

CHAPTER FOUR

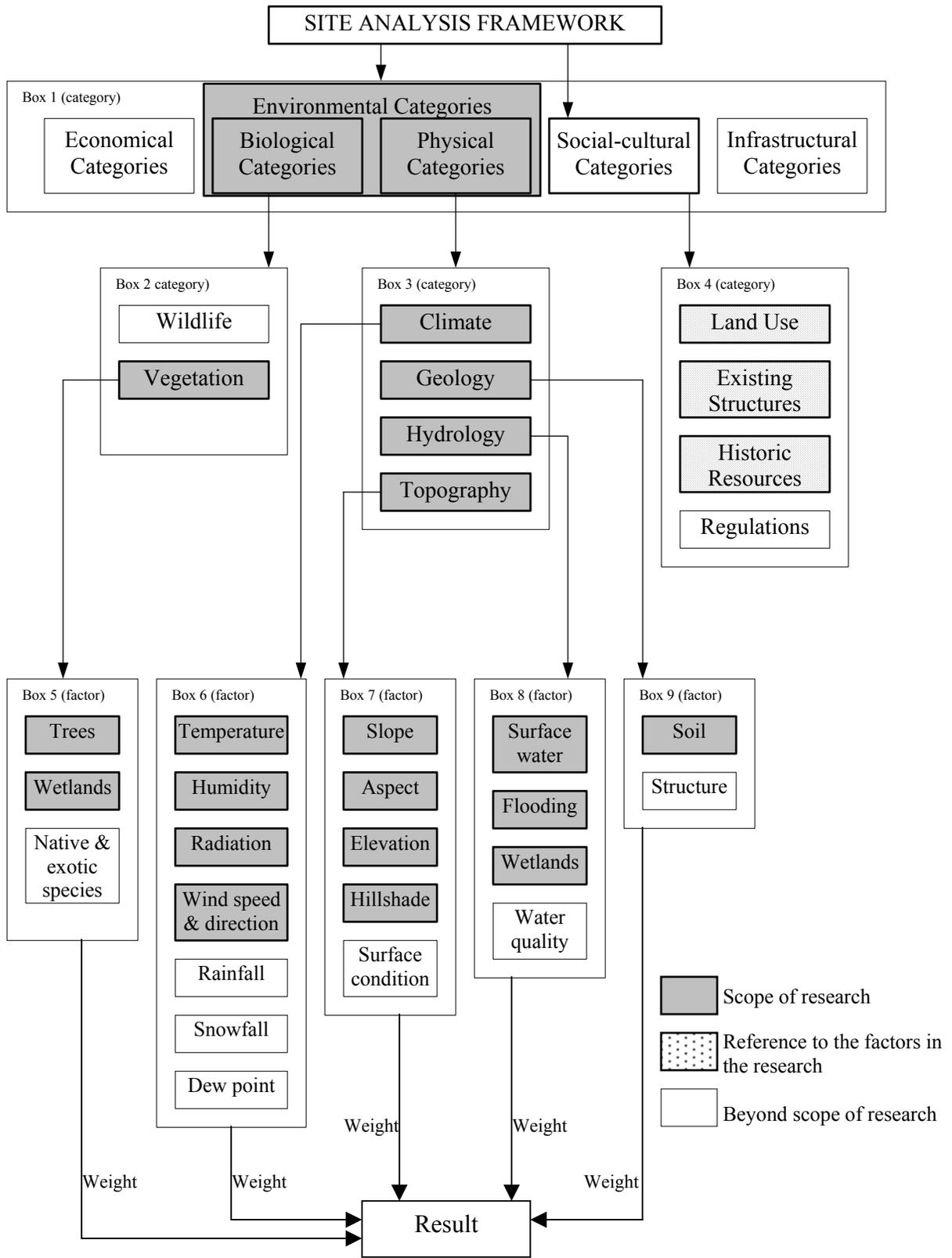
A SITE ANALYSIS FRAMEWORK

This chapter presents an integrated site analysis framework, discusses the environmental category within the framework, and describes implementation strategies. Then, it reviews existing methods and tools. Finally, the chapter introduces the implementation of a computer prototype system, SiteOne, which incorporates three analysis methods: feng shui (FS), contemporary environmental design principle (CE), and integration approach (FC). It highlights the concept, components, and structures involved in developing SiteOne.

4.1 Site Analysis Framework

The second chapter suggests an extended design process that begins with site analysis. It points out that most definitions divide the process into various steps within a structured and integrated approach. Traditional steps include selecting a site, locating buildings, and placing utilities. In an extended design process, however, the analysis and selection of a site includes site selection, inventory, analysis, concept development, and design implementation. Site analysis is a sub-system within the design process, and the major factors in the design process also form the essence of site analysis and selection. Consequently, this research suggests that site analysis can be broken down into several interactive categories.

The site analysis framework starts with the idea that a site analysis process can be segmented into steps, and that each step represents a snapshot of an analysis action at that point in time. As an integrated approach, this framework then incorporates each step and considers the interaction between steps. The most obvious are climate, geology, hydrology,



$$\text{Results} = \text{weight1} * \text{factor1} + \text{weight2} * \text{factor2} + \dots + \text{weightN} * \text{factorN}$$

Figure 4-1 Overview of the proposed site analysis framework

topography, vegetation, social and cultural background, and economic conditions (Figure 4-1). The environmental category consists of two sub-categories: biological categories and physical categories. Within the study field of each category, several major factors are identified. These factors include temperature, wind speed, and direction in the climate category. Because of the uniqueness of a site and the complexity of the procedure, the framework does not necessarily arrange these categories in a sequential order. Figure 4-1 presents overview of the proposed site analysis framework.

4.1.1 Environmental Categories

The environmental factors that were identified in the third chapter can fit into the following five groups: climate, geology, hydrology, topography, and vegetation. The proposed site analysis framework presents these groups as five separate categories, each of which contains several important factors. They may overlap and interact with others in the same or different categories.

The Climate Category

The climate category consists of several important weather factors, which are based on standard data sets and widely accepted methods. The Typical Meteorological Year (TMY) files provide standard data sets for performance and economic analyses of energy systems in selected locations across the country. TMY files contain hourly values of meteorological measurements for a one-year period, produced by the National Renewable Energy Laboratory of the U.S. Department of Energy. Monthly data sets, selected from individual years, form a complete year. In Virginia, data sets for five locations (Lynchburg, Norfolk, Roanoke, Richmond, and Sterling) are available. Table 4-1 lists the weather variables in the TMY files.

Widely accepted analysis methods emphasize fewer factors than those provided by TMY. The previous chapter reviews Olgyay's bioclimatic methods, which identify four major climatic factors (air temperature, solar radiation, air movement, and relative humidity) and their influence on human comfort. The bioclimatic chart, which assembles individual factors, shows the correlation between the various climatic factors and the comfort zone. Further, it suggests several modification strategies that can be used when the climatic

conditions do not fall within the comfort zone. Other elements listed in a TMY file can also serve as reference points, giving a comprehensive picture of the local weather condition.

Table 4-1 Weather variables in TMY files

<ul style="list-style-type: none">▪ Aerosol Optical Depth▪ Atmospheric Pressure▪ Broadband Turbidity▪ Days Since Last Snow▪ Dew Point Temperature▪ Dry Bulb Temperature▪ Illuminance Values▪ Opaque Sky Cover▪ Precipitable Water▪ Radiation Values (direct / diffuse)▪ Relative Humidity▪ Snow Depth▪ Total Sky Cover▪ Visibility▪ Wind Direction▪ Wind Speed

SiteOne, for instance, emphasizes four factors used in the bioclimatic analysis for its climate category. The climatic analysis using CE identifies thermal comfort¹ conditions based on these factors. With the consideration of radiation, relative humidity, and wind, the temperature for thermal comfort ranges from 73 to 84°F in the summer. The climatic analysis in FS only considers wind speed and wind direction. Section 4.3 gives detailed descriptions of both analyses.

The Geology Category

The geology category augments the framework by enabling soil type analysis and the examination of certain trace elements in the soil. On-site geological formations or bodies of water can be desirable or undesirable, depending on their specific characteristics, because natural elements within the soil and water are often difficult to change. These issues should be considered holistically.

¹ Thermal comfort is defined in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 55-1992 as “condition of mind which expresses satisfaction with the thermal environment; it requires subjective evaluation” (p.1). This standard considers the environment and personal factors to satisfy 80% or more people in thermal environmental conditions.

Geological analysis of sub-surface conditions can benefit the design process, because it can identify good bedrock and preferred soil foundations, as well as certain trace elements in the soil, such as zinc, fluorine, selenium, and molybdenum, which can endanger the health of residents through radiation or consumption of food grown in soil with these elements. Scientific measurements show that more than sixty elements exist in similar average proportions in both human blood and the earth's shell. These results indicate that humans have maintained harmony with the earth over the centuries; thus, unbalanced mineral composition is harmful and can lead to certain diseases.

SiteOne includes two analyses to illustrate the geological category in the framework² (Section 4.3). One is the soil type analysis based on regulations and building codes on soil ratings. In the case study of Reston, Virginia, the Problem Soils Ordinance of Fairfax County, Virginia differentiates soils into three classes: classes A, B and C. According to the ordinance and the BOCA National Building Code (1999), the soil analysis in Reston considers the land with "Class A" soils is unsuitable for development, and the land with other soil types is suitable. Sections 4.3 and 5.5 give detailed descriptions of soil analysis.

The other analysis is erosion. Both CE and FS are highly concerned with erosion that land developments should avoid potential erosion areas (Section 4.3). Texture, rock content, permeability, structure, and slope affect the potential erosion. Using SiteOne in Reston, there are five potential erosion symbols ("+", "0," "1," "2," and "3") and five slope classes (from A to E) on the soil maps. Based on the ordinance, the case study considers areas with low-potential erodible soils and moderate-potential erodible soils with gentle slopes are suitable for development (Sections 4.3 and 5.5).

The Hydrology Category

Since sunlight, air, and water resources are essential to life, a similar analysis for hydrological data can help designers avoid areas with hard water that is rich in sodium, calcium, magnesium, and sulfur. In addition, hydrological analysis should account for watersheds and floodplains. Most zoning codes have requirements about avoiding the

² Geological analysis is based on 1990 soil map and the Problem Soils Ordinance and Ratings of Soils for Urban Development in Fairfax County, Virginia. The soil ratings can be found at: <http://www.co.fairfax.va.us/gov/dpwes/environmental/soilrating.htm>.

floodplain. For example, Fairfax County Zoning Ordinance (2002) defines it as “land areas in and adjacent to streams and watercourses subject to continuous or periodic inundation from flood events with a one percent chance of occurrence in any given year and having a drainage area greater than seventy acres.” Finally, bodies of water, such as ponds, fountains, and streams, can affect the microclimate of a site by normalizing extreme temperatures.

