited area: the factors or forces favoring urban location. Deglomerating forces are those forces which tend to cause industry to scatter or to seek locations away from other industry: the factors or forces favoring rural location. (Reed, 1967)

6. Edgar M. Hoover, The Location of Economic Activity (New York: McGraw-Hill Book Co., 1958).

7. Melvin L. Greenhut, Plant Location in Theory and Practise (Chapel Hill, NC: University of North Carolina Press, 1956).

8. Although profit is an objective of the firm, profit maximization most frequently is not. From A.D.H. Kaplan, J.B. Dirlam, and R.F. Lanzillotti, Pricing in Big Business (Washington DC: The Brookings Institution, 1958).

9. The terms multi-criteria, multi-objective, and multi-attribute will be used interchangeably in this paper.

10. The Delphi technique involves the collection of estimates from experts followed by a blind review by these same experts of all the estimates. Successive rounds of refinement of the estimates eventually result in the final set of figures.

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APPENDICES

APPENDIX I

MAJOR FACTORS THAT AFFECT SITE SELECTION DECISIONS

MAJOR FACTORS THAT AFFECT SITE SELECTION DECISIONS

Item	Quantifiable?	Data typically developed from
1. Markets		
Access to Markets/Distribution Centers		
Cost of serving present markets/distribution ctrs.	Estimate possible	Location of markets/ distribution centers, quantities of each product shipped to each m/d center, shipping mode, freight rates, handling charges
Trends in sales by area, ability to generate sales by company presence in area	Somewhat	Estimates of same data listed above
Competitive Considerations		
Competition's location	Yes	Industry sources
Likely competition reaction to this new site	No	Industry sources, own knowledge
2. Labor		
Labor		
Prevailing wage rates	Somewhat	Bureau of Labor Statistics, State/ local publications, poll of manufacturers in the area
Extent and militancy of labor unions in area	Somewhat	Does state have "right-to-work" law?, BLS data on union workers, work stoppages, NLRB certification/ decertification elections, poll of area manufacturers
Productivity (absenteeism, turnover, worker attitudes)	Somewhat	Poll of area manufacturers
Availability (population, area unemployment, commuting distances)	Somewhat	BLS data, Census data
Skill levels available	Somewhat	Poll of manufacturers in area, local training programs

Item	Quantifiable?	Data typically developed from
3. Materials and services		
<u>Access to Supplies, Resources</u>		
Cost of transporting supplies	Estimate possible	Location of suppliers for which transport expenses will be incurred by plant, quantities shipped from each location, by which mode, freight rates, handling charges
Trends in supplier by area	Somewhat	Estimates of same data listed above
4. Transportation		
<u>Transportation</u>		
Trucking service (number and reputation of truckers, rates charged, quality of service)	Somewhat	Area trucking companies, other manufacturers in area
Rail service (number and reputation of railroads serving site, frequency of service, rates)	Somewhat	Railroads, other manufacturers in area
5. Government and legislation		
<u>Environmental Consideration</u>		
Government "attainment" area or not?	Yes	Federal/state environmental protection agencies
Are pollution rights of companies available for purchase?	Yes	State EPA development agencies, companies in area
Ease and speed of compliance	No	Federal/state EPA, militancy of local conservation efforts

Item	Quantifiable?	Data typically developed from
6. Financing		
Taxes and Financing		
State income tax (corporate, personal)	Yes	State government office
Local property and local income tax (if any)	Yes	Local government office
Unemployment and workmen's compensation	Yes	State government office
Other state/local business taxes	Yes	State/local offices
Tax incentives and/or concessions (holidays, abatements, exemptions, credits, accelerated depreciation, and the like)	Yes	State/local offices
Industrial and/or pollution control revenue bonds	Yes	State/local offices
7. Water and waste disposal		
8. Power and fuel		
Utilities, Services		
Availability, quality, and price of water, sewerage, electric power, natural gas	Somewhat	Utility companies, poll of manufacturers in area
Quality of roads, police, fire, medical, other services	Somewhat	Site visit, poll of manufacturers in area

Item	Quantifiable?	Data typically developed from
9. Community characteristics		
Community, Government Aspects		
Ambience, charisma of community	No	Site visit, hearsay, polls of people's preferences
Cost of living	Yes	Bureau of Labor Statistics area figures
Cooperation with established local industry	No	Site visit
Community pride (appearance, activity, citizen views)	No	Site visit
Housing (availability, prices)	Somewhat	Site visit, discussions with realtors
Schools, cultural attractions, recreation	Somewhat	Site visit, program offerings from state/ local sources, % going to college, etc.
Colleges nearby, graduate programs	Somewhat	State/local sources
Churches, civic groups	Somewhat	Site visit

Item	Quantifiable?	Data typically developed from
10. Individual sites		
Site Itself		
Area of site, sq. ft. and layout of each structure	Yes	State/local development agencies, railroads, power companies, developers, realtors, site visit
Price of site and any structures	Yes	Seller
Ability to option site, length, cost	Yes	Seller
Condition of site and any structures (including structural assessment, topography, geology, and other concerns for construction and improvement	Yes	Site visit, especially once option is taken
Area parking and traffic	Somewhat	Site visit
Construction, remodeling costs, insurance	Yes	Site inspections, engineering plans
Interaction with Rest of Corporation		
Is new plant to be a satellite of another plant or not?	Yes	Own knowledge
Is plant to be supplied by or to supply other company plants?	Yes	Own knowledge
Extent of expected engineering/management troubleshooting from headquarters	No	Own knowledge

APPENDIX II

SITE SELECTION FACTORS

SITE SELECTION FACTORS

MAJOR FACTOR CATEGORIES

I. LAND

II. UTILITIES

III. TRANSPORTATION

IV. MARKETS

V. MATERIALS, SUPPLIES AND SERVICES

VI. LABOR

VII. COMMUNITY CHARACTERISTICS (QUALITY OF LIFE)

VIII. GOVERNMENT AND LEGISLATIVE

IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS

X. FINANCING

SITE SELECTION FACTORS

I. LAND
  A. Availability of suitable sites
  B. Description of sites
    1. Acreage (for plant, access and interior roads, rail, parking, storage, utilities, easements)
    2. Adjacent acreage potentially available
    3. Dimensions (shape of tract and orientation)
    4. Nearest cities (distance and direction)
    5. Proximity to other company facilities
  C. Cost estimates of land (For detailed cost analysis, see Section X. FINANCING: A.2.b.(1))
    1. Initial cost, assuming secrecy of plans is maintained
    2. Cost of improvements
    3. Broker fees
    4. Probable appreciation of land value
  D. Zoning (See also Section VIII. GOVERNMENT AND LEGISLATIVE: I.10. and 12.)
    1. Zoning agency
    2. Present use and present zoning
      a. Raw land, previously agricultural
      b. Zoned industrial but not in planned industrial park
      c. Planned industrial park or district
      d. Urban, suburban, rural
      e. Waterfront or airport frontage
      f. Redevelopment area
      g. Drained or reclaimed land
      h. Cleared, graded land
      i. Site in large-scale Public Utility District (PUD) or new town
      j. Previous land use
    3. Change required
    4. Neighboring uses, character and zoning (north, east, south, west)
    5. Rights-of-way or easements
    6. Set-back requirements
    7. Parking requirements
    8. Screening, fencing or buffer requirements (landscaping)
    9. Minimum land-to-building ratio and height limitations
    10. Sign control

11. Provisions for unusual operations (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: F.)
    a. Fire, explosion or health hazards associated with materials used in process
    b. Conditions resulting from operation (smoke, dust, odors, fumes, noise, vibration, etc.)
    c. Special treatment required (smoke abatement, dust extraction, etc.)
    d. Security risks to which operation may be exposed

E. Topographic Conditions
   1. Character of terrain (slope and grade)
   2. Highest and lowest elevation (above sea level)
   3. Magnitude of grading required
   4. Drainage patterns (before and after plant construction)
   5. Need for flood protection
   6. Prevailing winds and storm winds
   7. Seismic risk
   8. Potential aesthetic problems
   9. Legislation restricting construction due to topography

F. Soil Characteristics (Geologic Considerations)
   1. Type of soil (soil analysis) (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: A.2.)
      a. Agricultural quality
      b. Structure support quality
      c. Depth
      d. Erosion characteristics
      e. Soil types
      f. Drainage
   2. Depth of bedrock and character of intervening soil strata (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: A.3.)
      a. Support quality
      b. Type of material
      c. Depth of material
   3. Load bearing strength (compared to requirements)
   4. Variations in groundwater level
   5. Artificial drainage required

G. Intangible Considerations (See also Section: VII. COMMUNITY CHARACTERISTICS: A.)
   1. Natural surroundings
   2. Advertising value of site

3. View of buildings from distance and view from within building
4. Neighbors

H. Legal Factors
1. Clear title
2. Number of owners
3. Willingness to sell
4. Easements
5. Mineral rights
6. Other rights
7. Protective covenants and deed restrictions
8. Pollution control agencies (For Pollution Assessment, see Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS)
    a. Air
    b. Water
    c. Noise
    d. Solid waste
    e. Basic waste

I. Special Strategies
1. Purchase of site large enough for more than one plant, setting up a "site bank" for future use
2. Use of surplus corporate property, including available land and buildings
3. Developing own industrial park or complex and locating plant in it, thus capturing some of own economic impact
4. Swapping company property elsewhere for site to avoid tax consequences
5. Leasehold on public land, such as an airport or urban renewal area
6. Site on closed military base, to use existing facilities, employ skilled workers, etc.
7. Establish a plant under the twin plant concept (unit outside the U.S. furnishing assemblies to unit in the U.S.)

J. Existing Buildings (if any)
1. Building type (special or multi-purpose)
2. Current or last use
3. Suitability for required use (manufacturing, warehousing, etc.)
4. Existing special facilities (computer room, clean rooms, etc.)
5. Suitability for special equipment
6. Type of construction (steel, masonry, other)
7. Age (year built)
8. Overall dimensions

9. Total area (total number of square feet, usable square feet)
    a. Production
    b. Storage
    c. Shipping, receiving, warehousing
    d. Office
    e. Research and engineering
    f. Data processing
    g. Employee services
    h. Building services
    i. Other
10. Ceiling height
11. Bay size
12. Photographs and floor plans
13. Type and condition of
    a. Roof
    b. Walls, doors, openings
    c. Windows
    d. Floors and floor loading
    e. Number of floor levels
    f. Mechanical, electrical equipment
    g. Freight and passenger elevators
    h. Conveyors, cranes, etc.
14. Restrooms
15. Type of heating/cooling (type, size, capacity)
16. Humidity control
17. Building insulation
18. Fire protection (See also Sections II. UTILITIES: G.1.e. and VII. COMMUNITY CHARACTERISTICS: H.2.)
    a. Sprinkler system
        (1) Type of system
        (2) Size of tank
        (3) Pressure
        (4) Number of fire extinguishers
        (5) Fire detection system
        (6) Fire water storage
    b. Fire hydrants on site
    c. Distance to nearest fire hydrant
    d. Distance to nearest fire station
    e. Insurance rating
19. Safety equipment (shower, eye wash)
20. Location on site
21. Neighborhood environment, appearance of surroundings
22. Parking spaces
23. Number of docks
24. Adequacy of truck aprons
25. Rail dock available
26. Oil, propane storage

27. Cost considerations (See also Section X. FINANCING: A.2.b.(4))
    a. Sale price and terms or leasing costs and conditions
    b. Estimated costs to modify or upgrade to usable condition
    c. Estimated costs to demolish and remove, if not suitable or usable
    d. Existing tax assessment
28. Permit agencies