There are two hydrology models in SiteOne, using FS or CE (Section 4.3). Based on the available data sets, the hydrological analysis using CE applies criteria to the wetland and floodplain maps in the case study. Suitable sites for development should avoid wetland and potential flood areas. In addition to areas identified in the wetland and floodplain maps, the hydrological analysis in FS also considers the lower, flat areas near rivers as potential flood areas. Moreover, bodies of water with good quality – without mud flowing, stinking smell, and muddy wetland – are desirable features in FS (Xu, 1990). Therefore, the hydrological analysis in FS also takes into account the accessibility to bodies of water, using distance to water as a criterion. Section 5.4 describes two analyses in details.

The Topography Category

More than any other factor, the topographic features affect the microclimate of a site. Generally, designers review land evaluation and selection from many alternatives in a region. Although many sites in a region have similar climate conditions, deviations in a microclimate, formed by different smaller scale land patterns, are highly important.

An ideal site for a residential building is a place well protected from winter winds with an opening for summer breezes and passive solar gain. It should not be on a steep slope, nor at the lowest point in the area, as these can lead to potential flooding and drainage problems. A low site also makes it hard to achieve natural ventilation in a building, while the top of a mountain or a ridge leaves the building unprotected from extreme weather. Therefore, neither site should be an option for a building. However, if a site does not offer an ideal location, it is possible to improve less favorable areas to make them more suitable. For example, Watson’s *Climate Design* suggests using structures and vegetation on neighboring land to protect the site from winter winds.

Because so many land patterns can influence a microclimate, the major factors in the topography category include elevation, slope, aspects, surface color, and reflectivity. This

study considers these factors and their relations with geologic and climatic factors. SiteOne has two topography models. CE considers areas with less than 16% slopes and northeast to northwest aspects are suitable for development. The topographical analysis in FS includes elevation, hillshade, slope, and aspect analyses. It identifies suitable development sites with less than 10% slopes and east to southwest aspects. These sites should not be located in shadows, hilltops, or in the low areas. Detailed descriptions of the hydrological analyses can be referenced in Sections 4.3 and 5.2.

The Vegetation Category

There are two reasons to analyze vegetation. First, since plants are specific to a particular environment, the history, pattern, and distribution of plants can provide more accurate information than the information about soil, water, and climate. Traditionally, land where crops and grasses can easily grow indicates that human inhabitants can survive and prosper, because they have adequate sources of nutrition.

Secondly, vegetation on a site can be an important factor because it can influence the microclimate by changing the speed and pattern of the air movement, temperature, humidity, solar radiation, and the quality of the air. In the winter, vegetation is also beneficial, because it blocks the winds that remove heat from the home. However, it is not always desirable to have trees too close to the house, because some varieties can damage foundations, clog drainage lines, and block gutters with leaves.

The vegetation model in SiteOne takes tree coverage information into consideration. The goal is to protect native plants and maintain large open space covered with vegetation (Section 4.3). Vegetation patterns and heights can also be used to analyze their impacts on microclimate, such as providing shades or blocking winter winds to adjust a site to a comfort zone condition. However, because the available tree coverage information only distinguishes coniferous or deciduous species, in the case study, the vegetation analysis considers areas covered by the deciduous are not suitable to development, in order to preserve the existing native plants (Section 5.5).

4.1.2 Economic Category

The economic conditions of housing sites also need to be part of the site analysis process, because housing and land prices are an important concern for both consumers and suppliers. The cost of housing includes planning, designing, construction, and marketing.

The most important price variation of new housing units is the cost of a building site in a metropolitan area (Bradbury, Engle, Irvine, and Rothenberg, 1977). In the land price, the location indicator is the focal point. For suppliers, the important components of a location include vacant land availability, zoning constraints, sewer systems, and units available for conversion.

Table 4-2 Variables used for Bradbury's site location analysis

Accessibility to employment
Age of housing
Crime rate
Highway
Income
Number of housing units
Population
Price
Property tax rate
Pupils-teacher ratio
Race
Residential acres
Sewer availability
Total acres
Vacant acres and rate
Welfare population

For consumers, the location suggests the neighborhood characteristics; the physical conditions of the site; the character of available shopping facilities; the variety, quality, and cost of local public services, such as parks, schools, health and sanitation services, and streets; and the accessibility to desirable destinations within and outside the area. As Bradbury et al. (1977) note, a detailed analysis of accessibility can use various indexes: “a general job accessibility index by income class in which destinations and their probably importance in measures of the relative frequency of trips, distance, and economic cost per trip are integrated in weighted form; an index of highway availability; and an index of transit availability” (pp. 56-57). Table 4-2 shows the major variables used for Bradbury's site location analysis.

Koebel and Renneckar (2002) further group socioeconomic factors that influence housing needs into three categories: demographic, economic, and existing housing conditions. Demographic conditions consist of the number of households, migration patterns, and population characteristics. Economic conditions consist of income, private earnings, the unemployment rate, and employment by industry. Existing housing conditions include the percent of occupied units and the percent of home ownership.

Obviously, the factors in these three categories have correlations. For a user group with certain demographic characteristics, one factor may be more important than the others. For example, when considering location characteristics, 55 to 70 year old professionals rank a low crime rate as the most important community feature among a variety of factors, including geographic and climatic conditions, local community characteristics, cost of living, housing, recreation, retirement community services, and neighborhood services. One fifth of the respondents rate warm weather with no snow as a very important factor (Virginia Center for Housing Research, 1995).

Other economic factors include the removal of old structures from the land, financing, installation of utility services, property taxes, and maintenance. The rate of interest, fees and discounts, methods of mortgaging, and the type of loan and insurance determine the cost of financing. In addition, factors related to supply and demand, including centralization of commerce and industry, uneven population distribution, and insufficient housing supply, impact the housing cost.

4.1.3 Social-culture Category

Cultural process and social variables also impact the selection and analysis of housing sites. The social-cultural category in the framework is based on discussions about the relationship between culture and housing, and its connection with other categories.

The interweaving of cultural influences provides architects rich resources in design projects. Tylor (1973) defines culture as a “complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society” (p.1). The character of cultural patterns and styles can vary with different religions and emphases on intellectual development, or in different national and geographical locations. Cultural influences in the architectural design process fit into three

major fields: earlier architecture, contemporary aesthetic expressions of cultural ideals, and creative results from architects. Some significant influences can evolve within every architectural style and ultimately generate new styles that will supplant their predecessors. Therefore, the important issues associated with culture include social tradition, contemporary influences, and innovations.

The definition of culture can also be specific and operational. In order to link culture and housing together, Rapoport (1989) suggests that among several components of culture, such as worldviews, values, and activity systems, “life-style” is a comprehensible expression to which economic resources and incorporate values can be allocated. Thus, two major aspects of housing vary with life-style. One is “a system of settings” akin to stage settings, but for daily life. These are related to activity systems and impact housing sites with different locations, arrangements, and relations to their neighborhood and community. The other aspect is the environmental quality profile of housing sites, including environmental components, rankings, and importance to other needs.

Four definitions of culture suggest different factors of the social-culture category (Low and Chambers, 1989). First, as a political and economic structure, culture influences site selection and housing design with behavior rules, group politics, economic factors, and social interactions. Examining the community values and needs, Jones and Turner (1989) notice that groups have a tendency to live in neighborhoods with a distinctive type of housing. The location value depends on the relation between sites and other facility units, such as shopping centers, schools, and sewer systems.

Secondly, culture is a cognition structure that contains codes and rules for directing spatial arrangement. Researchers show that there is a culturally governed cognitive system articulated in the layout of villages and subdivisions and in the views and activities of people who live there. Therefore, familiarity of place and behavior changes can modify an existing cognitive system of a residential environment.

The third definition describes the cultural meanings as symbols that represent human thoughts and behavior. The built environment not only maintains and reinforces traditional group identities and expressions of self, but also creates new symbolic expressions when buildings and their patterns are altered. Finally, the fourth definition views culture as the interpretation of the social structure, as well as the historical and cultural meanings of the

built environment. The interpretation process links the past, the present, and people's perceptions of the future. Designers use social, cognitive, and symbolic information to create a design based on their knowledge of the traditional and personal artistic senses. They should have a sensitive understanding of social and cultural change in order to create a new generation of form and design theory.

4.1.4 Infrastructure Category

The infrastructure category covers both social and physical infrastructures. The social infrastructure includes education and training facilities, hospitals, cultural and recreational services, and visitor accommodations. Physical infrastructure items include: local environmental services, such as water supply, waste water treatment, and landfill sites; the transportation network, which incorporates the accessibility of road, as well as rail, sea, and air transportation; energy supply; and information and communication services. For an individual site or sites located in a subdivision, detailed transportation factors also consider relationships between different systems, the volume of noise generated by the systems, traffic signals, the level of maintenance, and the relationship of parking area, walking distances, and the visual relationship of approaches to the site (Todd, 1985).

4.1.5 Summary of Categories

In summary, the proposed framework takes into account factors in environmental, economic, socio-cultural, and infrastructure categories. The environmental categories can be further broken down into climate, geology, hydrology, topography, and vegetation. In addition, various factors are listed under different categories in the framework. At the same time, the relationships between factors and categories are one-to-many; in other words, one factor may appear in several categories. For example, slope conditions can influence climatic, hydrologic, and topographic analyses (Chapter 5).

During the site analysis process, identifying and measuring relevant variables with respect to the established criteria can directly value factors of a particular site. The quality of the natural environment can also be rated, if only subjectively, by assigning a definite number of points to particular features, according to an adopted scale of values. The framework either generates a detailed analysis of a relatively small area or compares

alternative sites with similar areas of preset values. Therefore, four specific steps involved in the evaluation of these factors are: (1) selecting significant site factors to be measured, (2) designing a rating scale in a structured checklist, (3) assigning a value to each land attribute in a particular site, and (4) summarizing values in a structured format that represents a grading of the land units examined, making possible a comparative evaluation of any territorial unit.

This research also develops the SiteOne prototype system to demonstrate the concepts and ideas of the framework. SiteOne analyzes an area based on different criteria in its environmental models (Section 4.3). It can also be applied to a range of alternative solutions and then derives solutions from the suggested site conditions (Chapter 6). Its design is based on a comprehensive understanding of several methods and tools reviewed in the second chapter and in the next section.

4.2 Review of Existing Methods and Tools

As the result of a need to include ecological principles in the design process, many computer tools are now available that emphasize climatic factors, including temperature, solar radiation, and wind, and provide guidance for their proper utilization. Other computer tools analyze the physical environment. However, it is often difficult for designers to balance the many considerations for the climatic and physical factors. In addition, land information such as zoning and utility maps, aerial photographs, and topography maps are now available for many locations in electronic formats. This creates an opportunity for designers to download and combine these information sources into a digitized format for viewing and comprehensive analysis. With the development of high speed and large capacity computer hardware, using modern technology to manage environmental information becomes possible. The future development of the tool may also support the newest technologies such as web-based simulation. A detailed review of existing methods and tools provides useful structures and implementation strategies to identify and select suitable housing sites.

4.2.1 *McHarg's Method*

Ian MchHarg's *Design with Nature* (1969) is a seminal book in the modern environmental movement in the fields of architecture and landscape architecture. Known as the father of ecological planning, his landmark design projects include the Woodlands, Texas, the I-95 Richmond Parkway, Virginia, and Amelia Island, Florida.