II. UTILITIES
- A. Power Sources
  1. Thermal: natural gas, propane, fuel oil, coal, lignite
  2. Hydroelectric
  3. Other: nuclear, geothermal, solar, etc.
- B. Electricity (See also Section X. FINANCING: A.1.d. and 2.b.(2)(b))
  1. Electric power required (start and peak)
     a. Kilowatt (KW) demand
     b. Kilowatt-hour (KWH) monthly consumption
     c. Power factor (percent)
     d. Load factor (percent)
     e. Special load characteristics
  2. Supplier/source of supply
  3. Voltage, phase, cycles available
  4. Distance to nearest line and cost of extending service
  5. Location of nearest electric substations and whether interlocking
  6. Size of connection required at site
  7. Two-way feed
  8. Rates based on demand for services
     a. Lighting
     b. Machine operation
     c. Air conditioning
     d. Welding
     e. Furnaces
  9. Off-peak possibilities and rates
  10. Discounts and penalties
  11. Typical residential rates
  12. Distribution system's potential to handle a plant expansion program
  13. Interconnection with other systems
  14. Recent history of shortages or interruptions
      a. Average number of interruptions per year
      b. Maximum duration
  15. Vulnerability to natural disasters
  16. Fuel sources of the local utility
  17. Security or dependability of fuel supplies of the local utility
  18. Fuel adjustment provisions
  19. Plans to produce part or all of own electric power
- C. Natural Gas (See also Section X. FINANCING: A.1.d. and 2.b.(2)(b))
  1. Requirements (initial and projected maximum), compared with peak
     a. Thousand cubic feet/year (mcf/year)
     b. Thousand cubic feet/hour (mcf/hour)
  2. Supplier/source of supply

3. Types (natural, mixed, manufactured) and Btu values
4. Allocation for industrial use (available on a firm basis)
5. Distance to nearest line, size of line and cost to extend
6. Size of connection at proposed site
7. Two-way feed
8. Storage facilities
9. Industrial and residential rates, including interruptible rate (with standby fuel oil facilities)
10. Recent history of shortages and interruptions

D. Fuel Oil
1. Fuel oil required (start and peak)
2. Supplier/source of supply
3. Delivery method (pipeline, tank car, tank truck, barge, tanker)
4. Cost of oil delivered, per million Btu's
5. Standby storage facilities
6. Favorable component factors (tappable trunk line nearby, pipeline capacity, rate picture, Btu content, proximity to oil fields, etc.)

E. Coal
1. Tonnage required (initial and projected maximum)
2. Supplier/source of supply
3. Availability
4. Methods of delivery
5. Delivery problems
6. Cost of coal delivered, per million Btu's
7. Costs of coal handling and storage facilities versus competitive fuels
8. Effects of technological improvements in mining and usage
9. Potential use of lignite ("brown coal")

F. Special Energy Plans
1. On-site independent energy source (gas well, coal mine, nuclear reactor, cogeneration)
2. Location in energy park complex (with waste recovery plant, generating station, etc.)
3. Alternate fuel plans
4. Back-up systems

G. Water (See also Sections IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: D. and X. FINANCING: A.1.d. and 2.b.(2)(b))

1. Water requirements (start and peak): gallons per day (gpd)
    a. Process
    b. Cooling
    c. Potable and sanitary
    d. Air conditioning
    e. Fire protection (See also Sections I. LAND: J.16. and VII. COMMUNITY CHARACTERISTICS: H.2.)
    f. Percent recirculated
2. Water sources/suppliers
    a. Public water
    b. Private water
    c. Surface water: streams and lakes
    d. Ground water: wells
3. Public water
    a. Pumping and storage capacity
    b. Pressure
    c. Supply versus projected demand
    d. Rates (industrial and residential)
    e. Distance to nearest line, size of line, and cost to extend
    f. Quality of water (purity, temperature, pressure, chemical content, salinity, hardness, etc.), including method and extent of treatment, such as fluoridation
    g. Likelihood of restricted use
4. Surface water
    a. Daily, seasonal and long-term flow variations
    b. Adequacy of surface water supply during dry months
    c. Quality of water (same as 3.f. above)
    d. Influence of upstream users on availability and quality of the water
    e. Distance to site
    f. Feasibility of dam or pumping station
5. Ground water (site potential)
    a. Recent trend of water table elevation
    b. Recharge rate
    c. Legal restrictions on withdrawal and recharging rates of flow on ground water
    d. Pumping cost
    e. Quality of water (same as 3.f. above)
6. Cost of water treatment, if needed

7. Sewage disposal
   a. Projected load (start and peak): gpd
      (1) Sanitary/storm (separate or combined sanitary and storm sewers)
      (2) Process
      (3) Special waste treatment required
      (4) Solid waste
   b. Sanitary
      (1) Agency/supplier of service
      (2) Type of treatment
      (3) Distance to nearest line, size of line and cost to extend
      (4) Fees for service
   c. Sanitary treatment other than sewer
      (1) Approving agency
      (2) Treatment used by others nearby
      (3) Cost estimate
   d. Secondary sewage treatment
   e. Space for lagoon to process wastes
   f. Requirements for septic tanks
   g. Storm sewer
      (1) Agency
      (2) Distance to nearest line, adequacy and cost to extend
      (3) Adequacy of streams and ditches
      (4) Risk of flooding
      (5) Fees
      (6) Retention requirements
   h. Solid waste treatment (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: E.)
      (1) Nature of collection system (incineration, landfill or dump, transfer stations, resource recovery)
      (2) Methods and frequency of collection
      (3) Capacity compared with present and projected load
      (4) Cost of collection
      (5) Pollution and aesthetic problems
   i. Ordinances on industrial waste
8. Attention of municipal authorities directed toward future community water problems

H. Communications
1. Local telephone companies
   a. Capacity and percent available
   b. Installation costs and rates
   c. Capability to handle large installations
   d. Teletype service
   e. Private wire system
   f. Range of toll-free area
2. New communications systems
   a. Digital transmission
   b. Microwave and satellite transmission
   c. Telecommunications (voice and data)
3. Postal service (See also Sections V. MATERIALS, SUPPLIES AND SERVICES: D.9. and VII. COMMUNITY CHARACTERISTICS: O.)
   a. Nearest post office
   b. Frequency of deliveries
   c. Proximity of bulk mail center
   d. Availability of alternative delivery services (overnight, etc.)

III. TRANSPORTATION (See also Section X. FINANCING: A.1.c.)

A. Rail (See also Section V. MATERIALS, SUPPLIES AND SERVICES: D.6.)

1. Lines serving area
2. Railroad offices in area
3. Reciprocal switching arrangements and interlines with others serving sources/markets
4. Classification territory
5. Daily freight and passenger service
6. Shipping time to particular cities or areas
7. Adequacy of car supply
8. Rates: rates to principal markets, on rate-blanketing basis
    a. Bulk or quantity
    b. Commodity
    c. Carload (minimum size of carload)
    d. Less than carload or mixed-car
    e. Containerized, palletized and special-car shipments
    f. Pattern of differential freight rate increases
9. Special tariffs, regulations or restrictions that might apply to rail service to the community or site, or to market areas
10. Shipment or delivery minimums
11. Piggy-back and other interchange services
12. Freight forwarders or car-loading companies for LCL type of shipping operations
13. Demurrage charges
14. Transit or stop-off privileges and rates for partial loading or unloading enroute
15. Truck-handling facilities at freight terminals
16. On-time-performance record, claims record and customer-service record
17. Service at site (See also Section X. FINANCING: A.2.b.(2)(c))
    a. Relation of siding to main system
    b. Switching frequency and limits
    c. Switching charges
    d. Probable cost of erecting siding, if none at site
    e. Apportionment of cost between plant and railroad
    f. Effect of siding on plant design
    g. Complications (sidings jointly used, public road crossings, etc.)
18. Financial strength of rail system serving area

19. Potential impact of planned or proposed mergers, government or state legislation, or rail bankruptcies
20. Possibility of branch line abandonment (under the various United States Railway Association, Interstate Commerce Commission and other plans

B. Highways and Streets (Motor Transportation)
   1. Trucking Service (See also Section V. MATERIALS, SUPPLIES AND SERVICES: D.7.)
      a. Companies serving area (local, intrastate, interstate): common carriers, contract carriers, special-commodity carriers
      b. Trucker interlines with other lines serving markets, plants, suppliers
      c. Terminals and facilities
      d. Adequacy of carrier equipment
      e. Overnight service radius
      f. Schedules (trips per day) and transit times
      g. Rate structure
         (1) Pattern of recent truck freight rate increases
         (2) Containerized, palletized or unitized shipments
         (3) Economics of total-load versus less-than-total-load shipments
         (4) Mixed-trailer shipments at truckload rates
      h. Minimum-weight restrictions
      i. Carrier imposed shipment or delivery minimums
      j. Stop-off or intransit privileges
      k. Demurrage charges
      l. Adequacy and compatibility of loading/unloading/material-handling systems at the site, plant/supplier, and customer locations
      m. Adequacy of truck docks and maneuvering areas for the types and sizes of vehicles to be used at the site, plant/supplier, and customer locations
      n. Specialized equipment (liquid or dry bulk, heavy hauling, etc.)
      o. Express and transfer service
      p. Freight consolidating and forwarding service, export services
      q. Location of commercial zone
      r. State laws on truck size and weight (doubles or triples allowed)

- s. On-time-performance record, claims record and customer-service record of the trucklines
- t. Special tariffs, regulations or restrictions that apply to truckers in the site area, in plant/supplier areas, or in market areas
- u. Planned or proposed mergers, or state or federal legislation likely to affect truck transportation to the site

2. Roadways (See also Section VIII. GOVERNMENT AND LEGISLATIVE: I.13.)
   - a. Access and distance to nearest state highways, interstate highway interchanges, other major highways and feeder roads (existing and proposed) (See also Section X. FINANCING: A.2.b.(2)(c))
   - b. Condition, length and width of roads and streets
   - c. Weight, height and length limitations
   - d. Capacity versus current usage and projected demand
   - e. Traffic lights, medians, acceleration and deceleration lanes, rail crossings
   - f. Traffic congestion on access roads, state highways, interstate highways, in market areas, in plant/supplier areas
   - g. Seasonal restrictions on road use
   - h. Toll roads (amount of toll)
   - i. State gasoline taxes
   - j. State and county highway, and city street departments
   - k. Bond issues for new roads
3. Other motor transportation
   - a. Local mass and/or rapid transit (facilities, schedules, proposed extensions)
   - b. Inter-city bus service (terminals, schedules)
   - c. Taxi service (rates, adequacy of service, radio equipment)
   - d. Car rentals and limousine service
   - e. Nearest services to plant site

C. Air

1. Airlines, air taxis and commuter service (national, regional, feeder, all-freight)
2. Passenger and freight schedules and transit times
3. Fares and rates
4. Air charter and rental

5. Helicopter-shuttle service (including costs to set up, if not available)
6. International service
7. Pickup and delivery zones and services
8. Distance and travel time from plant site to airports (scheduled-service or municipal)
9. Service to plant/supplier and market areas (direct route, by interline routes, by air/truck routes)
10. On-time-performance record, claims record and customer-service record of air carriers
11. Airport facilities
    a. Terminal
    b. Runway (length, surfacing, lighting)
    c. Radio and radar
    d. Instrument approaches
    e. Availability of gas, jet fuel
    f. Repair services
12. Airfields used by executive aircraft
13. Hangar and office facilities
14. Taxiway access to plant sites
15. Air freight (See also Section V. MATERIALS, SUPPLIES AND SERVICES: D.8.)
    a. Sizes and types of containers
    b. Air cargo forwarders
    c. Density of average shipment
    d. Bulk or quantity rates
    e. Shipment or delivery minimums
16. Weather closures of airport (frequency and duration)
17. Planned or proposed new airports
18. Planned or proposed legislation (noise control, approach or takeoff patterns) that would affect operations at the airport

D. Water (inland water transport and/or overseas shipping)
1. Channel width and depth
2. Waterways capacity
3. Depth alongside, if on waterway
4. Access and distance to channel, if not adjacent
5. Access and distance to nearest piers and overseas docks (deepwater, barge)
6. Construction costs, if new piers are needed (See also Section X. FINANCING: A.2.b.(2)(c))
7. Lines serving area (schedules, rates, commodities handled, capacities)
8. Port facilities (handling facilities, warehousing, transit shed, storage areas, stevedoring, lighterage, container handling capability)