In MchHarg's model, the basic concern is the fitness of an environment for a certain type of land development. He suggests a scientific understanding of natural processes helps the designer to select an appropriate plan for development. MchHarg establishes guidelines for choosing sites for development in various geographic locations, especially in metropolitan areas. He argues that his method is rational and explicit and that following his guidelines enables designers to obtain scientific approvable conclusions. He uses mapping and measurement techniques to identify eight natural processes related to land use. Further interpretation of these values can be seen in the case study of Staten Island in New York City:

- o Identify the major physical and biological processes. The basic information includes the data on climate, geology, physiography, hydrology, pedology, vegetation, wildlife habitats, and land use. All these analyses are mapped in color on transparencies.
- o Establish a value system to interpret the data. The factors are ranked in importance using a gradient of five values, and also in a hierarchy using color and tonal intensity.
- o Transform the natural resource maps and the interpretation values in the previous steps into a series of suitability maps.
- o Overlay the suitability maps and get the composite maps. The relevant factors on the composite maps show the result of the aggregate shades of gray for all the possible factors, and indicate the suitability of each land parcel.

In terms of residential development, the positive factors include features such as good soil and bedrock foundation conditions, as identified by geology and pedology studies, riparian land of water features in the physiography study, and historical and scenic values in the land use category. The negative factors include excessive slopes, poor drainage areas, likely flooding or erosion areas, and existing forests. Finally, MchHarg demonstrates the results from each analysis in a transparency, and attaches them together to get the summary.

However, several researchers criticize McHarg's method for equal-weighted variables, adaptability to large-scale analysis, his ecological assumptions, and resource availability. McHarg values all variables in his analyses equally. This is largely because of the limitations of hand-drawn maps. It is difficult to assign different weights to each data set. The task can become unmanageable with hand drawings. In addition, using color ranges limits the number of maps that can be composites at one time. For complex analysis, sub-composition maps need to be produced first in order to generate the final output. The composition process is time-consuming. Further, Gold (1974) argues that the character of activities in a certain location should have impact on the selection of variables, instead of all factors predetermined by nature. Marusic (1980) also points out that McHarg's methods emphasize the values of natural processes, however, underestimate social and economic influences. Even though an area is suitable for residential development, developers will not build housing units in the location if there is not enough population demand and necessary economic condition. Finally, McHarg's methods have a tendency to analyze those areas with many relevant factors, and neglect unusual sites that need special consideration or with one or two significant resources (Roggenbuck, 1969; Dooling, 1977).

Currently, computerized geographic information system (GIS) techniques can overcome some of the previously mentioned drawbacks. The design of computer tools demonstrates similar concepts: the ArcView GIS from the Environmental Systems Research Institute (ESRI) separates the information in layers, and enables users to apply rules in its analytical functions (Section 4.2.3).

4.2.2 *HOK's Guidelines*

Hellmuth, Obata & Kassabaum (HOK), a large international design and consulting firm that emphasizes sustainable design, uses several checklists in its design process, and identifies the roles of planners, architects, interior designers, engineers, landscape architects, and owners. HOK argues that the design process integrates every participant involved in the project. The design process includes seven key steps: (1) team formation; (2) education and goal setting; (3) gathering information; (4) design optimization; (5) documents and specification; (6) bidding, construction, and commissioning; and (7) operations and maintenance (Mendler and Odell, 2000). The checklists also include detailed suggestions

such as avoiding development on floodplains, considering the effects on the wildlife habitat when changing water flow patterns through wetlands, and holding an environmental design charrette when a large project is developed in a community.

In the “Energy Checklist,” the “Gathering Information” step lists site analysis as a separate part. Detailed recommendations include collecting local climate information, such as means and extremes of local temperature, solar radiation, relative humidity, and wind patterns. Careful examination of these data sets suggests different design strategies. For example, using thermal mass or ventilation at night can be effective if a diurnal temperature swing is twenty degrees F or higher. Prevailing wind direction and velocities will also affect the calculation of the heating and cooling load and the development of natural ventilation.

Further, HOK also notes that site features impact microclimatic and energy performance. These features include:

1. Topographical features, including elevation, slope, aspects, surface color, and reflectivity, can modify microclimatic conditions. Certain land shapes collect cool air at night, and the surface could retain or reject heat from the sun, modifying prevailing climatic conditions.
2. Existing vegetation may reduce summer exposure and temperature, control wind direction, and reduce wind speed.
3. Bodies of water, such as ponds or fountains, can normalize extreme temperatures.
4. Adjacent structures will impact energy performance. Neighboring buildings, walls, and fences can block prevailing winds and influence solar access.
5. Other features related to ground conditions, including elevation of water line and the soil structure, can also influence building design and energy load.

Another item in the “Energy Checklist”, the “Optimization” step, provides further suggestions and recommendations for site analysis. The first recommendation is to “integrate energy analysis into the design process; review and monitor energy analysis methodology as the design progresses.” Systematic optimization of energy efficient design can be broken down into a series of steps: collecting information, generating a base case energy model, estimating energy consumption and cost, deriving design alternatives, analyzing daylighting design and performance, and establishing overall energy use and cost. It is necessary to repeat and refine the above steps in order for the team to identify a detailed

final solution. Furthermore, periodic updates during the design and construction phases can ensure desirable energy performance and confirm the design objectives. It is also important to record and analyze post-occupancy evaluations.

The second suggestion of the “Optimization” step is to incorporate passive solar heating and cooling strategies into the site and building design. Passive solar heating designs utilize glazing control and thermal mass storage to collect, absorb, store, distribute, and circulate heat. Passive cooling options involve shading, natural ventilation, and insulation.

Finally, the third advice is to “optimize design of the building envelope.” Seven detailed recommendations cover the topics of optimization of building insulation and glazing, energy-efficient material selection, utilization of exterior and interior sun control, design of adjustable building-envelope components, and the impact of thermal mass construction.

HOK’s checklists provide comprehensive guidelines towards sustainable design. However, these checklists only suggest necessary information and corresponding design strategies. The guidelines do not include detailed criteria for items in the checklists. In addition, HOK’s guidelines cover six checklists and hundreds of strategies; it is hard for individual designers to efficiently and effectively manage the information and personnel that are related to site analysis. A computer tool will be helpful for designers to link, sort, and manage these data sets.

4.2.3 GIS-Based Computer Tools

GIS represents a variety of software packages widely used for the organization, integration and visual display of spatial data sets. Most of the decision support tools available for site inventory and analysis are GIS-based. With increasing sophisticated analytical models, GIS software packages are useful to provide results in the format of maps and tables, and to support strategic decision-making processes.

Normally, GIS applies to site analysis in the design professions of urban planning and landscape architecture. For planners, using computer technology to assist planning, the underlying idea of planning support systems (PSS), has been studied and implemented for forty years. Since the 1950s, a rational, mathematical approach has been developed in land use planning. In the 1960s, 1970s and early 1980s, this approach continued to develop decision-making models that based on optimization methods, non-quantitative methods,

human activities, and natural processes (Davis and McDonald, 1993). The complexity of the planning problem and the increasing awareness of the value of public participation played an important role in the development of planning support tools. In the 1990s, paradigms shifted to expert systems and decision support systems when more participants have different interests and conflict opinions. Along this trend, Harris initiated the concept of PSS that incorporate a board range of knowledge, information resources, and computer models. The literature further discusses the definition, structure, and implementation of PSS, focusing on the use of GIS and the development of 3-D visualization technology in planning (Brail and Klosterman, 2000).

PSS incorporate three components of traditional decision-support systems – information, models, and visualization. The most important component of any PSS will be GIS. The literature shows that GIS in land use planning is applied mainly to land supply monitoring and related areas. Brief descriptions of several GIS programs as follows:

ArcView³

ArcView, the world's most popular desktop GIS and mapping software provided by ESRI, is a mapping software that links layered information (Figure 4-2). The digital map created by GIS has points, lines, and small areas, representing features such as cities, roads, and lakes, respectively. The information database stores data on layers and users can activate layers based on their needs. ArcView can analyze climatic information, water, roads, facility information, vegetation conditions, and topographical information for a selected site. The software can also output charts, graphics, and tables that can be used for further interpretation.

ArcView is an exceptional stand-alone GIS of ArcGIS, an integrated and scalable family of GIS software products. Among twelve ArcGIS extensions, Spatial Analyst, 3D Analyst, and Geostatistical Analyst are three most important ones for site inventory and selection. Spatial Analyst supports a broad range of spatial modeling and analysis requirements. 3D Analyst supports interactive and perspective viewing methods and advanced tools for three-dimensional modeling and analysis. Geostatistical Analyst provides

³ Please check more information from ESRI website: <http://www.esri.com/software/arcgis/arcview/index.html>

tools for users to investigate, visualize, and generate optimal surfaces using sophisticated methods.

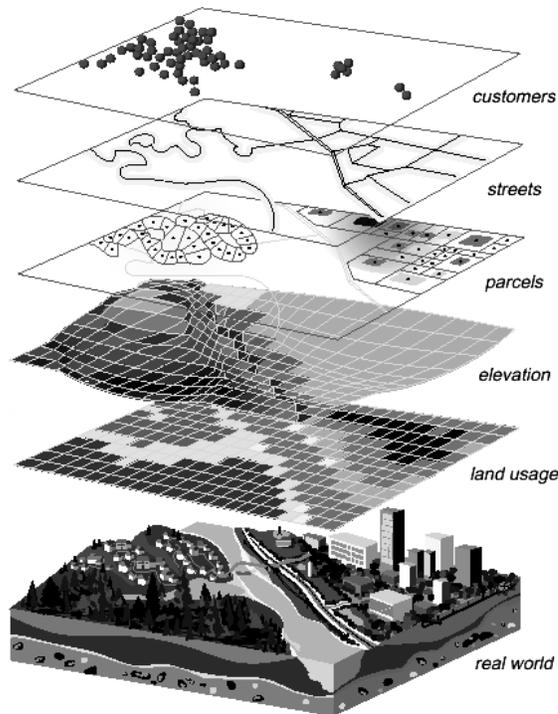


Figure 4-2 Layered structure in ArcView GIS (from ESRI website)

Planners, landscape designers, and government agents use ArcView and other ArcGIS extensions in site inventory and selection. However, the scale is normally larger than a county. It is too broad for architects and engineers to perform site-specific analysis.

Other GIS-based Programs

Using GIS as a base, METROPILUS integrates at least four different modeling programs, excel spreadsheets, and then the GIS capabilities into an urban modeling/ support software. It uses script writing to connect components.

CUF I & II, CURBA are parcel-based urban simulation models that depend on GIS for data manipulation, analysis and presentation. All three apply to actual planning situations and serve slightly different purposes.

INDEX is a GIS-based PSS that supports the community planning process. It is the most widely distributed PSS in 70 local governments and other organizations. Described as a contemporary planning tool, it is able to perform day-to-day planning functions such as

zoning changes and use permits. The program can be integrated through an ArcView extension (Network Analyst) or as an application in ESRI's MapObjects software.

WhatIf? is a policy oriented planning tool to determine what would happen if clearly defined policy choices are made. The model was developed using Visual Basic and operates through MapObjects and is adaptable to local GIS.

CommunityViz⁴ was initially developed to preserve rural areas. The program is a GIS-based decision-support system for community planning and design, which integrates GIS, 2D, and 3D modeling. There are three modules that were developed as stand alone extensions: Scenario Constructor, Policy Simulator, and SiteBuilder 3D. All three modules are built on ArcView. Scenario Constructor has alternative-comparison capabilities. It offers quantitative impact analysis capabilities and performs a "spatial spreadsheet" with numerical computations on geographic data in real time. Policy Simulator simulates possible impacts of community planning proposals and provides future economic and demographic outcomes for planners. SiteBuilder 3D enables users visualize land-use proposals by providing "photo-realistic, three-dimensional, interactive" models of their land-use proposals.

The above mentioned programs are mostly used for simulating possible impacts of planning proposals, zoning changes, and other policy-related decisions. The data sets do not have detailed information for architects and engineers to perform site-specific analysis. Moreover, none of them focuses on environmental impacts, although some of them can be used to test the impacts on the community's infrastructure systems such as water usage and sewage. For example, Scenario Constructor in CommunityViz can model several options for a proposed building project at different locations. It allows the project team to sketch alternative land-use scenarios and evaluate their implications for the community objectives and constraints.

4.2.4 Other Analysis Tools

Climate Consultant⁵ can graphically display climate data, including temperatures, wind velocity, sky coverage, timetable of bioclimatic needs, sun charts and sundials. Based

⁴ For more information, please check the website of CommunityViz at <http://www.communityviz.com>.

⁵ Climate Consultant was developed by School of Arts and Architecture of the University of California, Berkeley and released in 1991. It can be downloaded from <http://www.aud.ucla.edu/energy-design-tools>.

on the passive design strategy as outlined by Givoni (1981) and Waston (1992), it also provides psychrometric analysis that recommends the most appropriate environmental integration strategies using the TMY data sets.

Climate Consultant provides analytical results using TMY data sets, which are available for limited number of cities. Users have to use the available data set of the nearest city for other locations. However, micro-climatic conditions vary even within miles. The results from Climate Consultant only provide a rough description of climatic conditions of a site. Based on these conditions, the environmental integration strategies may not appropriate.

Reviews of literature, application methods and tools provide useful information to implement the framework into a computer simulation program. The third chapter sheds light on important environmental factors that are considered in the framework and SiteOne. The methods and items proposed by McHarg and HOK further confirm these factors, identify the interactions between factors, and group them into several categories. Additionally, ArcView and its extensions provide a large number of spatial modeling and analysis functions, which act as pre-processors to SiteOne (Section 4.3). Moreover, SiteOne and other GIS tools have a complementary relationship. For example, if SiteOne and CommunityViz use data sets in the same scale, SiteOne can use the transportation analysis results from CommunityViz in the infrastructure models. In this case, CommunityViz becomes a pre-processor to SiteOne. If SiteOne performs site-specific analyses, results from other tools, using data sets in a larger scale, can define the analysis boundary for SiteOne; meanwhile, the output from SiteOne can provide feedbacks for other tools to revise their analysis and redefine the boundary.

4.3 SiteOne Design: Implementation of the Framework

A system design normally begins with defining its boundaries, setting the components and the structure for the components, and determining the fundamental elements based on design goals (Churchman, 1971). Computerized systems fall into different categories based on their goals and behaviors. Their system structure and the environment in which they are used may also vary. The former can be considered as the "inner" system that represents the system organization and structure, and the latter as the "outer" environment that reflects the

surroundings in which the system performs. In addition, a site analysis system should be inexpensive, capable of providing usable data rapidly, easy to be operated by designers with a minimum of specialized training, and adaptable to a wide variety of geographic conditions.

The prototype program should be developed from three contexts, which are: (1) the purpose of the site analysis is to identify suitable housing sites; (2) the coverage of the study area is an urban/suburban area; and (3) the program implements the analysis module focusing on environmental aspects, which incorporates both contemporary and traditional principles.

The SiteOne prototype system, developed to demonstrate the concepts and framework presented in this research, provides five areas (climate, geology, hydrology, topography, and vegetation), three methods (contemporary, feng shui, and integrated methods), and two levels (standard and expert) for analyzing building sites. SiteOne, which is based on a full understanding of several methods and tools reviewed in the second chapter and the previous section, analyzes a range of alternative solutions and then derives solutions from the suggested site conditions. The various modules that make up the prototype system are: an analysis module, a database module, and a result generation module. In the analysis definition module, users can choose different categories, set the analysis methods, and define user levels. The database module includes basic data sets related to each variable in the analysis module. The result module generates output graphically. Users can also print or export the output. Each module has a graphical user interface (GUI), which acts as a preprocessor for the analysis module and postprocessor for the result module. The following sections provide in-depth descriptions of each module.

4.3.1 Analysis Definition Module

The analysis definition module considers the factors in the existing methods and tools as different types of variables. The user chooses from variables in up to five models, and the module applies appropriate sets of criteria. The module also provides three analysis methods: contemporary principles, feng shui, and the integrated method. For experienced users, the rating scales or the user-defined settings enable the performance of more sophisticated analyses. Therefore, there are three major steps in the analysis definition module: defining analysis variables, setting criteria, and designing rating scales for the variables, which Figure 4-3 depicts.

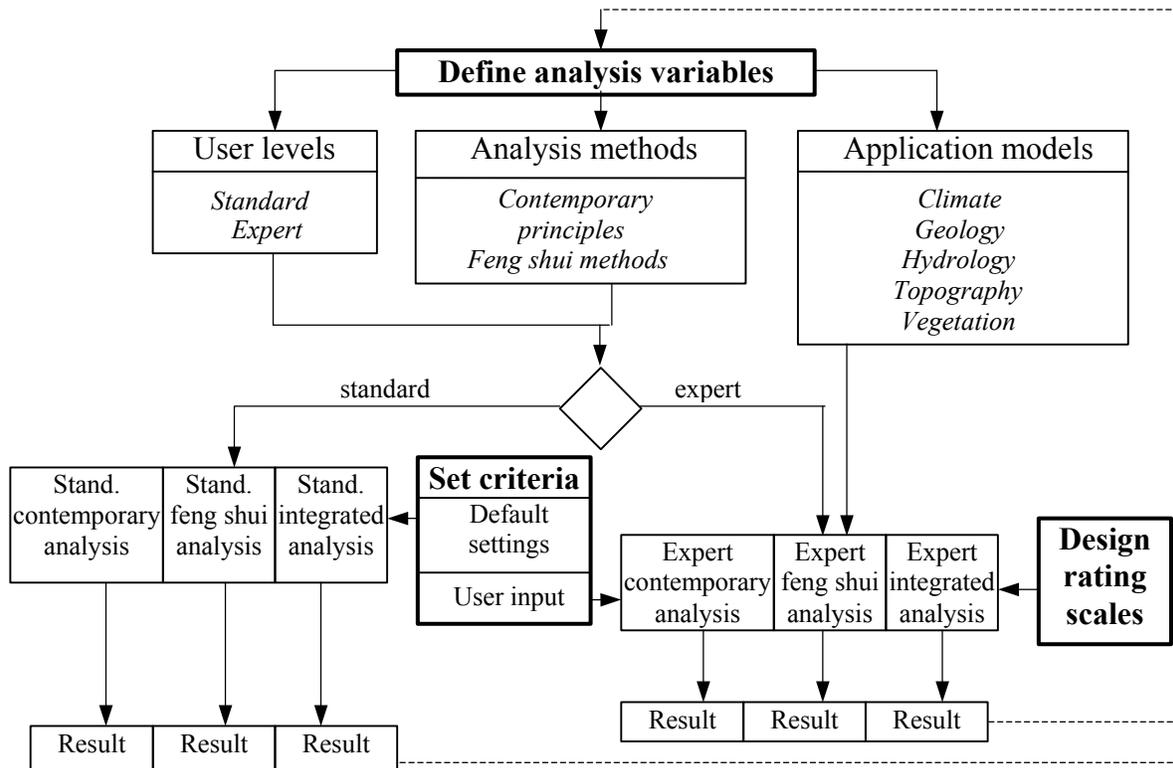


Figure 4-3 Three major steps in the analysis definition module

Defining Analysis Variables

In order to accurately represent site conditions, the analysis module considers variables in five application models. A computer simulation can represent site analysis factors in many ways. For example, designers can describe site characteristics according to the contexts of different spatial scales, or analyze site conditions based on the different categories described in Section 4.1. SiteOne implements the analysis module, focusing on environmental aspects, although the framework presented in this research covers a broader spectrum. In SiteOne, site characteristics fall into five models related to environmental aspects: climate, geology, hydrology, topography, and vegetation. Each application model also includes several factors and their applied conditions. Table 4-3 divides all factors into the five models of the analysis module.

Table 4-3 Factors in five categories

Category	Factor	Task
Climate	Temperature Wind speed and direction Relative humidity Solar radiation	Calculate thermal comfort zones (CE); analysis wind effects (FS)
Geology	Soil type Erosion and slope	Identify suitable areas for building foundations
Hydrology	Floodplain and wetland Relation to bodies of water	Avoid floodplain and wetland, and find suitable area accessible to water
Topography	Slope Aspect Hillshade Elevation	Identify suitable areas
Vegetation	Tree coverage	Preserve native plants

Climate Model

SiteOne considers five factors in its climate models: temperature, wind speed, relative humidity, solar radiation, and wind direction. Using the first four factors, the climate model for CE of SiteOne generates thermal comfort zone analyses in a default time range condition, such as a year-round analysis covering hourly data (Section 5.3). These are two settings available to users to specify the time range for the comfort zone analyses. One is a seasonal setting, which offers the choice of summer, winter, or year-round data sets; the other is a daily setting, which offers the choice of day-time⁶, night-time, or daily data sets.

SiteOne uses ArcView GIS as a pre-processor to generate both descriptive and result maps. The descriptive maps include hourly temperature (°F), relative humidity (%), wind direction, and wind speed (mph) maps. The result maps include comfort zone maps (including hourly, daily, night-time, day-time, seasonal, and annual maps), wind direction maps, and wind speed maps.

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) sets the comfort zone for indoor environments. This study assumes the outdoor comfort zone in winter is lowered by 10 °F for the increasing insulation of thick winter clothing (ASHRAE Standard 55). The spring and fall comfort zones lie between the winter

⁶ Olgyay (1973) suggests that for climatic analysis, the daytime counts from seven o'clock in the morning to seven o'clock at night.

and summer comfort zones. Therefore, using the contemporary method, the comfort zone criteria in summer is from 73 to 84 °F with less than 50% relative humidity. By adjusting the original ASHRAE indoor comfort zone, which ranges from 68 to 75 °F, the winter comfort zone ranges from 58 to 65 °F in this research. The spring and fall comfort zones range from 65 to 74°F. Desirable areas should fit the comfort zone criteria more than 80% of the time⁷. Figures 4-4 and 4-5 shows the analysis flowchart of the climate model using CE in SiteOne.