9. Port authority or commission, if any
10. Longshoremen situation
11. Interchange facilities
12. Seasonal limitations (closed in winter: icebreakers)
13. Insurance rates

E. Potential for intermodal transfer of containers
1. Rail-truck
2. Rail-air
3. Rail-ship
4. Air-truck
5. Ship-truck
6. Ship-air
7. Barge-rail
8. Barge-truck
9. Barge-air

F. Other (Pipelines)
1. Possibility of use
2. Commodities (natural gas, oil, refined products)

IV. MARKETS
- A. Description/Definition of Markets (past, present and future trends for industry)
- B. Consumer/Retail Markets
  1. Consumer characteristics
     - a. Population trends
       - (1) Growth trend
       - (2) Age composition (especially age groups 15-19, 20-44, 45-64)
       - (3) Sex composition
       - (4) Ethnic and racial composition
       - (5) Urban, suburban, rural non-farm, rural
       - (6) Institutional population, if any
     - b. Living (family) units
       - (1) Average family size
       - (2) Occupations
       - (3) Home ownership
       - (4) Automobile registration
       - (5) TV, major appliance ownership
     - c. Income trends
       - (1) Total, per capita, and per family income
       - (2) Disposable and discretionary income
       - (3) Size of various income groups
  2. Retail sales trends
     - a. Division of sales by retail categories (department stores, drug stores, etc.)
     - b. Seasonal variations in trade
     - c. Items in unusual local demand (water sports equipment, air conditioners, water softeners, etc.)
  3. Tourism in Area
     - a. Annual volume of visitors
     - b. Sources of visitors
     - c. Length of stays
     - d. Income level of visitors
     - e. Average number in party
     - f. Destination
     - g. Purpose of visit (business, personal)
     - h. Estimated amount spent
       - (1) Per day
       - (2) Per trip
     - i. Facilities, services, attractions available
     - j. Method of travel (land, air, sea)
- C. Industrial Markets
  1. Major economic activities, by SIC number
  2. Major industrial purchases and output (input-output study of area if available)

   3. Trend of industries moving into and out of area (reasons for moves)
   4. Growth industries (including announced plants not yet built)
   5. Branches of national known firms

D. Competition
   1. Past sales in area compared with competitors
   2. Location of competitors
   3. Possible relocation of competitors in region as reaction to new location
   4. Possible new competition from within area
   5. Future market share of likely competitors

E. Location
   1. Type of location
      a. Within Standard Metropolitan Statistical Area
      b. Within central business district
      c. Small town or rural area
   2. Approximate location of market center
   3. Layout of area (streets, existing and proposed highways, railroad, topography, land use including existing and proposed industrial land, zoning patterns, political subdivisions)
   4. Distance and means of access to major metropolitan areas
   5. Modes of shipment of products
   6. Geographical area of which city is dominant retail center, dominant wholesale center

V. MATERIALS, SUPPLIES AND SERVICES

A. Raw Materials, Semi-Finished Materials, and Components

1. Location of suppliers (especially for perishable, bulky, or low value materials; key parts or subassemblies)
2. Quantity and quality produced
3. Long-term production outlook
4. Alternate suppliers (multiple supply areas to cover short supplies)
5. Amount produced available to new customers
6. Competition for materials from other companies
7. Prices, terms of sale and delivery (cost of transport to site) (See also Section X. FINANCING: A.1.b.)
8. Delivery time, reliability, interruptibility
9. Nearby natural transportation transfer point
10. Availability of rapid transportation from suppliers by truck or other means
11. Ease of consultation with key suppliers
12. Usable by-products from nearby existing or proposed manufacturers
13. Lease or buy options for large natural resource areas (such as timber or ores)
14. Consideration of building homes and facilities for workers required by remoteness of raw materials
15. Evidence of depletion or shortage of resources (minerals, timber, soil, water, others)
16. Forecasted new sources

B. General (Routine) Supplies

1. Maintenance supplies (lubricants, etc.)
2. Lumber and allied materials
3. Engineering department supplies
4. Office supplies and equipment

C. Storage Facilities

1. Public warehouses
2. Bulk storage terminals

D. General Services

1. Machine shops
2. Major repair shops (including electric motor maintenance)
3. Subcontractors
4. Industrial distributors
5. Food and sundry vending, catering
6. Railway express (See also Section III. TRANSPORTATION: A.)
7. Local trucking (See also Section III. TRANSPORTATION: B.1.)

8. Air freight service (See also Section III. TRANSPORTATION: C.15.)
9. Postal service (See also Section II. UTILITIES: H.3.)
10. Air conditioning service
11. Janitorial service
12. Professional services
    a. Attorneys
    b. Accountants (CPA's)
    c. Advertising agencies
13. Job printers
14. Credit bureau
15. Plant protection services
16. Telephone answering services
17. Employment services

E. Technical or Special Services
1. Special equipment repair
2. Laboratories (product research, testing, chemical analysis, instrumentation, etc.)
3. Blueprint service
4. Industrial photography and x-ray
5. Consultants (management, engineering)
6. Computer service bureaus

F. Construction Services (See also Section VII. COMMUNITY CHARACTERISTICS: S.)
1. Architects
2. Engineers
3. Prime contractors
4. Subcontractors
5. Mechanical
6. Electrical
7. Piping
8. Carpenter
9. Labor
10. Rigger
11. Special equipment
12. Mason
13. Plasterer
14. Tile
15. Painting
16. Landscape
17. Paving

VI. LABOR

A. Availability/Labor Force Inventory

1. Population (See also Section VII. COMMUNITY CHARACTERISTICS: B.)
    a. At last census
    b. Density per square mile
2. Areawide potential employment (within reasonable commuting radius)
3. Categories of employment: number (or percent) employed
    a. Agricultural
    b. Manufacturing (by type)
    c. Nonmanufacturing (by type)
    d. Government
    e. Total nonavailable work force (institutional, military and student)
    f. Distribution among industrial, commercial, service activities
4. Unemployment
    a. Number and percent unemployed
    b. Trend last five years (Number and percent)
5. Distribution of available labor
    a. Skilled, semiskilled, unskilled
    b. Professional, technical, clerical
    c. Union, nonunion
    d. Male, female
    e. Age
    f. Educational levels
    g. Shortage, abundance of skills
6. Seasonal variations in employment
    a. Nearby resort areas
    b. Other seasonal labor variations (farms, etc.)
7. Competition for labor force
    a. Degree of competition for skills
    b. Direct (or indirect) competition with an industrial pacesetter
    c. Migration of young people taking jobs elsewhere

B. Wages and Benefits (Local Practices) (See also Section X. FINANCING: A.1.a.)

1. Wage rates, by skill or occupation
2. Hourly or piece rates
3. Working hours (average work week)
4. Shift patterns, willingness and premiums
5. Overtime compensation
6. Patterns of year-end bonuses
7. Pensions
8. Health and life insurance
9. Holidays
10. Vacations

11. Coffee breaks, rest periods
12. Cost-of-living index

C. Productivity/Safety
1. Absenteeism
2. Turnover
3. Housekeeping practices and care of equipment
4. Industrial accident rates compared with national averages
5. Other productivity measures

D. Personnel Policies
1. Trial periods
2. Seniority provisions
3. Layoff provisions
4. Grievance patterns
5. Promotion procedure
6. Transfer procedure

E. Labor Legislation (See also Subsection F. below and Section VIII. GOVERNMENT AND LEGISLATIVE: B.5.)
1. Right-to-work law
2. Laws pertaining to shift work and total hours per week permissible
3. Minimum wage law
4. Equal employment (EEOC) requirements
5. Laws regulating union activities
6. Fair-employment-practices law
7. Laws concerning collective bargaining
8. Laws dealing with secondary boycotts or injunctions
9. Occupational-safety-and-health laws
10. Workmen's compensation rate
11. Unemployment compensation rate
12. Incentives for training or retraining industrial employees
13. Incentives for locating facilities in areas of high unemployment

F. Unions (See also Subsection E. above and Section VIII. GOVERNMENT AND LEGISLATIVE: B.5.)
1. Degree of unionization (dominant union)
2. History of unions in the area
3. History of organization attempts and success rates
4. Time lost due to strikes in the last five years
5. External or local control of unions
6. Caliber or quality of union leadership
7. Caliber of quality of union "followership"
8. Union political activity
9. Attitude toward technological change (automation, etc.)
10. Degree of and trend toward white-collar unions

11. Presence of any unusual or radical tendencies (by either management or labor)

G. Management Potential (See also Section VII. COMMUNITY CHARACTERISTICS: F.)

1. Expected requirements for next five years
2. Opportunity to recruit certain management echelons locally
3. Number of college graduates available
4. Specialized skills available, such as scientific and technical manpower
5. Undergraduate and graduate programs of colleges
6. Executive development programs
    a. Colleges
    b. Associations and organizations
7. Local experience with inplant training

VII. COMMUNITY CHARACTERISTICS (QUALITY OF LIFE)

A. General Appearance of Community or Area (See also Section I. LAND: G.)
   1. Natural environment
   2. Appearance of commercial, industrial, residential areas
      a. Active
      b. New construction
      c. Empty buildings

B. Population (See also Section VI. LABOR: A.1.)
   1. Total population
   2. Density (number of residents per square mile)
   3. Rate of increase

C. Climate (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: A.5., B. and C.4.)
   1. Monthly average, maximum, minimum and long-term extreme temperatures
   2. Degree days by month
   3. Number of days over 90 degrees and under 32 degrees
   4. Period between killing frosts
   5. Average monthly rainfall, snowfall
   6. Maximum rainfall, snowfall in 24 hours
   7. Fifty-year low, high precipitation
   8. Monthly averages of relative humidity
   9. Monthly wind velocity, prevailing wind direction
   10. Number of clear, partly cloudy and cloudy days
   11. Number of days with poor visibility and low ceilings
   12. Special weather hazards (hurricanes, tornadoes, dust or hail storms, droughts, floods, temperature inversions, fog)
   13. Geographical extremes
   14. Climatic Effects
       a. On building design, construction and maintenance
       b. On cost of heating and air conditioning
       c. On transportation to and from plant
       d. On operations within plant, including technical processes
       e. On employee morale and recruiting
   15. Air Pollution Index
   16. Mean Annual Inversion Frequency

D. Cost of Living
   1. Food
   2. Shelter
   3. Clothing
   4. Medical
   5. Education

6. Transportation
7. Utilities
8. Entertainment/recreation

E. Housing
1. Location of in-town, suburban residential areas
2. Areas served by all utilities
3. Photographs of typical areas and homes
4. Housing available in various price ranges
5. Housing built in last five years
6. Community housing starts relative to expected growth
7. Typical construction (frame, brick, basements, garages, air conditioning, setbacks)
8. Lot sizes and costs
9. Building costs per square foot for various types of houses
10. Residential property values as index of community values
11. Rental units (size range, rates, lease requirements, terms of leases)
12. Percent of total housing stock in rental units
13. Apartments (type, rates, terms of lease)
14. Submarginal or slum areas
15. Urban renewal (public and private)
    a. Progress
    b. Method of financing
    c. Effect on other areas of city
16. Undeveloped acreage in city

F. Education (See also Section VI. LABOR: G.)
1. Number, enrollment, teachers, accreditation
    a. Public schools (elementary, junior high, senior high)
    b. Parochial schools (elementary and high)
    c. Private schools
    d. Pupil-teacher ratio
2. Cost of education per pupil
3. Investment per pupil and public school debt per capita; responsibility for funding; school property tax trends
4. Teacher requirements and salary scales
5. School building expansion program and need for split shifts
6. History of voter rejection of school bond issues
7. Capacity versus existing demand versus projected demand
8. Condition and appearance of school buildings and grounds