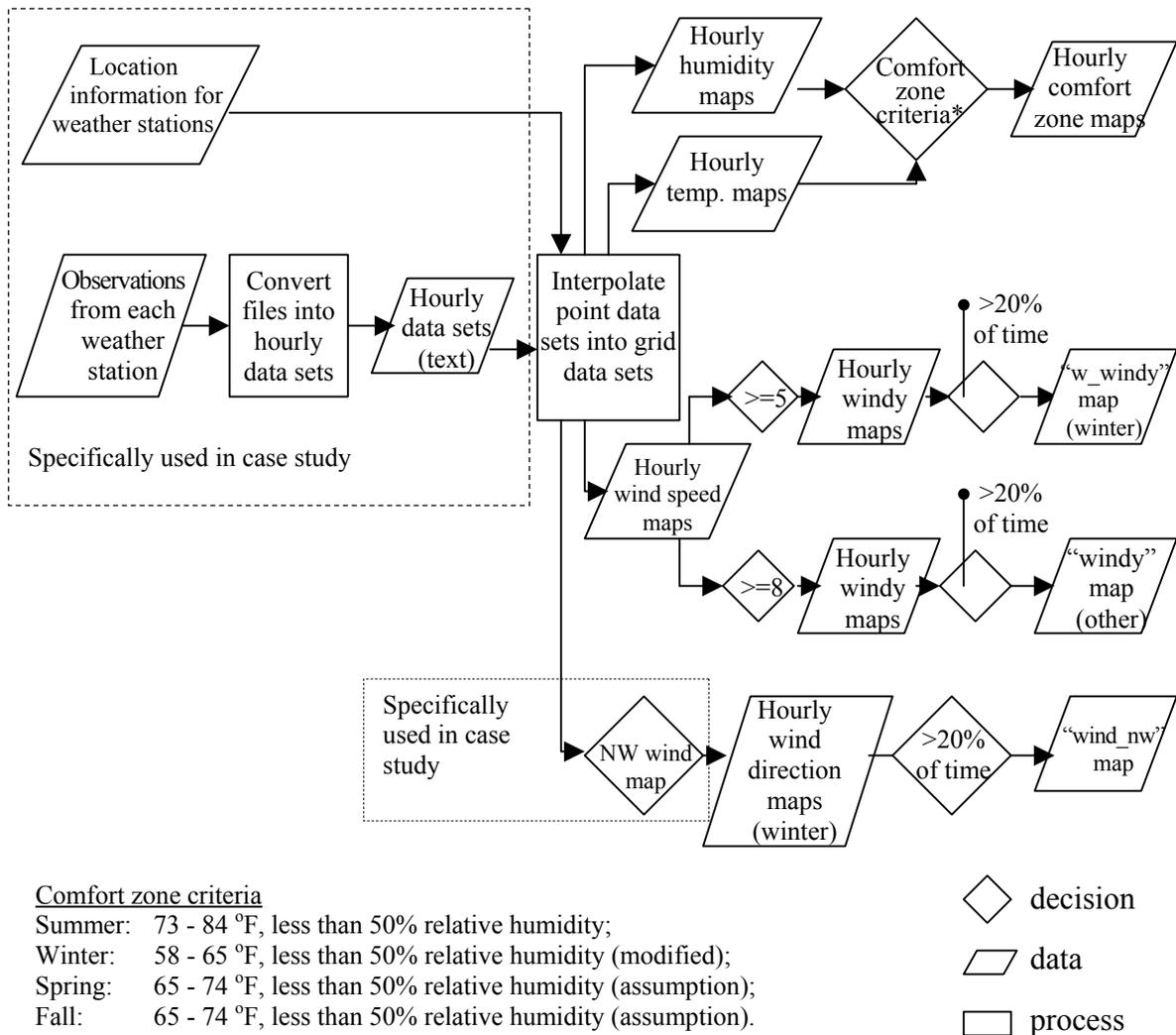


Figure 4-4 Flowchart of climatic data collection and management

⁷ ASHRAE standard considers the environment and personal factors to satisfy 80% or more people in thermal environmental conditions.

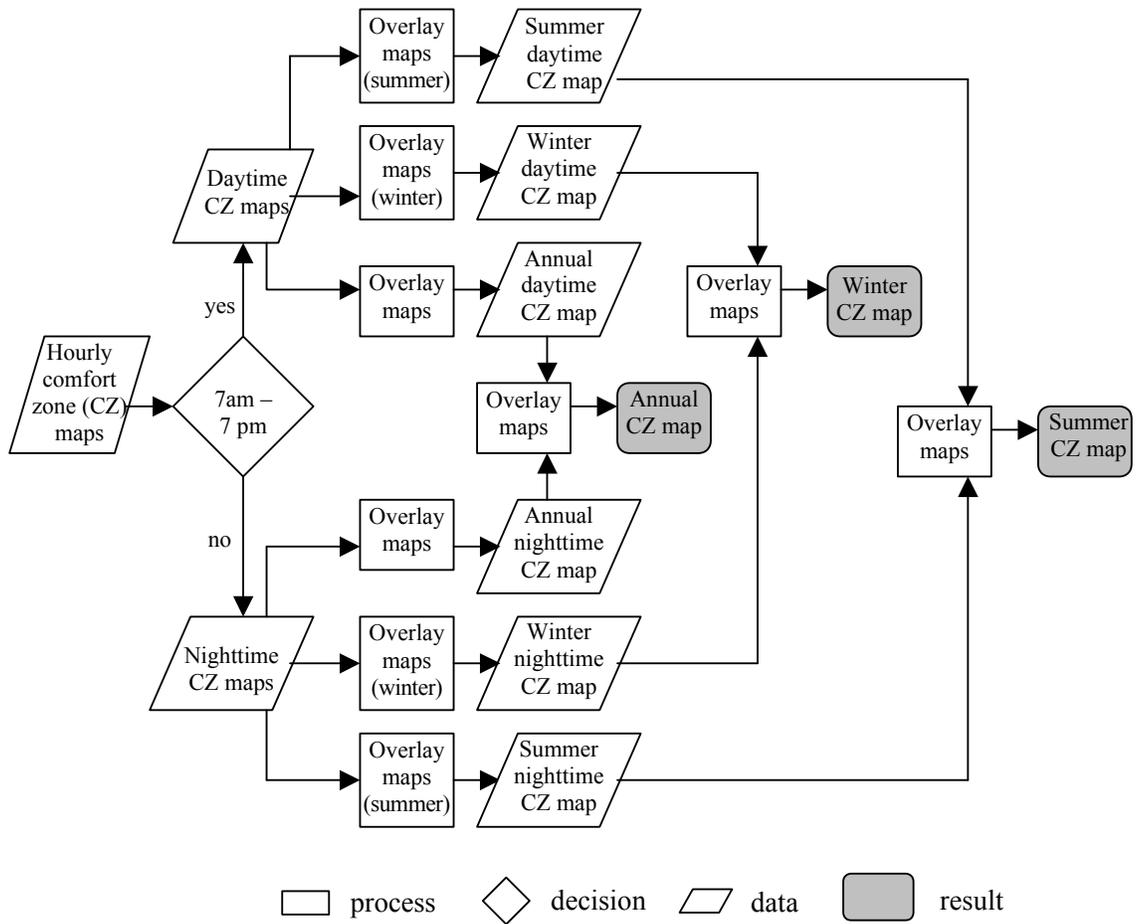
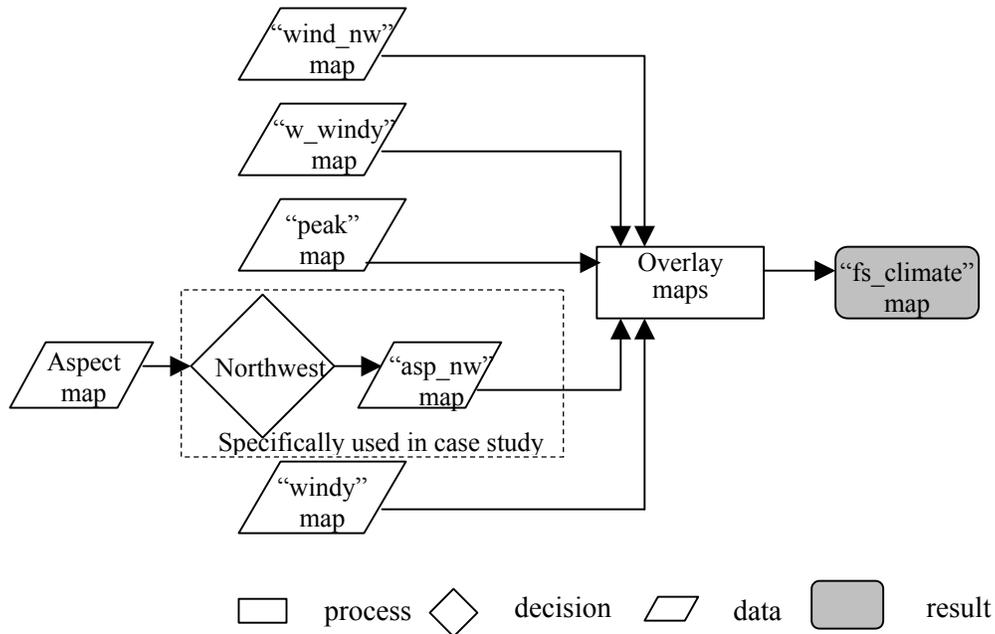


Figure 4-5 Flowchart of climatic data management and comfort zone analysis

In addition, wind speed and direction are important for feng shui analysis, because a site should be protected from the winter wind, but welcome a gentle summer breeze. The Beaufort Scale⁸ rates a wind that has four to eight mph speed as a “light breeze.” The comfort standards published by ASHRAE Standard 55 set the winter air movement speed limit at 60% of that of the summer. Thus, under the feng shui criteria, the ideal wind speed is less than five mph for less than 20% of the time in the winter and less than eight mph in summer. In addition, hilltops and areas facing the prevailing winter wind are also possible windy areas. Therefore, the climate model for FS uses five maps: north wind map (“wind_nw”), winter windy map (“w_windy”), year-around windy map (“windy”), peak area

⁸ According to the World Meteorological Organization, the Beaufort Scale, devised in 1805 by Sir Francis Beaufort (1774-1875), is a system for estimating wind strengths without the use of instruments, based on the effects wind has on the physical environment. The behavior of smoke, waves, trees, etc., is rated on a thirteen point scale of 0 (calm) to 12 (hurricane).

map (“peak”), and northwest aspect map (“asp_nw”) (Figure 4-6). The “wind_nw” map identifies areas with northwest winter wind in the wind direction map. Both “peak” and “asp_nw” maps are derived from the topographic analyses. Detailed descriptions can be referenced in the topography models of SiteOne.



Note

The process of generating the “wind_nw,” “w_windy,” and “windy” maps can be found in Figure 4-4. The process of generating the “peak” map can be found in Figure 4-11.

Figure 4-6 Flowchart for wind analysis in feng shui

Geology Model

In the geology model, the analysis focuses on soil type and erosion (Figure 4-7). The soil type analysis based on the soil ratings. For example, the Problem Soils Ordinance of Fairfax County, Virginia differentiates soils into three classes. It also states that no construction shall occur on land containing “Class A” soils. Wetness and drainage problems of “Class B” soils can be addressed with appropriate geotechnical notes and drawings. Additionally, no special foundation treatment is needed for “Class C” soils. Based on the ordinance and the BOCA National Building Code (1999), the soil analysis in the case study considers the land with “Class A” soils is unsuitable for development, and the land with other soil types is suitable.

The other analysis is erosion. The contemporary environmental design approaches are highly concerned with erosion that land developments should avoid potential erosion areas. Texture, rock content, permeability, structure, and slope affect the potential erosion. According to the ordinance, there are five potential erosion symbols and five slope classes on the soil maps for the case study. Erosion symbols “+,” “0,” and “1” indicate low erosion potential. Erosion symbols “2” and “3” represent moderate and severe erosion potential. A and B slopes are less than 7%; and C, D, and E slopes are greater than 7%. Based on the ordinance, the geology model considers areas with low-potential erodible soils, indicated by erosion symbols “+,” “0,” and “1”, and moderate-potential erodible soils with less than 7% slopes, indicated by erosion symbol “2” with A and B slopes, are suitable for development (Section 5.5).

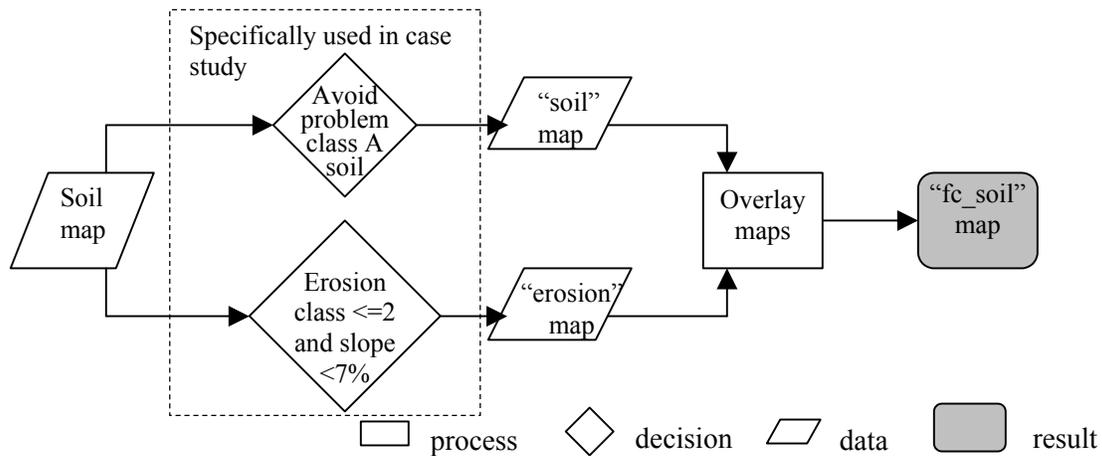


Figure 4-7 Flowchart for geologic analysis

Hydrology Model

In the hydrology models, the major task is to identify floodplains. In the CE model, suitable sites for development should avoid wetland and potential flood areas. Therefore, these areas should not be located in areas that show in the wetland and floodplain maps (Figure 4-8).

Additionally, the hydrology model for FS considers the lower, flat areas near rivers as potential flood areas. Thus, feng shui uses the hydrological data sets and the derived topographic data sets: lower area map (“lowest”) and flat area map (“slope4”). The hydrology model for FS also considers the distance to bodies of water as another factor,

because according to feng shui principles, a favorable site might have access to a body of water (Section 5.4). However, while it should be near a body of water, it should also avoid potential floods. Consequently, this study assumes that a distance between 300 ft. and 1500 ft.⁹ from a body of water is desirable. As result, the topographic analysis maps (“lowest” and “slope4” maps) and the hydrological maps (the wetland, floodplain, and “river” maps) are used to generate the resulting flood map (Figure 4-9).

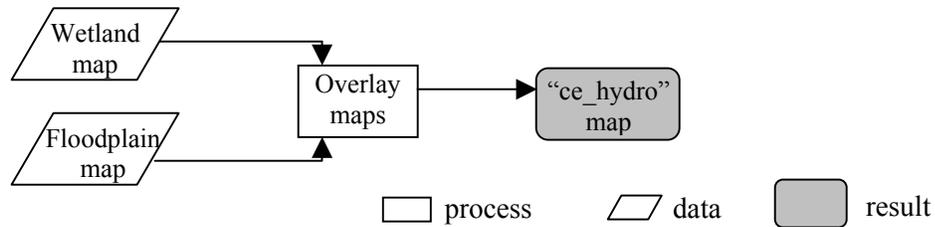
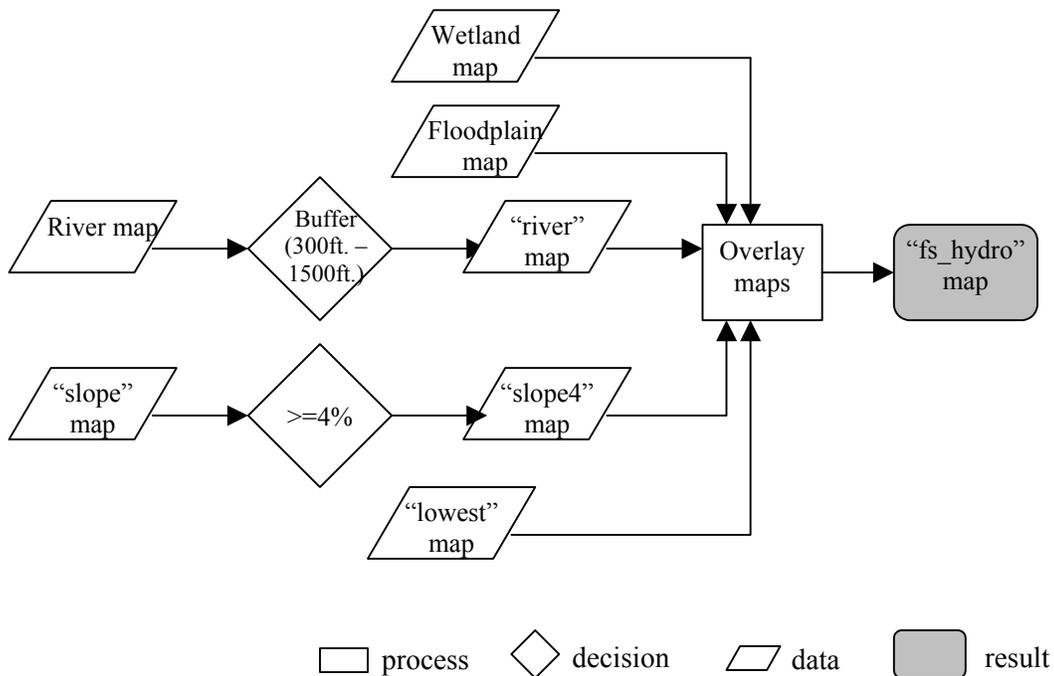


Figure 4-8 Flowchart for hydrological analysis using contemporary principles



Note

The process of generating the “lowest” map can be found in Figure 4-11.

Figure 4-9 Flowchart for hydrological analysis in feng shui

⁹ The distance is based on 5 minutes walking distance at average speed of 3 mph.

Topography Model

In the topography models, analysis factors include slope, aspect, elevation, and hillshade. Slope analysis uses an interval scale. SiteOne shows different results if the slope is less than 10% or 16%. Aspect analysis also uses an interval scale. Aspect, a slope's orientation, is the direction of the slope's surface. SiteOne defines the orientation as starting from the 0° north and increasing clockwise. There are eight directions, each of which covers a 45° arc. As soon as the user selects the preferred orientation, directions transfer to a numerical interval. For example, an east orientation corresponds to directions between 67.5 and 112.5°. The preferred orientation in feng shui is from southeast to west, corresponding to directions between 112.5 and 292.5°.

The topographic analysis for CE comes from both the slope and aspect maps. Favorable slopes should be less than 16%, and the preferred orientation is ranging from northeast to northwest (Hendler, 1977). Therefore, the model considers areas with less than 16% slopes ("slope16") and northeast to northwest aspects ("asp_nenw") are suitable for development (Figure 4-10).

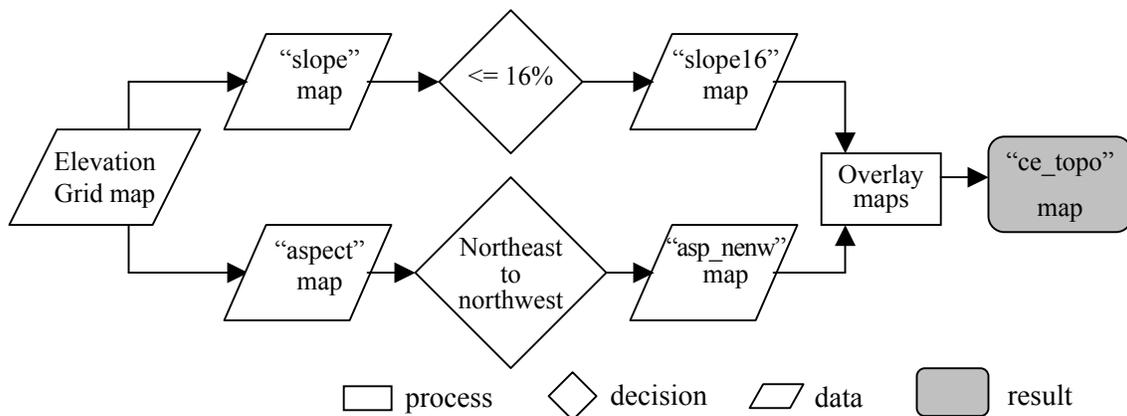


Figure 4-10 Flowchart for topographic analysis using contemporary principles

The topography model for FS includes elevation, hillshade, slope, and aspect analyses. The landform analysis of feng shui described in the third chapter shows that a low site leads to potential flooding and drainage problems, while the top of a mountain or a ridge leaves the building unprotected from extreme weather. Neither site should be an option for residential development. Therefore, the topography model highlights the areas that have higher elevations ("peak" map) and also shows the lower areas ("lowest" map) in the region.