9. Special facilities (libraries, laboratory facilities)
10. Special programs for exception students
11. Average SAT scores
12. Percent of high school graduates who go to college
13. Percent of high school drop-outs
14. Trade and business courses in regular high schools
15. Adult evening classes (vocational and avocational)
16. Kindergartens and nursery schools
17. Schools buses and area served
18. Status of desegregation
19. History of racial conflict in schools
20. Programs to deal with drug abuse, alcoholism
21. Colleges and universities in 50-mile radius
    a. Enrollment, faculty, accreditation
    b. Degrees granted, graduate programs
    c. Evening courses offered
    d. Extension programs
    e. Special facilities for research
    f. Research undertaken for industry in last five years
    g. Expansion programs
22. Vocational schools (trade, apprentice-training)
    a. Courses offered
    b. Curricula flexibility
    c. Federal, state or local training programs tailored to specific industry requirements
    d. Training cost reimbursement programs for industry
    e. Median school years completed by those 25 or older
    f. Percent of those applying for military service who fail mental test

G. Health and Welfare
1. Hospitals and clinics
    a. Number of hospital beds per 1,000 population
    b. Semi-private room rate
    c. Special equipment
    d. Rating (State Board of Health)

2. Medical personnel
    a. General practitioners
    b. Surgeons
    c. Specialists
    d. Dentists
    e. Visiting nurses, midwives, physician's assistants, etc.
    f. Number of physicians, dentists, nurses per 1,000 population
3. Ambulance service
4. Public health program and regulations
    a. Community sanitary laws
    b. State industrial and health laws
5. Social services
    a. Groups assisted
    b. Number of social workers per 1,000 population
    c. Source of funds
    d. Expenditures for social services as percent of total city/county budget
    e. Percent of total population on welfare
    f. Adequacy of services for existing populations
6. General health of population
    a. Infant mortality rate
    b. Death rates from heart disease, cancer
    c. Tuberculosis rate
7. Average per capita government expenditure on public welfare
8. Community-fund program
9. Community disaster plan

H. Police and Fire Protection

1. Law enforcement
    a. Personnel per 1,000 population
    b. Personnel attrition
    c. Training programs
    d. Annual expenditures for police force
    e. Equipment
    f. Surveillance of industrial areas
    g. Cooperation with county and state police
    h. Crime and juvenile delinquency rates, major categories (murder, rape, aggravated assault, burglary)
    i. Performance during strikes and labor disputes
    j. Injunctions against illegal strikes or picketing
    k. Traffic regulation during shift changes at plants
    l. Municipal courts

2. Fire protection (See also Sections I. LAND: J.16. and II. UTILITIES: G.1.e.)
    a. Personnel per 1,000 population (paid, volunteer)
    b. Personnel attrition
    c. Training programs
    d. Fire insurance classification
    e. Extent of protected area
    f. Stations (location and time to outer limits of protected area)
    g. Equipment, including that for chemical fires
    h. Hydrants, size of mains and water pressure
    i. Availability of apparatus from adjacent communities
    j. Fire inspection of local industry
    k. Sprinkler system requirements
3. Civil defense
    a. Shelters in downtown area
    b. Trained disaster squads and civil defense units
4. Plant security
    a. Availability of private security agency protection, if needed
    b. Other

I. Churches
1. Denominations represented, number of churches
2. Percentage of church membership
3. Leading faiths in area
4. Interfaith groups
5. Community activities
6. Attitudes of church leaders toward business and industry

J. Culture and Recreation
1. Libraries (including university)
    a. Number of volumes
    b. Branches, bookmobiles
    c. Circulation
    d. Budget
2. Legitimate theatre
    a. Nationally/regionally recognized residence groups
    b. Traveling shows last five years
    c. Local repertory groups
3. Music and dance groups
    a. Symphony orchestra
    b. Choral and chamber music groups
    c. Ballet/other dance groups
4. Lecture and concert series

5. Museums and art galleries
6. Discussion groups, forums
7. Theaters, including drive-ins
8. Parks (acres per 1,000 population)
9. Playgrounds
10. Golf courses
    a. Ownership (public, private clubs)
    b. Fees and membership dues
11. Tennis courts
12. Water sports facilities
13. Winter sports facilities (skiing, skating, etc.)
14. Bowling alleys (number of lanes)
15. Professional sports
    a. Stadium capacity
    b. Baseball, football, basketball, hockey, soccer, boxing
16. Race tracks (racing days per year)
17. Team sports facilities
    a. Little league baseball and football
    b. Softball leagues
18. Hunting areas nearby (types of game)
19. Summer camps
20. Other paid amusements

K. Shopping Facilities
1. Major department stores, including parking provisions
2. Specialty stores
3. Branches of metropolitan stores
4. Shopping centers or malls

L. Banks
1. Number
2. Proximity
3. Total deposits

M. Communications Media
1. Newspapers (local and major out-of-town)
    a. Number and time of editions
    b. Circulation
    c. Editorial philosophy
    d. Percent of population subscribing to daily newspapers
2. Television
    a. Channels, affiliations
    b. Quality of reception
    c. Local interest programs of special quality
    d. Educational TV
    e. Cable TV
3. Radio
    a. Call letters and reception
    b. Quality of programs

4. Other media
   a. Trade publications
   b. Farm journals

N. Mail and Express Service (See also Section II. UTILITIES: H.3.)
   1. Number, location and hours of local post offices
   2. Frequency of delivery (business areas, residential)
   3. Express service (area served, average shipment time to major cities)
   4. Messenger service
   5. Location of bulk mail facilities

O. Organizations
   1. Civic, fraternal and social groups
   2. Economic development organizations
   3. Outstanding programs and expenditures per capita
   4. Extent of active participation
   5. United Way and similar funds
      a. Results of last three drives
      b. Per capita giving
      c. Agencies included and those conducting separate drives
      d. Participation by local industry (employee contributions by payroll withholding)
   6. Professional societies
      a. Membership
      b. Frequency of meetings
      c. Programs conducted

P. Travel and Meeting Facilities
   1. Hotels and motels
      a. Number of rooms
      b. Maximum and minimum rates
      c. Recognition by national hotel and motel associations
      d. Conventions and meeting facilities
      e. Major conventions accommodated (attendance and schedules)
   2. Auditorium, arena, exhibit hall
      a. Capacities
      b. Special facilities
   3. Restaurants
      a. Number and capacity
      b. Inspection by local health authorities
      c. Banquet and meeting facilities
      d. Noted specialties

Q. Amenities and Intangibles
   1. Points of unusual, historic or scenic interest
   2. Prestige factors

R. Construction Facilities and Services (architects, engineers, prime contractors, subcontractors, mechanical, electrical, piping, carpenters, labor, masons, plasterers, painters, landscape artists and paving contractors) (See also Section V. MATERIALS, SUPPLIES AND SERVICES: F.)

S. Political and Social Attitudes (See also Section VIII. GOVERNMENT AND LEGISLATIVE: I.3.)
   1. Majority of local civic, business and religious leaders with progressive attitude toward business and industry
   2. Proportion of population registered to vote and voting in national and local elections
   3. Business leader participation
      a. Election to local office
      b. Service on planning boards, school boards, tax councils
      c. Local businessmen prominent at state and national levels
   4. Economic education programs
      a. Ethnic, racial and religious groups prominent in local affairs
      b. Reception accorded new residents
      c. Restrictions on sale of alcoholic beverages
      d. Unusual "blue laws"

T. General Business Climate (See also Section VIII. GOVERNMENT AND LEGISLATIVE: I.3.)
   1. Banks capable of meeting business needs
   2. Record of local government as to honesty, efficiency and principles
   3. Business-sponsored civic organizations devoted to improving business climate
      a. Tangible results
      b. Harmonious relationships with similar organizations
   4. Reaction of local industries as to business climate
   5. Manufacturers recently migrated from community
   6. Normal industrial growth in the community expected
   7. Existing or new industries in the community that help contribute to a stabilized economy
   8. Community well diversified industrially
   9. Community's industries dynamic and growing
   10. Size of community geared to needs (quantity and quality of industrial neighbors, labor pool, etc.)

VIII. GOVERNMENT AND LEGISLATIVE

A. Federal Regulation and Programs (See also Section VI. LABOR: E.)
   1. Representation in Congress
      a. Voting records of representatives and senators on issues of key interest to business
      b. Committee positions held by area representatives
   2. Nearby government installations
   3. Economic Development Administration assistance
   4. Environmental Protection Agency programs (See also IX. ENVIRONMENTAL AND ECOLOGICAL FACTORS: D.9.b.)
   5. Occupational Safety and Health Administration regulations
   6. Other government programs
      a. Federal aid to schools
      b. Incentives offered in depressed areas
      c. Housing and Community Development Act programs
      d. Coastal Zone Management Act programs

B. State Regulation and Programs
   1. Structure and performance of legislative, executive and judiciary branches
   2. Regulations and legislation
      a. Private use of natural resources
      b. Laws affecting incorporation of businesses
      c. Laws affecting out-of-state (or foreign) businesses
   3. Reputation regarding attitudes towards industry
   4. Ability of state salaries to attract and keep good people
   5. State wage and hours laws, workmen's compensation, unemployment compensation, use of injunctions to prevent unreasonable union acts, laws prohibiting secondary boycotts, illegal strikes and picketing, etc. (See also Section VI. LABOR: E. and F.)
   6. History of state protection in law enforcement when required locally
   7. Presence of hidden restrictive state laws
   8. Active and progressive development commission
   9. Existing gross debt of state, as a partial indication of future revenue needs
   10. Indications of debt increasing faster than the growth of services

C. State Taxation (See also Section X. FINANCING: A.1.f. and 2.a.)
   1. Property tax
   2. Personal income tax
      a. Rate, exceptions and deductions
      b. Method of collection
   3. Corporate income, franchise and excise taxes
   4. Corporate incorporation taxes and organization fees
   5. Occupancy tax
   6. Foreign corporation tax
   7. Sales, use and payroll taxes
   8. Unemployment compensation taxes (rates, administration)
   9. Workmen's compensation taxes
   10. Inventory, machinery and equipment taxes
   11. Gasoline, liquor and tobacco taxes
   12. Vehicle and other license fees

D. Comparison of Total State Tax Load with Services Rendered

E. Future Tax Prospects in the Area, in View of Needs for Major Capital Improvements

F. Special Tax Incentives (See also Section X. FINANCING: B.5.)
   1. Corporate income tax exemption
   2. Personal income tax exemption
   3. Excise tax exemption
   4. Tax exemption or moratorium on land, capital improvements
   5. Tax exemption or moratorium on equipment, machinery
   6. Tax exemption on manufacturer's inventories
   7. Sales/use tax exemption on new equipment
   8. Tax exemption on raw materials used in manufacturing
   9. Tax credits for use of specified products
   10. Tax stabilization agreements for specified industries
   11. Tax exemption to encourage research and development
   12. Accelerated depreciation of industrial equipment
   13. Special incentives for locating in economically depressed areas

G. State Industrial Financing Programs (See also Section X. FINANCING: B.2. and 5.)
   1. State-sponsored industrial development authority
   2. Privately-sponsored development credit corporation
   3. State authority or agency revenue bond financing

4. State authority or agency general obligation bond financing
5. State loans for building construction
6. State loans for equipment, machinery
7. State loan guarantees for building construction
8. State loan guarantees for equipment, machinery
9. State financing aid for existing plant expansions
10. State matching funds for city and/or county industrial financing programs
11. State incentives for establishing industrial plants in areas of high unemployment
12. Tax-increment financing

H. Special State Services for Industry (See also Section X. FINANCING: B.2. and 5.)
1. State-financed speculative building
2. State-provided free land for industry
3. State-owned industrial park sites
4. State funds for city and/or county development related public works projects
5. State funds for city and/or county master plans
6. State funds for city and/or county recreational projects
7. State programs to promote research and development
8. State programs to increase export of products
9. State-conducted feasibility studies to attract or assist new industry
10. State help in bidding on federal procurement contracts
11. State science and/or technology advisory council

I. Local Regulation and Programs
1. Structure of municipal government
    a. Elected and appointed officials (responsibilities, terms of office)
    b. Background of incumbents
    c. Local political structure (relation to state and national parties)
    d. Record of local government (honesty, efficiency, major policies)
2. Financial Condition
    a. Annual budget
    b. Sources of revenue (industrial, commercial, residential)
    c. Debt per capita
    d. Salaries of local officials
    e. Bond rating of municipality

3. Civic Attitudes (See also Section VII. COMMUNITY CHARACTERISTICS: T. and U.)
   a. Attitudes of city officials toward industry
   b. Attitudes of city officials toward bordering jurisdictions (county or other municipalities)
   c. Problem areas
      (1) New revenue sources
      (2) Public improvements
      (3) Redevelopment of private property
      (4) Urban plans to rehabilitate "ghetto" areas
      (5) Annexations
4. Civil Disorders
   a. History of riots
   b. Civic action to solve social problems
5. Local Taxes (See also Section X. FINANCING: A.1.f. and 2.a.)
   a. Property taxes (real and personal)
      (1) Tax rates for last five years
      (2) Method of tax assessment and equalization
      (3) Balance between tax loads on industrial, commercial and residential property
      (4) Amount of tax-free property in area
      (5) Local tax revenue per capita
   b. School taxes, if separate
   c. Fire district taxes, if separate
   d. Local sales and use taxes
   e. Local license tax
   f. Comparison of local tax load with services rendered
6. Special Tax Incentives (See Subsection F. above)
7. Industrial Financing Programs
   a. City and/or county revenue bond financing
   b. City and/or county general obligation bond financing
   c. City and/or county loans for building construction
   d. City and/or county loans for equipment, machinery
   e. City and/or county loan guarantees for building construction
   f. City and/or county loan guarantees for equipment, machinery

g. City and/or county incentives for establishing industrial plants in areas of high unemployment

8. Planning Commission
   a. History and makeup
   b. Status of "master" or "comprehensive" plan
   c. Use of professionals in preparing master plan and in administering plan
   d. Coordination of plan with those of adjoining areas
   e. History of over-all economic planning
   f. Attitude of planning commission toward industrial growth in community
   g. Relationship with governing body
9. Industrial Zoning (See also Section I. LAND: D.)
   a. Definition of industrial and research areas
   b. Protection against residential or commercial encroachment
   c. Policies on zoning changes and variances
10. Building Codes
    a. Date written, recent revisions
    b. Unusual requirements
11. Traffic and Parking (See also Section I. LAND: D.)
    a. Professional supervision of traffic planning
    b. Routing of through traffic
    c. Adequacy and plans for downtown and industrial area parking
12. Streets (See also Section III. TRANSPORTATION: B.2.)
    a. General condition of surfaces
    b. Percentage unpaved, particularly in industrial areas
    c. Street cleaning facilities
    d. Snow removal facilities

IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS

A. Analysis of Site from Ecological Viewpoint
   1. Description of land form
   2. Soil analysis (See also Section I. LAND: F.1.)
   3. Bedrock/foundation (See also Section I. LAND: F.2.)
   4. Existing vegetation
      a. Vegetation types
      b. Timber quality
      c. Food value
      d. Landscape design potential
   5. Climate analysis (See also Section VII. COMMUNITY CHARACTERISTICS: C.)
   6. On-site construction materials
      a. List of materials
      b. Availability
      c. Quantity
   7. Wildlife habitats
      a. Existing wildlife
      b. Range
      c. Sensitivity
      d. Effect of development
   8. Description of watershed or drainage basin
   9. Ground water/hydrology
   10. Reef/offshore analysis
      a. Condition of reef
      b. Configuration of ocean floor
      c. Bottom condition (rock, sand, coral, etc.)
      d. Aquatic life
   11. Tidal area analysis
      a. Condition of river mouth or estuary
      b. Salt water/fresh water mix zone
      c. Effect of development
   12. Shoreline analysis
      a. Length of beach
      b. Quality of beach material
      c. Configuration of shoreline/beach
      d. Rocky shoreline
      e. Swamp
   13. Harbor analysis
      a. Depth
      b. Bottom conditions/anchorage
   14. Surface water
      a. Lakes/ponds/pools (size, quality, accessibility)
      b. Rivers/streams
      c. Navigation characteristics
      d. Use as domestic water
      e. Pollution problems

15. Existing pollution
    a. Source
    b. Areas affected
    c. Alternative
    d. Cost of alternative

B. Geographic Factors Affecting Pollution (See also Section VII. COMMUNITY CHARACTERISTICS: C.)
   1. Record of smog or smoke
   2. Effect of local topography on air circulation, frequency of temperature inversions
   3. Local waste treatment systems
   4. Waste assimilation capacity of streams and rivers

C. Air Pollution Control
   1. Regional airshed standards
   2. State air pollution standards
   3. Local air pollution regulations and ordinances and enforcement
   4. Meteorological conditions (See also Section VII. COMMUNITY CHARACTERISTICS: C.)
      a. Wind direction
      b. Wind velocity
      c. Inversion frequency
      d. Other microclimatology factors
   5. Effect of other area industrial emissions on the quality of new plant environment or on allowable emission rates
   6. Impact of Federal Clean Air Act programs
      a. Air quality maintenance plans
      b. Indirect source controls
      c. Transportation controls
      d. Parking management regulations
      e. Significant deterioration regulations

D. Water Pollution Control (See also Section II. UTILITIES: G.)
   1. Waste water problems
   2. Type of waste water
      a. Storm water
      b. Cooling water
      c. Process water
   3. Ability of nearby streams to accommodate waste water
   4. On-site waste water disposal possibilities

5. City sewer services
    a. Within limits
    b. Capacity and capabilities
    c. Special pretreatment for discharge to public sewers
    d. Combined or separate sanitary and storm sewers
    e. Plans to expand sewage network and equipment
6. Imposition of sewer moratoria
7. Space available for a lagoon to process wastes
8. Feasibility of using septic tanks
9. Impact of Federal Water Pollution Control Act programs
    a. National pollution discharge elimination system
    b. Environmental Protection Agency water quality management programs (See also Section VIII. GOVERNMENT AND LEGISLATIVE: A.4.)
    c. Nonpoint source control
    d. Dredge and fill permits
    e. Waste water treatment facilities planning

E. Solid-Waste Disposal (See also Section II. UTILITIES: G.7.h.)
1. Solid-waste disposal problems
2. Disposal facilities
    a. Landfill or dump
    b. Incineration
    c. Transfer station
    d. Reclamation
3. Within pickup limits
4. Private contractors available
5. Capacity requirements
6. Nearby companies that can use or process waste
7. Special handling and/or disposal practices (hazardous)
8. Capacity of solid-waste disposal sites keeping up with the industrial growth in the area

F. Other Environmental/Ecological Problems
1. Noise
2. Visual or aesthetic pollution
3. Land use regulation
4. Power plant siting
5. Coastal resources protection
6. Radiation
7. Hazardous wastes
8. Other

G. Criteria/Standards for Measuring Pollution
H. Community Progress in Reducing Pollution
I. Additional Regulations Anticipated for Future
J. Trade-Off Situations
    1. Contribution of other industries in area to pollution level
    2. Potential for reduction in existing pollution levels

X. FINANCING
- A. Feasibility
  - 1. Final tally of annual costs
    - a. Wages and salaries (professional, craft, labor, etc.) (See also Section I. LABOR: B.)
    - b. Materials (See also Section V. MATERIALS, SUPPLIES AND SERVICES: A.7.)
    - c. Transportation (incoming materials, outgoing products, other) (See also Section III. TRANSPORTATION)
    - d. Utilities (See also Section II. UTILITIES)
      - (1) Electricity
      - (2) Fuel (coal, fuel oil, natural gas, etc.)
      - (3) Water
      - (4) Waste treatment
    - e. Amortization of facility
      - (1) Land and buildings
      - (2) Equipment, machinery
      - (3) Pollution control (See also Section IX. ENVIRONMENTAL AND ECOLOGICAL CONSIDERATIONS: C., D. and E.)
      - (4) Financing
    - f. Taxes (state, local) (See also Section VIII. GOVERNMENT AND LEGISLATIVE: C. and I.5.)
    - g. Other costs
    - h. Comparison of costs with similar data for alternate sites
      - (1) Sites near major source of raw materials
      - (2) Sites near major market
      - (3) Sites in intermediate locations
  - 2. Return on investment analysis
    - a. Returns (See also Section VIII. GOVERNMENT AND LEGISLATIVE: C. and I.5.)
      - (1) Net sales from facility
      - (2) Cost of products sold
      - (3) Gross profit from facility
      - (4) Operating expenses, other expenses
      - (5) Earnings before taxes
      - (6) Income tax
      - (7) Investment tax credit
      - (8) Depreciation, tax saving from accelerated depreciation, salvage value
      - (9) Total cash inflow from facility

b. Investment and other cost factors
   (1) Land (See also Section I. LAND: C.)
      (a) Price per acre and total price
      (b) Probable appreciation of land value
   (2) Cost of improvements
      (a) Clearance and drainage
      (b) Extension of utility services (See also Section II. UTILITIES)
         i) Electricity
         ii) Gas
         iii) Water
         iv) Sewer
      (c) Transportation access (See also Section III. TRANSPORTATION)
         i) Rail
         ii) Highway
         iii) Water
   (3) Connection fees and permits
   (4) Building/leasehold improvements (See also Section I. LAND: J.28.)
   (5) Machinery and equipment
   (6) Furniture and fixtures
   (7) Other costs/fees
   (8) Working capital (accounts receivable, inventory, accounts payable)
   (9) Total cash outflow
   (10) Net cash flow
c. Tax, accounting considerations

B. Financing
1. Requirements
   a. New buildings or existing structures
   b. Lease or purchase
   c. Purchase lease-back
   d. Effect of alternate proposals on working capital
   e. Effect on tax liability
   f. Payout time
2. Sources of funds (See also Section VIII. GOVERNMENT AND LEGISLATIVE: G. and H.)
   a. Retained earnings
   b. Sale of stock, debentures or other securities
   c. Short-term bank loan
   d. Private long-term loan or mortgage
   e. Pooling of institutional funds
   f. Merger

g. Loan from affiliated firm
h. Loan from supplier
i. Insurance company
j. Mutual funds
k. Commercial financing
l. Factoring organization
m. Municipal or state industrial bonds
n. Local development corporation
o. Regional development corporation
p. State development corporation (privately financed)
q. State development authority (publicly financed)
r. Small Business Administration
s. Loan guarantees by a government entity
t. Economic Development Administration (in depressed areas)

3. Credit Factors
   a. Reputation of firm
   b. Type of business
   c. Length of time in business
   d. Quality and continuity of management
   e. Training of young executives
   f. Earning history
   g. Cash position
   h. Other short- and long-term commitments
   i. Size and type of plant (adaptability for other uses)
4. Factors Affecting Loan Terms
   a. General business conditions
   b. Length of loan
   c. Interest rate
   d. Importance of industry to community
5. Special Inducements (See also Section VIII. GOVERNMENT AND LEGISLATIVE: F., G. and H.)
   a. Free land, plant
   b. Nominal rent
   c. Low interest rates
   d. Tax incentives

C. Leasing Data
1. Nature and duration of lease
2. Description of premises, including appurtenances
3. Renewal and purchase options and options for additional space
4. Right of first refusal on additional space
5. Right to lease adjacent or substitute space
6. Availability of month-to-month tenancy when holding over
7. Rent
   a. Amount
   b. When and how payable