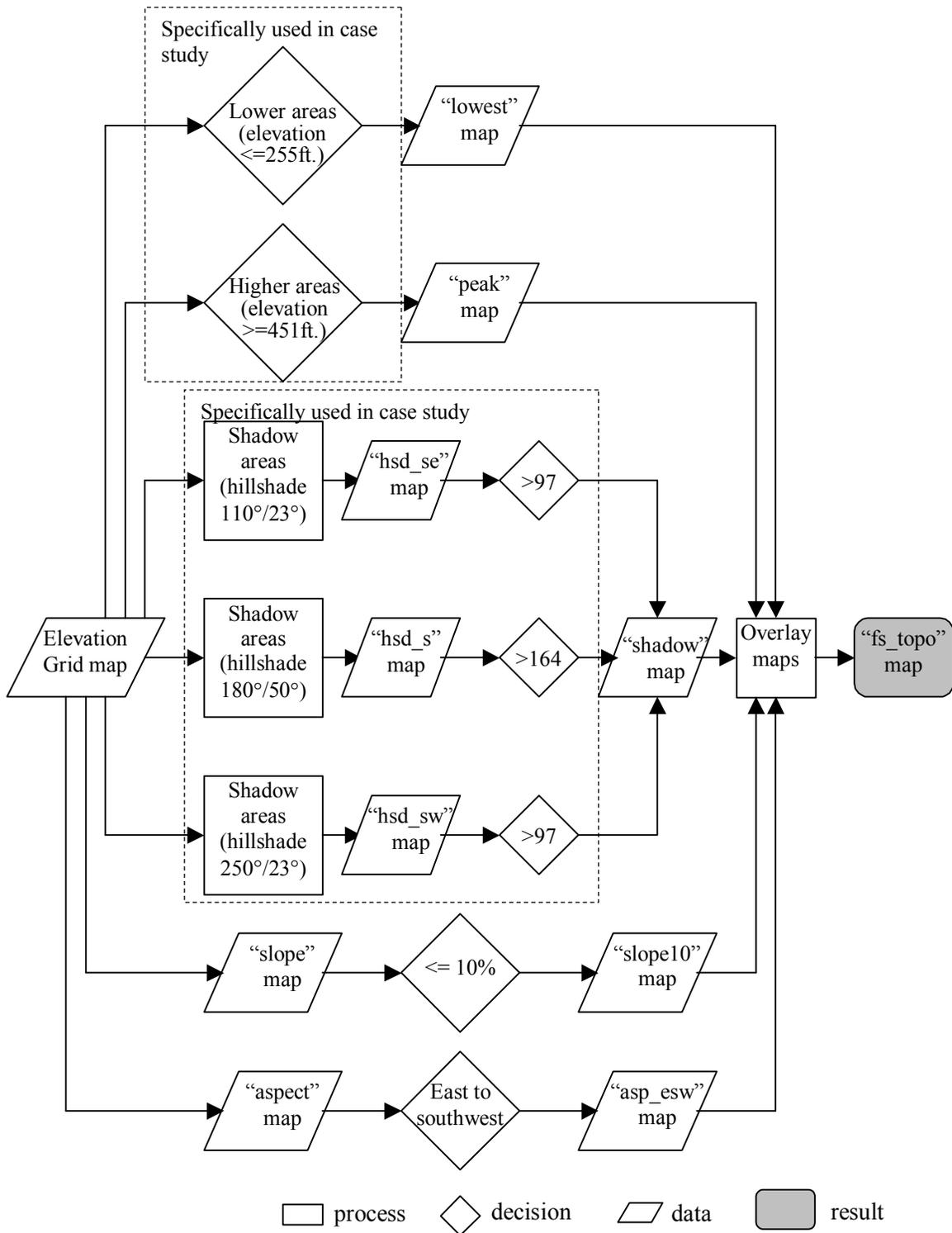


Figure 4-11 Flowchart for topographic analysis using feng shui

In addition, the model uses several hillshade maps to identify areas that are shadowed. Based on the sun's azimuth and altitude angles on a selected date, the overall

“shadow” map shows the favorable areas that are not shadowed in most of the hillshade maps. In this study, three hillshade maps are generated based on the sun’s positions at 8, 12, and 16 o’clock on September or March 21 in Reston (Section 5.2). Furthermore, the topographic analysis identifies suitable development sites with less than 10% slopes¹⁰ and east to southwest aspects (Chapter 3). Figure 4-11 shows the flowchart of the topography model for FS. The result “fs_topo” map comes from five sub-composition maps, including elevation analysis maps (“lowest” and “peak” maps), hillshade (“shadow” map), slope (“slope10” map), and aspect maps (“asp_esw” map).

Vegetation Model

The vegetation model in SiteOne takes tree coverage information into consideration. The important factors include vegetation patterns, heights, and maturity. Feng shui also has several specific criteria about types of trees, and their locations around a site. However, this research cannot undertake a detailed vegetation analysis due to a lack of data. In the case study, the vegetation analysis considers areas covered by the deciduous are not suitable to development, in order to preserve the existing native plants¹¹ (Figure 4-12).

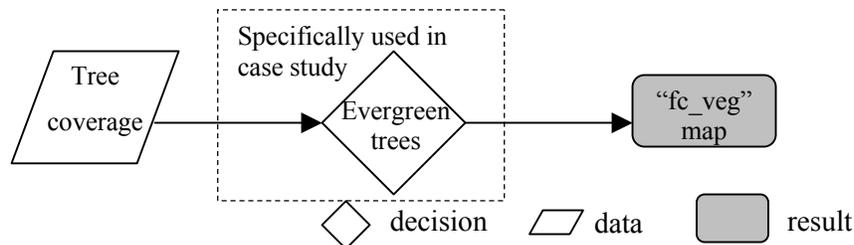


Figure 4-12 Flowchart for vegetation analysis

After selecting different analysis models, users can choose contemporary principles or feng shui, or both methods. The selection variable thus has three different modes: the contemporary mode, the feng shui mode, and the integrated mode. The mode selection influences the factors from the application categories and the criteria applied to those factors.

Finally, the analysis module provides two user levels. For standard analysis, SiteOne has a detailed generation procedure that automatically provides the analytical results. Expert

¹⁰ Lynch (1984) rates 0 to 4% as flat grades, 4 to 10% as easy grades, and over 10% as steep grades.

¹¹ Please see the native plant list at <http://www.dcr.state.va.us/dnh/natvtree.htm>. Most Virginia native plants are deciduous.

users can also define or even prioritize rules and constraints based on how the site conditions are set. Figures 4-13 and 4-14 show these features.

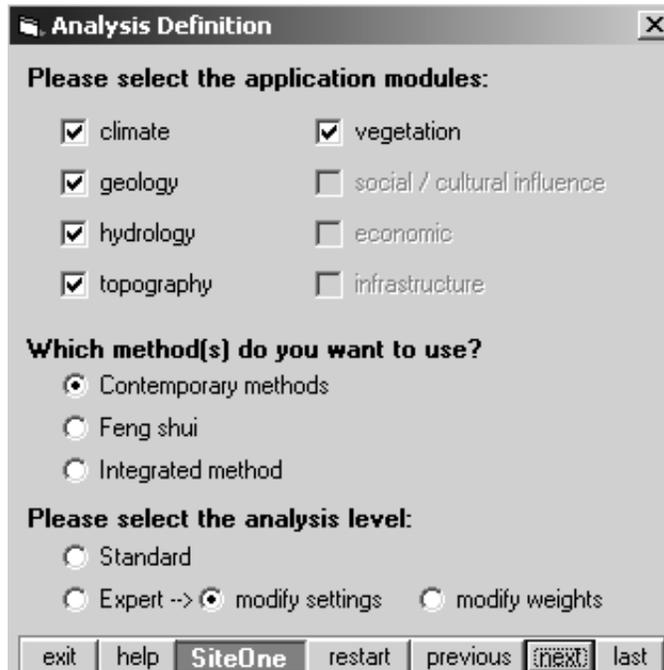


Figure 4-13 Analysis definition user input interface

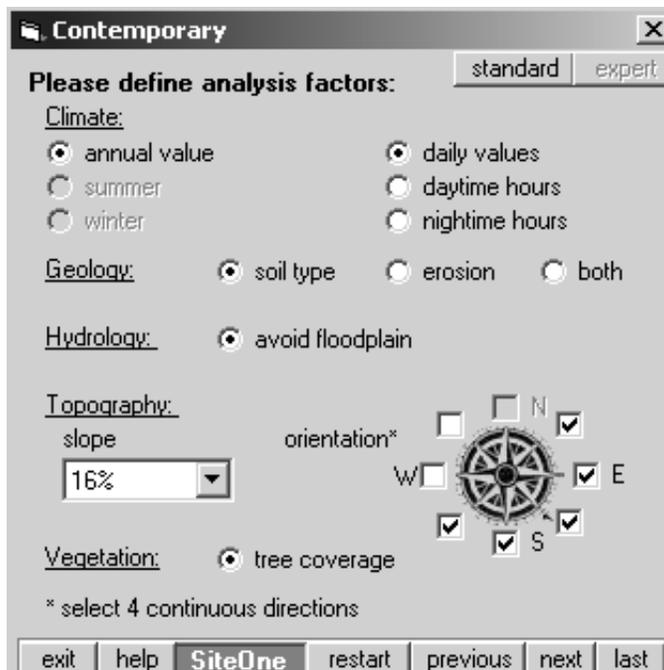


Figure 4-14 Expert user settings

Setting Criteria

SiteOne applies criteria based on both contemporary and feng shui site analysis principles to a layered information structure. For this, computer tools such as ArcView GIS from ESRI have shown the ability to separate digital site information into layers and support the user's application of rules in its analytical function. Consequently, a tool such as this can be combined with site information, including zoning and utility maps, aerial photographs, and topography maps that are now available for many locations in electronic format, which the user can often access over the Internet. This creates an opportunity for these information sources to be downloaded and combined into a digitized format for viewing and comprehensive analysis. The availability and accessibility of digitized information and analytical technique determine the approach used for this research.

The implementation strategies build on the concept of a rule-based information system – a computational information representation system based on a structured database. Rule-based systems emphasize reasoning according to certain hypothesized rules. Archetype analysis, style characterization, shape grammar, and expert systems are new developments in the process of design by rules. A combination of rules can be further used to support case-based design, knowledge-based design, and incorporation of a sophisticated expert system. Variations of these techniques are applied to the proposed research.

Two steps are needed to establish a rule-based system. First, a system design is required. The nature of the rules, used by McHarg (Section 4.2), Lynch, and Hendler in several publications concerning landscape design, indicates that it is possible to apply both sequential and hierarchical organizational approaches when establishing a rule-based system. Both are considered for this research and the most appropriate will be selected. Secondly, the rules will be identified. For this, each rule is established based on contemporary principles as well as feng shui in five groups of information, including climate, geology, hydrology, topography, and vegetation.

The application and modification to the rules vary from project to project based on user inputs. Depending on the wants and needs of individuals, the rule-based system must be flexible. This would allow various issues with the associated rules to be prioritized based on user preferences.

Using the contemporary mode, the feng shui mode, or the integrated mode, the analysis module sets criteria for each applicable analysis in the five categories in three different conditions. SiteOne defines these criteria largely for the default settings for standard users based on existing site analysis methods and principles.

As shown in Table 4-4, there are three groups of criteria in SiteOne. The different criteria are collected from a variety of sources. The decision to incorporate these criteria in SiteOne is based on the data availability.

Since it is impossible to include all criteria used to analyze site suitability, SiteOne only considers a few criteria as examples. Other criteria can be added easily in a structured database in the future. The following chapter describes how these criteria are applied to different data sets and the corresponding results in detail.