8. Grace period
9. Escalations
    a. In real estate taxes
    b. In building operating expenses
    c. Basis for escalation (CPI, etc.)
10. Penalty for early termination
11. Right to possession
12. Measure of damages
13. Subletting and assignment
14. Responsibility for taxes, other expenses
15. Building services, utilities furnished by landlord
    a. Heating (hours supplied)
    b. Air conditioning (hours supplied)
    c. Janitorial
    d. Window cleaning
    e. Building maintenance
    f. Security
    g. Parking
    h. Exterminating service
    i. Water
    j. Exterior grounds maintenance and snow removal
16. Leasehold improvements allowance
17. Number of parking spaces included in lease
18. Right to erect signs, other advertising matter
19. Responsibility for repairs and conformity with building codes, laws
20. Title, zoning and other restrictions on use of land
21. Liability, insurance coverage and subrogation
22. Destruction or condemnation of premises
23. Building and construction of new leased facilities (Specify location, date of construction, date of construction completion, type of construction, etc.)
24. Permissible uses

D. Points to Cover in Leases on Public Property (Such as an Airport)
1. Term adequate for financing: 50 years or shorter term with option to extend
2. Realistic subordination provision to permit financing
3. Lessee to have right to substitute a joint venture or subsidiary, sublease or assign
4. Lessor to provide survey of property
5. FAA reversion clause to be modified (if necessary) to provide that parcel leased not be recaptured if improper use made of other sites on airport by other lessees

6. Height restrictions and building restriction lines affecting site not to be changed during lease term
7. Taxiway access guarantee

E. Lease versus Buy (leasing strategies)
1. Use of a lease as a financing vehicle
2. Sale-leaseback as a financing method
3. Tax treatment of advance rental payments
4. Improvements on leased premises
5. Amortization or depreciation of leasehold and improvements
6. Tax consequences of rental options
7. Distinction between ordinary repairs and capital expenditures
8. Tax treatment of options to purchase
9. Tax treatment of net leases
10. Use of percentage lease provisions to cope with inflation
11. Tax treatments of payment by lessee to secure or cancel lease
12. Tax consequences of subletting premises or assigning lease
13. Risk avoidance
14. Short-term situation
15. Administrative convenience

APPENDIX III

FACTORS OF INTEREST IN INTERNATIONAL LOCATION DECISIONS

FACTORS OF INTEREST IN INTERNATIONAL LOCATION DECISIONS

I. Foreign Location Considerations
   A. Corporate Rationale for Location Outside U.S.
      1. Materials availability, minerals source
      2. Market opportunity
      3. Production cost factors (wage rate differentials, etc.)
      4. Capital availability
      5. Other
   B. Government Regulations on Capital Investment in Foreign Ventures
   C. Political Situation in Foreign Country
      1. International orientation
      2. Stability of regime
      3. Attitude of leading political parties toward foreign capital
      4. Protection against expropriation of foreign companies
      5. Special treatment for host nation industries
      6. Treaties or pacts between U.S. and foreign country
      7. Sanctity of contract with foreign government
      8. Military alliances of foreign government
      9. Record of terrorism, protection of human rights
      10. Social and legal issues (environmental pollution, nuclear and/or toxic wastes)
   D. Government Regulations
      1. Fairness of administrative procedures
      2. Prevalence of bureaucratic red tape
      3. Clarity of corporate investment laws
      4. Record of courts in regard to foreign companies
      5. Regulations concerning joint ventures or mergers with local firms
      6. Requirements for setting up local corporations
      7. Percentage of capital that may be foreign
      8. Percentage of all employees and of supervisory employees that may be foreign
      9. Regulations concerning patents
      10. Price controls
      11. Regulations on transfer of earnings out of the country
      12. Restrictions on exploitation of natural resources
      13. Taxation of foreign-owned companies
      14. Value added tax
      15. Taxation of export income and income from operations abroad

E. Tariffs and Customs Regulations
   1. Present and foreseen participation in regional tariff agreements
   2. Other tariff protection, export subsidies
   3. Tariff rates on raw materials and components
   4. Export taxes on finished product
   5. Duty or tax penalties when imported goods are exported
   6. Regulations regarding free trade zones
   7. Availability of bonded warehouses

F. Economic Factors
   1. Export-import records and trends
   2. Standard of living, per capita income
   3. Trends in Gross National Product
   4. Stability of economy, cyclic trends
   5. Fiscal policies and practices
   6. Record of payment of foreign debts
   7. Strength of currency against U.S. dollar (currency exchange rates and fluctuations: monetary risk)
   8. Balance of payments status and trends
   9. Major components of economy and trends (agriculture, industry, commerce)
   10. Trends in U.S. and other foreign investment
   11. Trends in prices and inflation rate

G. Financing
   1. Availability of local investment capital
   2. Local interest rates and terms
   3. Availability of convertible currencies
   4. Availability of export financing and insurance
   5. Debt/equity requirements
   6. Quality of local banking system, savings and loan associations
   7. Availability of a development bank
   8. Government credit aids to new companies
   9. Policies of international capital sources on loans in the foreign country
   10. Special incentives (see "II. Categories of Foreign Investment Incentives")

H. General Business Factors
   1. Official language for conduct of business, if any
   2. Availability of U.S. investment guaranty, covering war, expropriation and convertibility risks
   3. Overall reputation of the business community
   4. National and local marketing and distribution systems
   5. Units of measurement used
   6. Corporate law heritage (British, Latin, Dutch, etc.)

7. Availability and quality of telex, telephone systems, satellite communications
8. Availability of spare parts
9. Availability of an international airport
10. Capacity and quality of industrial gases
11. Literacy rate
12. Ethnic tensions
13. Quality of local workmanship
14. Skilled labor matrix
15. Availability of local supplies, services
16. Percent of crude oil imported
17. Local electrical power system -- cycles, voltage, phase
18. Railroad gauge
19. Normal freight car capacity

I. Other Factors
1. Major differences in culture and management styles
2. Employee fringe benefits, both compulsory and voluntary practices
3. Time difference from New York, London, Tokyo
4. Local taboos or unusual product preferences

II. Categories of Foreign Investment Incentives
   A. Percentage of Foreign Participation Allowed
      1. For most-desired type of investment
      2. For least-desired type of investment
   B. Percentage Venture Profit Repatriation
      1. Maximum per year
      2. Minimum per year
   C. Percentage Investment Capital Repatriation
      1. Maximum per year
      2. Minimum per year
   D. Current Guarantee Treaties
      1. With the United States
      2. With other nations
   E. Percentage Tax Exemption (for limited number of years)
      1. Corporate income tax
      2. Property tax
   F. Percentage Customs Duty Exemption on Goods in Transit
   G. Percentage Value-Added Tax on Finished Products and Services
   H. Special Incentives
      1. To attract outside investment
      2. Offered to certain industries
      3. According to status of investment (pioneer, etc.)
      4. Offered for certain areas
      5. Other types
   I. Subsidies
      1. Industrial sites free or for less than market price
      2. Industrial buildings free of for less than market price
      3. Training for new workers
      4. Wages for new workers

APPENDIX IV

BIOMASS RESEARCH PROJECT SURVEY

Department of Forest Products
Oregon State University
Corvallis, Oregon 97331-5704 (503) 754-2017

OREGON STATE UNIVERSITY

BIOMASS RESEARCH PROJECT

The Forest Products department at Oregon State University is currently involved in a research project to determine the feasibility of locating and building a 10-15 MW(e) forest residue fueled generating plant. As a part of this project, we are performing a plant location analysis.

We would appreciate your assistance in developing a ranking system for a set of factors influencing the location of a forest residue fueled electric generating plant. The information you provide will be used in coded form for statistical analyses and all information will be completely confidential.

Please answer the questions on the following pages and we would appreciate your response by August 1, 1986. Please return in the enclosed envelope to:

Rhonda Wright
Biomass Research Project
Forest Research Lab
3015 S.W. Western Blvd.
Corvallis, OR 97331

If you have any questions regarding any part of the survey, please contact Rhonda Wright at (503) 753-9166. Thank you for your time and cooperation in participating in this survey.

GENERAL DATA

Company name: ____

Location: ____

Respondent's name and position: ___________________________

____

Telephone number: ____

For this study, we have a list of factors which influence the location of a forest residue fueled generating plant and we have a list of technically feasible sites. However, each of these sites will require some modifications either at the site or in the plant design before a plant can be built there. With this background information in mind, please circle the letter associated with the site factor which you believe is most important in each of the paired sets listed below.

A Volume of wood supply
B Proximity to a road network

A Site preparation required
B Air quality standards at the location

A Total amount of available land
B Volume and quality of water supply

A Proximity to transmission lines
B Current zoning of land

A Distance from wood supply
B Volume of wood supply

A Labor availability
B Distance from wood supply

A Volume wood supply
B Water quality standards at the location

A Proximity to road network
B Topography and soil conditions

A Volume of wood supply
B Site preparation required

A Site preparation required
B Water quality standards at location

A Distance from wood supply
B Site preparation required

A Labor availability
B Volume of wood supply

A Competition for available wood supply
B Labor availability

A Topography and soil conditions
B Air quality standards at location

A Proximity to road network
B Air quality standards at location

A Volume and quality of water supply
B Site preparation required

A Proximity to road network
B Current zoning of land

A Proximity to transmission lines
B Topography and soil conditions

A Volume of wood supply
B Total amount of available land

A Proximity to road network
B Proximity to transmission lines

A Site preparation required
B Topography and soil conditions

A Volume and quality of water supply
B Topography and soil conditions

A Total amount of land available
B Air quality standards at location

A Proximity to transmission lines
B Site preparation required

A Volume of wood supply
B Proximity to transmission lines

A Proximity to road network
B Total amount of land available

A Distance from wood supply
B Proximity to road network

A Labor availability
B Site preparation required

A Competition for available wood supply
B Distance from wood supply

A Volume of wood supply
B Competition for available wood supply

A Proximity to road network
B Water quality standards at location

A Distance from wood supply
B Proximity to transmission lines

A Labor availability
B Proximity to road network

A Competition for available wood supply
B Site preparation required

A Proximity to road network
B Competition for available wood supply

A Proximity to transmission lines
B Water quality standards at location

A Distance from wood supply
B Current zoning of land

A Labor availability
B Proximity to transmission lines

A Labor availability
B Current zoning of land

A Competition for available wood supply
B Proximity to transmission lines

A Current zoning of land
B Competition for available wood supply

A Air quality standards at location
B Water quality standards at location

A Distance from wood supply
B Water quality standards at location

A Labor availability
B Water quality standards at location

A Competition for available wood supply
B Topography and soil conditions

A Current zoning of land
B Water quality standards at location

A Distance from wood supply
B Total amount of land available

A Labor availability
B Volume and quality of water supply

A Volume and quality of water supply
B Current zoning of land

A Proximity to transmission lines
B Volume and quality of water supply

A Total amount of land available
B Topography and soil conditions

A Current zoning of land
B Air quality standards at location

A Volume of wood supply
B Volume and quality of water supply

A Proximity to road network
B Site preparation required

A Proximity to transmission lines
B Air quality standards at location

A Volume of wood supply
B Topography and soil conditions

A Total amount of land available
B Site preparation required

A Volume and quality of water supply
B Air quality standards at location

A Proximity to road network
B Volume and quality of water supply

A Volume of wood supply
B Current zoning of land

A Current zoning of land
B Site preparation required

A Proximity to transmission lines
B Total amount of available land

A Current zoning of land
B Topography and soil conditions

A Volume of wood supply
B Air quality standards at location

A Current zoning of land
B Total amount of available land

A Topography and soil conditions
B Water quality standards at location

A Distance from wood supply
B Air quality standards at location

A Total amount of land available
B Labor availability

A Air quality standards at location
B Competition for available wood supply

A Volume and quality of water supply
B Water quality standards at location

A Topography and soil conditions
B Distance from wood supply

A Air quality standards at location
B Labor availability

A Competition for available wood supply
B Water quality standards at location

A Total amount of land available
B Competition for available wood supply

A Water quality standards at location
B Total amount of land available

A Distance from wood supply
B Volume and quality of water supply

A Labor availability
B Topography and soil conditions

A Competition for available wood supply
B Volume and quality of water supply

Suggestions for additional factors you feel should be

included: ____

____

APPENDIX V

BIOMASS SITES SCORING

USING ALTERNATIVE WEIGHTS

Site Evaluations Using Alternative Weights (Ranking)

			Site A		Site B		Site C		Site D		Site E		Site F	
		Weights	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
Factor 1	Current zoning of land	0.0641	4.0	0.256	6.0	0.385	8.0	0.513	4.0	0.256	9.0	0.577	6.0	0.385
Factor 2	Site preparation required	0.0513	3.0	0.154	7.0	0.359	6.0	0.308	3.0	0.154	8.0	0.410	7.0	0.359
Factor 3	Amount of land available	0.0385	2.0	0.077	8.0	0.308	1.0	0.038	7.0	0.269	0.0	0.000	7.0	0.269
Factor 4	Topography & soil conditions	0.0256	1.0	0.026	9.0	0.231	3.0	0.077	8.0	0.205	2.0	0.051	5.0	0.128
Factor 5	Volume of water supply	0.1090	6.0	0.654	4.0	0.436	2.0	0.218	2.0	0.218	10.0	1.090	6.0	0.654
Factor 6	Distance from roads	0.0769	5.0	0.385	5.0	0.385	7.0	0.538	4.0	0.308	7.0	0.538	5.0	0.385
Factor 7	Distance from power lines	0.0897	5.0	0.449	5.0	0.449	4.0	0.359	3.0	0.269	8.0	0.718	6.0	0.538
Factor 8	Volume of wood supply	0.1538	10.0	1.538	0.0	0.000	9.0	1.385	5.0	0.769	2.0	0.308	5.0	0.769
Factor 9	Competition for wood	0.1410	9.0	1.269	1.0	0.141	9.0	1.269	7.0	0.987	3.0	0.423	5.0	0.705
Factor 10	Distance from wood supply	0.1090	7.0	0.763	3.0	0.327	2.0	0.218	2.0	0.218	9.0	0.981	7.0	0.763
Factor 11	Labor availability	0.0128	0.0	0.000	10.0	0.128	1.0	0.013	6.0	0.077	3.0	0.038	7.0	0.090
Factor 12	Air quality standards	0.1282	8.0	1.026	2.0	0.256	8.0	1.026	8.0	1.026	1.0	0.128	6.0	0.769
TOTAL SCORE		1.0000		6.596		3.404		5.962		4.756		5.263		5.814
RANK				1		6		2		5		4		3

Site Evaluations Using Alternative Weights (Hierarchial/Ranking)

		Weights	Site A Measure	Site A Wtd Value	Site B Measure	Site B Wtd Value	Site C Measure	Site C Wtd Value
Factor 1	Current zoning of land	0.0286	4.0	0.114	6.0	0.171	8.0	0.229
Factor 2	Site preparation required	0.0214	3.0	0.064	7.0	0.150	6.0	0.129
Factor 3	Amount of land available	0.0143	2.0	0.029	8.0	0.114	1.0	0.014
Factor 4	Topography & soil conditions	0.0071	1.0	0.007	9.0	0.064	3.0	0.021
Factor 5	Volume of water supply	0.1786	6.0	1.071	4.0	0.714	2.0	0.357
Factor 6	Distance from roads	0.1071	5.0	0.536	5.0	0.536	7.0	0.750
Factor 7	Distance from power lines	0.1429	5.0	0.714	5.0	0.714	4.0	0.571
Factor 8	Volume of wood supply	0.1042	10.0	1.042	0.0	0.000	9.0	0.938
Factor 9	Competition for wood	0.1042	9.0	0.938	1.0	0.104	9.0	0.938
Factor 10	Distance from wood supply	0.0417	7.0	0.292	3.0	0.125	2.0	0.083
Factor 11	Labor availability	0.0357	0.0	0.000	10.0	0.357	1.0	0.036
Factor 12	Air quality standards	0.2143	8.0	1.714	2.0	0.429	8.0	1.714
TOTAL SCORE		1.0000		6.521		3.479		5.780
RANK				1		6		3

Site D Measure	Site D Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
4.0	0.114	9.0	0.257	6.0	0.171
3.0	0.064	8.0	0.171	7.0	0.150
7.0	0.100	0.0	0.000	7.0	0.100
8.0	0.057	2.0	0.014	5.0	0.036
2.0	0.357	10.0	1.786	6.0	1.071
4.0	0.429	7.0	0.750	5.0	0.536
3.0	0.429	8.0	1.143	6.0	0.857
5.0	0.521	2.0	0.208	5.0	0.521
7.0	0.729	3.0	0.313	5.0	0.521
2.0	0.083	9.0	0.375	7.0	0.292
6.0	0.214	3.0	0.107	7.0	0.250
8.0	1.714	1.0	0.214	6.0	1.286
	4.812		5.339		5.791
	5		4		2

Figure 33. Site Evaluations Using Alternative Weights (Hierarchial/Equal)

			Site A		Site B		Site C	
		Weights	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
Factor 1	Current zoning of land	0.0357	4.0	0.143	6.0	0.214	8.0	0.286
Factor 2	Site preparation required	0.0357	3.0	0.107	7.0	0.250	6.0	0.214
Factor 3	Amount of land available	0.0357	2.0	0.071	8.0	0.286	1.0	0.036
Factor 4	Topography & soil conditions	0.0357	1.0	0.036	9.0	0.321	3.0	0.107
Factor 5	Volume of water supply	0.1429	6.0	0.857	4.0	0.571	2.0	0.286
Factor 6	Distance from roads	0.1429	5.0	0.714	5.0	0.714	7.0	1.000
Factor 7	Distance from power lines	0.1429	5.0	0.714	5.0	0.714	4.0	0.571
Factor 8	Volume of wood supply	0.0476	10.0	0.476	0.0	0.000	9.0	0.429
Factor 9	Competition for wood	0.0476	9.0	0.429	1.0	0.048	9.0	0.429
Factor 10	Distance from wood supply	0.0476	7.0	0.333	3.0	0.143	2.0	0.095
Factor 11	Labor availability	0.1429	0.0	0.000	10.0	1.429	1.0	0.143
Factor 12	Air quality standards	0.1429	8.0	1.143	2.0	0.286	8.0	1.143
TOTAL SCORE		1.0000		5.024		4.976		4.738
RANK				3		4		5

Site D		Site E		Site F	
Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
4.0	0.143	9.0	0.321	6.0	0.214
3.0	0.107	8.0	0.286	7.0	0.250
7.0	0.250	0.0	0.000	7.0	0.250
8.0	0.286	2.0	0.071	5.0	0.179
2.0	0.286	10.0	1.429	6.0	0.857
4.0	0.571	7.0	1.000	5.0	0.714
3.0	0.429	8.0	1.143	6.0	0.857
5.0	0.238	2.0	0.095	5.0	0.238
7.0	0.333	3.0	0.143	5.0	0.238
2.0	0.095	9.0	0.429	7.0	0.333
6.0	0.857	3.0	0.429	7.0	1.000
8.0	1.143	1.0	0.143	6.0	0.857
	4.738		5.488		5.988
	6		2		1

Site Evaluations Using Alternative Weights (Equal)

			Site A		Site B		Site C		Site D		Site E		Site F	
		Weights	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
Factor 1	Current zoning of land	0.0833	4.0	0.333	6.0	0.500	8.0	0.667	4.0	0.333	9.0	0.750	6.0	0.500
Factor 2	Site preparation required	0.0833	3.0	0.250	7.0	0.583	6.0	0.500	3.0	0.250	8.0	0.667	7.0	0.583
Factor 3	Amount of land available	0.0833	2.0	0.167	8.0	0.667	1.0	0.083	7.0	0.583	0.0	0.000	7.0	0.583
Factor 4	Topography & soil conditions	0.0833	1.0	0.083	9.0	0.750	3.0	0.250	8.0	0.667	2.0	0.167	5.0	0.417
Factor 5	Volume of water supply	0.0833	6.0	0.500	4.0	0.333	2.0	0.167	2.0	0.167	10.0	0.833	6.0	0.500
Factor 6	Distance from roads	0.0833	5.0	0.417	5.0	0.417	7.0	0.583	4.0	0.333	7.0	0.583	5.0	0.417
Factor 7	Distance from power lines	0.0833	5.0	0.417	5.0	0.417	4.0	0.333	3.0	0.250	8.0	0.667	6.0	0.500
Factor 8	Volume of wood supply	0.0833	10.0	0.833	0.0	0.000	9.0	0.750	5.0	0.417	2.0	0.167	5.0	0.417
Factor 9	Competition for wood	0.0833	9.0	0.750	1.0	0.083	9.0	0.750	7.0	0.583	3.0	0.250	5.0	0.417
Factor 10	Distance from wood supply	0.0833	7.0	0.583	3.0	0.250	2.0	0.167	2.0	0.167	9.0	0.750	7.0	0.583
Factor 11	Labor availability	0.0833	0.0	0.000	10.0	0.833	1.0	0.083	6.0	0.500	3.0	0.250	7.0	0.583
Factor 12	Air quality standards	0.0833	8.0	0.667	2.0	0.167	8.0	0.667	8.0	0.667	1.0	0.083	6.0	0.500
TOTAL SCORE		1.0000		5.000		5.000		5.000		4.916		5.166		6.000
RANK				3		4		5		6		2		1

Absolute and Percentage Differences in Scores (Ranking Weights)

SITE	SCORE	DIFFERENCES									
Site A	6.596										
Site C	5.962	0.635	9.6%								
Site F	5.814	0.782	11.9%	0.147	2.5%						
Site E	5.263	1.333	20.2%	0.699	11.7%	0.551	9.5%				
Site D	4.756	1.840	27.9%	1.205	20.2%	1.058	18.2%	0.506	9.6%		
Site B	3.404	3.192	48.4%	2.558	42.9%	2.410	41.5%	1.859	35.3%	1.353	28.4%

Absolute and Percentage Differences in Scores (Hierarchial/Ranking Weights)

SITE	SCORE	DIFFERENCES									
Site A	6.521										
Site F	5.791	0.730	11.2%								
Site C	5.780	0.741	11.4%	0.011	0.2%						
Site E	5.339	1.182	18.1%	0.452	7.8%	0.441	7.6%				
Site D	4.812	1.709	26.2%	0.979	16.9%	0.968	16.7%	0.527	9.9%		
Site B	3.479	3.042	46.6%	2.311	39.9%	2.301	39.8%	1.860	34.8%	1.333	27.7%

Absolute and Percentage Differences in Scores (Hierarchial/Equal Weights)

SITE	SCORE	DIFFERENCES									
Site F	5.988										
Site E	5.488	0.500	8.3%								
Site A	5.024	0.964	16.1%	0.464	8.5%						
Site B	4.976	1.012	16.9%	0.512	9.3%	0.048	0.9%				
Site C	4.738	1.250	20.9%	0.750	13.7%	0.286	5.7%	0.238	4.8%		
Site D	4.738	1.250	20.9%	0.750	13.7%	0.286	5.7%	0.238	4.8%	0.000	0.0%

Absolute and Percentage Differences in Scores (Equal Weights)

SITE	SCORE	DIFFERENCES									
Site F	6.000										
Site E	5.166	0.833	13.9%								
Site A	5.000	1.000	16.7%	0.167	3.2%						
Site B	5.000	1.000	16.7%	0.167	3.2%	-0.000	-0.0%				
Site C	5.000	1.000	16.7%	0.167	3.2%	0.000	0.0%	0.000	0.0%		
Site D	4.916	1.083	18.1%	0.250	4.8%	0.083	1.7%	0.083	1.7%	0.083	1.7%

APPENDIX VI

WEIGHT SENSITIVITY ANALYSIS

FOR BIOMASS SITES

Remaining Contenders (Equal Weights)

		Weights	Site A Measure	Site A Wtd Value	Site C Measure	Site C Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
Factor 1	Current zoning of land	0.0833	4.0	0.333	8.0	0.667	9.0	0.750	6.0	0.500
Factor 2	Site preparation required	0.0833	3.0	0.250	6.0	0.500	8.0	0.667	7.0	0.583
Factor 3	Amount of land available	0.0833	2.0	0.167	1.0	0.083	0.0	0.000	7.0	0.583
Factor 4	Topography & soil conditions	0.0833	1.0	0.083	3.0	0.250	2.0	0.167	5.0	0.417
Factor 5	Volume of water supply	0.0833	6.0	0.500	2.0	0.167	10.0	0.833	6.0	0.500
Factor 6	Distance from roads	0.0833	5.0	0.417	7.0	0.583	7.0	0.583	5.0	0.417
Factor 7	Distance from power lines	0.0833	5.0	0.417	4.0	0.333	8.0	0.667	6.0	0.500
Factor 8	Volume of wood supply	0.0833	10.0	0.833	9.0	0.750	2.0	0.167	5.0	0.417
Factor 9	Competition for wood	0.0833	9.0	0.750	9.0	0.750	3.0	0.250	5.0	0.417
Factor 10	Distance from wood supply	0.0833	7.0	0.583	2.0	0.167	9.0	0.750	7.0	0.583
Factor 11	Labor availability	0.0833	0.0	0.000	1.0	0.083	3.0	0.250	7.0	0.583
Factor 12	Air quality standards	0.0833	8.0	0.667	8.0	0.667	1.0	0.083	6.0	0.500
TOTAL SCORE		1.0000		5.000		5.000		5.167		6.000
RANK				3		4		2		1

Sensitivity Analysis (Factor 8 weight decreased 50 percent)

		Weights	Site A Measure	Site A Wtd Value	Site C Measure	Site C Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
Factor 1	Current zoning of land	0.0871	4.0	0.348	8.0	0.697	9.0	0.784	6.0	0.523
Factor 2	Site preparation required	0.0871	3.0	0.261	6.0	0.523	8.0	0.697	7.0	0.610
Factor 3	Amount of land available	0.0871	2.0	0.174	1.0	0.087	0.0	0.000	7.0	0.610
Factor 4	Topography & soil conditions	0.0871	1.0	0.087	3.0	0.261	2.0	0.174	5.0	0.436
Factor 5	Volume of water supply	0.0871	6.0	0.523	2.0	0.174	10.0	0.871	6.0	0.523
Factor 6	Distance from roads	0.0871	5.0	0.436	7.0	0.610	7.0	0.610	5.0	0.436
Factor 7	Distance from power lines	0.0871	5.0	0.436	4.0	0.348	8.0	0.697	6.0	0.523
Factor 8	Volume of wood supply	0.0417	10.0	0.417	9.0	0.375	2.0	0.083	5.0	0.208
Factor 9	Competition for wood	0.0871	9.0	0.784	9.0	0.784	3.0	0.261	5.0	0.436
Factor 10	Distance from wood supply	0.0871	7.0	0.610	2.0	0.174	9.0	0.784	7.0	0.610
Factor 11	Labor availability	0.0871	0.0	0.000	1.0	0.087	3.0	0.261	7.0	0.610
Factor 12	Air quality standards	0.0871	8.0	0.697	8.0	0.697	1.0	0.087	6.0	0.523
TOTAL SCORE		1.0000		4.773		4.818		5.311		6.045
RANK				4		3		2		1

Sensitivity Analysis (Factor 8 weight increased 50 percent)

			Site A		Site C		Site E		Site F	
		Weights	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
Factor 1	Current zoning of land	0.0795	4.0	0.318	8.0	0.636	9.0	0.716	6.0	0.477
Factor 2	Site preparation required	0.0795	3.0	0.239	6.0	0.477	8.0	0.636	7.0	0.557
Factor 3	Amount of land available	0.0795	2.0	0.159	1.0	0.080	0.0	0.000	7.0	0.557
Factor 4	Topography & soil conditions	0.0795	1.0	0.080	3.0	0.239	2.0	0.159	5.0	0.398
Factor 5	Volume of water supply	0.0795	6.0	0.477	2.0	0.159	10.0	0.795	6.0	0.477
Factor 6	Distance from roads	0.0795	5.0	0.398	7.0	0.557	7.0	0.557	5.0	0.398
Factor 7	Distance from power lines	0.0795	5.0	0.398	4.0	0.318	8.0	0.636	6.0	0.477
Factor 8	Volume of wood supply	0.1250	10.0	1.250	9.0	1.125	2.0	0.250	5.0	0.625
Factor 9	Competition for wood	0.0795	9.0	0.716	9.0	0.716	3.0	0.239	5.0	0.398
Factor 10	Distance from wood supply	0.0795	7.0	0.557	2.0	0.159	9.0	0.716	7.0	0.557
Factor 11	Labor availability	0.0795	0.0	0.000	1.0	0.080	3.0	0.239	7.0	0.557
Factor 12	Air quality standards	0.0795	8.0	0.636	8.0	0.636	1.0	0.080	6.0	0.477
TOTAL SCORE		1.0000		5.227		5.182		5.023		5.955
RANK				4		3		2		1

Sensitivity Analysis (Factor 9 weight decreased 50 percent)

		Weights	Site A Measure	Site A Wtd Value	Site C Measure	Site C Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
Factor 1	Current zoning of land	0.0871	4.0	0.348	8.0	0.697	9.0	0.784	6.0	0.523
Factor 2	Site preparation required	0.0871	3.0	0.261	6.0	0.523	8.0	0.697	7.0	0.610
Factor 3	Amount of land available	0.0871	2.0	0.174	1.0	0.087	0.0	0.000	7.0	0.610
Factor 4	Topography & soil conditions	0.0871	1.0	0.087	3.0	0.261	2.0	0.174	5.0	0.436
Factor 5	Volume of water supply	0.0871	6.0	0.523	2.0	0.174	10.0	0.871	6.0	0.523
Factor 6	Distance from roads	0.0871	5.0	0.436	7.0	0.610	7.0	0.610	5.0	0.436
Factor 7	Distance from power lines	0.0871	5.0	0.436	4.0	0.348	8.0	0.697	6.0	0.523
Factor 8	Volume of wood supply	0.0871	10.0	0.871	9.0	0.784	2.0	0.174	5.0	0.436
Factor 9	Competition for wood	0.0417	9.0	0.375	9.0	0.375	3.0	0.125	5.0	0.208
Factor 10	Distance from wood supply	0.0871	7.0	0.610	2.0	0.174	9.0	0.784	7.0	0.610
Factor 11	Labor availability	0.0871	0.0	0.000	1.0	0.087	3.0	0.261	7.0	0.610
Factor 12	Air quality standards	0.0871	8.0	0.697	8.0	0.697	1.0	0.087	6.0	0.523
TOTAL SCORE		1.0000		4.818		4.818		5.265		6.045
RANK				4		3		2		1

Sensitivity Analysis (Factor 9 weight increased 50 percent)

		Weights	Site A Measure	Site A Wtd Value	Site C Measure	Site C Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
Factor 1	Current zoning of land	0.0795	4.0	0.318	8.0	0.636	9.0	0.716	6.0	0.477
Factor 2	Site preparation required	0.0795	3.0	0.239	6.0	0.477	8.0	0.636	7.0	0.557
Factor 3	Amount of land available	0.0795	2.0	0.159	1.0	0.080	0.0	0.000	7.0	0.557
Factor 4	Topography & soil conditions	0.0795	1.0	0.080	3.0	0.239	2.0	0.159	5.0	0.398
Factor 5	Volume of water supply	0.0795	6.0	0.477	2.0	0.159	10.0	0.795	6.0	0.477
Factor 6	Distance from roads	0.0795	5.0	0.398	7.0	0.557	7.0	0.557	5.0	0.398
Factor 7	Distance from power lines	0.0795	5.0	0.398	4.0	0.318	8.0	0.636	6.0	0.477
Factor 8	Volume of wood supply	0.0795	10.0	0.795	9.0	0.716	2.0	0.159	5.0	0.398
Factor 9	Competition for wood	0.1250	9.0	1.125	9.0	1.125	3.0	0.375	5.0	0.625
Factor 10	Distance from wood supply	0.0795	7.0	0.557	2.0	0.159	9.0	0.716	7.0	0.557
Factor 11	Labor availability	0.0795	0.0	0.000	1.0	0.080	3.0	0.239	7.0	0.557
Factor 12	Air quality standards	0.0795	8.0	0.636	8.0	0.636	1.0	0.080	6.0	0.477
TOTAL SCORE		1.0000		5.182		5.182		5.068		5.955
RANK				4		3		2		1

Sensitivity Analysis (Factor 12 weight decreased 50 percent)

		Weights	Site A Measure	Site A Wtd Value	Site C Measure	Site C Wtd Value	Site E Measure	Site E Wtd Value	Site F Measure	Site F Wtd Value
Factor 1	Current zoning of land	0.0871	4.0	0.348	8.0	0.697	9.0	0.784	6.0	0.523
Factor 2	Site preparation required	0.0871	3.0	0.261	6.0	0.523	8.0	0.697	7.0	0.610
Factor 3	Amount of land available	0.0871	2.0	0.174	1.0	0.087	0.0	0.000	7.0	0.610
Factor 4	Topography & soil conditions	0.0871	1.0	0.087	3.0	0.261	2.0	0.174	5.0	0.436
Factor 5	Volume of water supply	0.0871	6.0	0.523	2.0	0.174	10.0	0.871	6.0	0.523
Factor 6	Distance from roads	0.0871	5.0	0.436	7.0	0.610	7.0	0.610	5.0	0.436
Factor 7	Distance from power lines	0.0871	5.0	0.436	4.0	0.348	8.0	0.697	6.0	0.523
Factor 8	Volume of wood supply	0.0871	10.0	0.871	9.0	0.784	2.0	0.174	5.0	0.436
Factor 9	Competition for wood	0.0871	9.0	0.784	9.0	0.784	3.0	0.261	5.0	0.436
Factor 10	Distance from wood supply	0.0871	7.0	0.610	2.0	0.174	9.0	0.784	7.0	0.610
Factor 11	Labor availability	0.0871	0.0	0.000	1.0	0.087	3.0	0.261	7.0	0.610
Factor 12	Air quality standards	0.0417	8.0	0.333	8.0	0.333	1.0	0.042	6.0	0.250
TOTAL SCORE		1.0000		4.864		4.864		5.356		6.000
RANK				4		3		2		1

Sensitivity Analysis (Factor 12 weight increased 50 percent)

			Site A		Site C		Site E		Site F	
		Weights	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value	Measure	Wtd Value
Factor 1	Current zoning of land	0.0795	4.0	0.318	8.0	0.636	9.0	0.716	6.0	0.477
Factor 2	Site preparation required	0.0795	3.0	0.239	6.0	0.477	8.0	0.636	7.0	0.557
Factor 3	Amount of land available	0.0795	2.0	0.159	1.0	0.080	0.0	0.000	7.0	0.557
Factor 4	Topography & soil conditions	0.0795	1.0	0.080	3.0	0.239	2.0	0.159	5.0	0.398
Factor 5	Volume of water supply	0.0795	6.0	0.477	2.0	0.159	10.0	0.795	6.0	0.477
Factor 6	Distance from roads	0.0795	5.0	0.398	7.0	0.557	7.0	0.557	5.0	0.398
Factor 7	Distance from power lines	0.0795	5.0	0.398	4.0	0.318	8.0	0.636	6.0	0.477
Factor 8	Volume of wood supply	0.0795	10.0	0.795	9.0	0.716	2.0	0.159	5.0	0.398
Factor 9	Competition for wood	0.0795	9.0	0.716	9.0	0.716	3.0	0.239	5.0	0.398
Factor 10	Distance from wood supply	0.0795	7.0	0.557	2.0	0.159	9.0	0.716	7.0	0.557
Factor 11	Labor availability	0.0795	0.0	0.000	1.0	0.080	3.0	0.239	7.0	0.557
Factor 12	Air quality standards	0.1250	8.0	1.000	8.0	1.000	1.0	0.125	6.0	0.750
TOTAL SCORE		1.0000		5.136		5.136		4.977		6.000
RANK				4		3		2		1