The criteria used in the integrated mode are more rigid than those used in the contemporary and the feng shui modes. For example, in the hydrology category, the contemporary mode sets the 100-year floodplain as a threshold to determine if a site is suitable for residential development; whereas feng shui principles indicate that the site is favorable when a body of water forms a lake or joins into a stream. Furthermore, these principles state that favorable sites be inside the bend of a river, in the confluence of two streams, or on an island. Therefore, the integrated mode highlights areas that meet both contemporary and feng shui criteria.

Another example is the aspect analysis. Different slope and aspect conditions impact the microclimate of a site by influencing the amount of solar radiation it receives. North-facing slopes normally receive less radiation than south-facing slopes. Hendler (1977) suggests that buildings should not be built on north-facing slopes and favors south-facing slopes. The contemporary criteria, therefore, reject north-facing slopes, and only offer the remaining seven options: northeast, east, southeast, south, southwest, west, and northwest. Feng shui principles also favor south-facing slopes. More specifically, Xu (1990) notes that in her survey of 56 sites mentioned in Chinese feng shui literature, 46% of the sites face south, 5% face north, and only 2% face west. Based on Xu's survey results, the feng shui criteria used in this research considers aspects that face east (20%), southeast (13%), south (46%), and southwest (7%). None of the other orientations exceeded 5% of the survey sites (Table 3-3). In short, the contemporary criteria favor seven aspects; the feng shui criteria

favor four; and the integrated criteria mirror the more rigid of the two, which in this case, it is the feng shui criteria.

Table 4-4 Summary of Criteria for each variable in five categories

Variables	Contemporary principles	Feng shui methods	Integration methods
Climate -- Temperature -- Relative humidity -- Wind speed & direction -- Radiation	Comfort zone: 73 - 84 °F (summer), 58 - 65 °F (winter) at <50% humidity; wind speed, direction, and radiation will impact comfort zone	Balanced temperature, radiation, and elevation; no wind or mild wind: < 8 mph (summer), < 5 mph (winter)	Comfort zone: 73 - 84 °F (summer), 58 - 65 °F (winter) at <50% humidity, and wind speed < 8 mph
Geology -- Soil Type	Avoid Problem class A of soil rating; good foundation support rate; low erosion potential; slope class: A-b (0% - 7%)		
Hydrology -- Flood	100-year floodplain and wetland	Avoid floodplain and favor locations near a body of water	Avoid floodplain and wetland; favor locations near a body of water
Topography -- Slope -- Aspect -- Elevation	Slope < 16%; northeast to northwest (22.5°-337.5°, 0° = North)	Slope < 10%; east to southwest (67.5°-247.5°, 0° = North); avoid peaks, low, and shadowed areas	Slope < 10%; east to southwest (67.5°-247.5°, 0° = North)
Vegetation -- Tree coverage	Consider tree coverage		

Designing Rating Scales

The third step in the analysis module involves designing a rating scale in a structured system. SiteOne uses information in the five categories in layers and analyzes them using multi-criteria analysis (MCA), which provides an encouraging direction in meeting those challenges. MCA “investigate[s] a number of possibilities in the light of multiple criteria and conflicting objectives” (Voogd, 1983) and generates compromise alternatives and rankings of alternatives (Janssen and Rietveld, 1990). To further enhance the MCA techniques, criterion weight can be assigned to each criterion based on its relative importance.

For the default settings for standard users, SiteOne values each variable equally. For expert users, SiteOne offers an ordinal scale with three choices: very important, important, and not considered. The user assigns the relative weight for each category according to the importance: scores for very important categories are doubled; those for important ones remain the same. Finally, SiteOne calculates the scores of the five categories to a total

analysis score. Three examples are listed in Table 4-5. Figure 4-15 displays the rating scale setting of the example three in Table 4-5. Figure 4-16 shows the results map, which is different from the default result in Figure 5-35. The evaluation scores not only describe the level of resource, but also present a rough picture of the total diversity.

Table 4-5 Three examples of relative weights of categories with different settings

	Example 1					Example 2					Example 3							
Category	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5			
Very important (2x)	x													x				
Important (1x)		x	x	x	x		x		x	x		x	x		x			
Not concerned (0)						x		x			x							
Relative importance (%)	33.3	16.7	16.7	16.7	16.7	100.1	0	33.3	0	33.3	33.3	99.9	0	20	20	40	20	100

Importance index (II): very important=2, important = 1. Assume scores for all categories in the three examples are the same.
 Relative importance for category n = $II_n \cdot \text{Score}_n / (II_1 \cdot \text{Score}_1 + II_2 \cdot \text{Score}_2 + II_3 \cdot \text{Score}_3 + II_4 \cdot \text{Score}_4 + II_5 \cdot \text{Score}_5)$

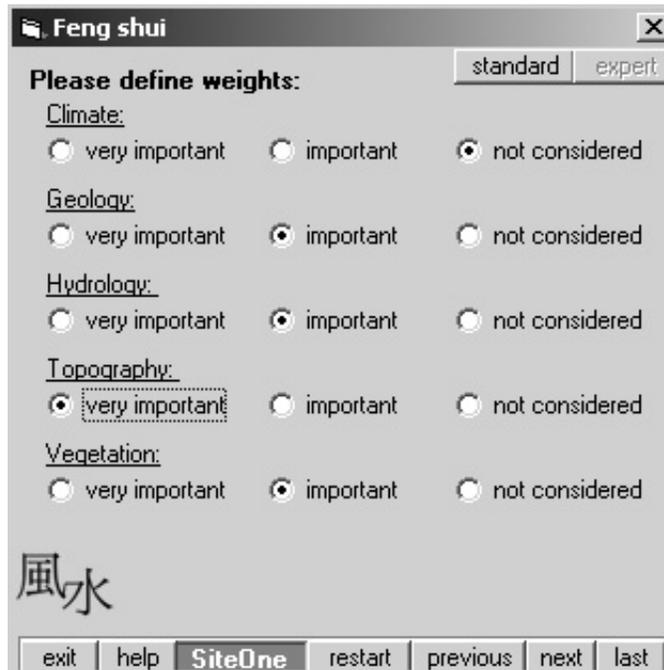
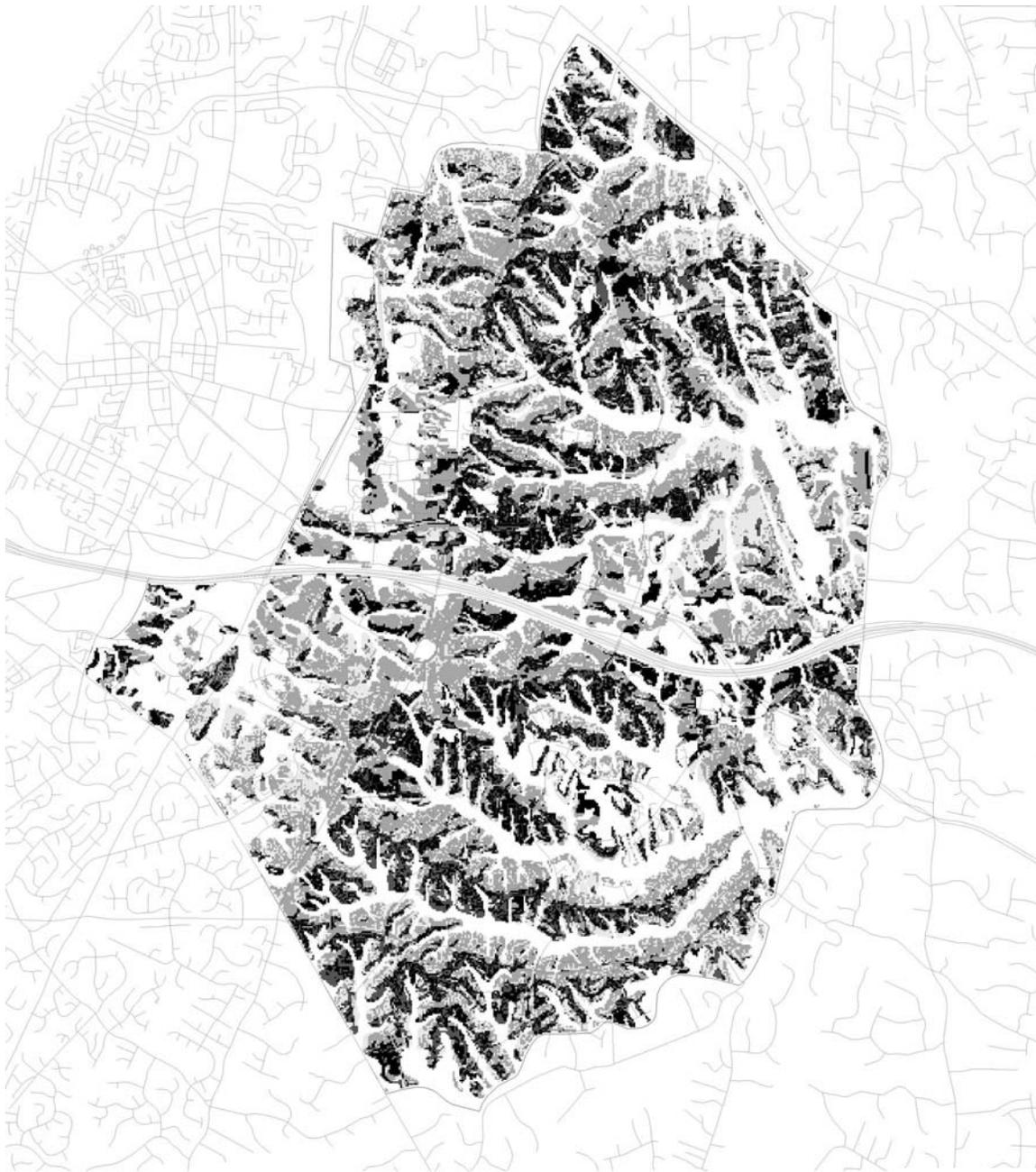


Figure 4-15 Variable weight selection interface



Reston, VA



Figure 4-16 Result map

4.3.2 Database Module

SiteOne database offers a site analysis procedure that evaluates the study area based on sets of criteria weighted according to their importance. Five data sets used are: climate, geology, hydrology, topography, and vegetation. Each data set also includes information for up to five different variables. The criteria specify analysis rules applied to the original data sets to generate the results. The following chapter describes in detail the process of collecting the original data, deriving new data sets, and generating the output.

Data sets

Data sets in SiteOne consist of the original data sets and the results, because managing the information is a two-step process: collecting information, and converting and deriving new data sets. First, the database module stores original data sets in five categories (Table 4-6). Since the availability of original data sets also defines the boundary of the field study, this research uses the town of Reston, Virginia as the study area (Section 5.1), because of the availability of information. Among these data sets, most climatic information is available in a larger scale than can be used directly in this research. The original climatic data sets, such as hourly temperature and relative humidity from each weather station in the study area, are needed in order to generate detailed maps instead of using the general weather maps. In addition, other available regional information from Fairfax County, Virginia, where Reston is located, including the soil map, the floodplain and wetland maps, the elevation map, and the tree-coverage map, are the primary data set used for analysis because of the increasing housing demand in this region and available environmental data sets.

Secondly, the database module also stores maps of the results in their corresponding categories with the indication of the analysis mode. After being collected, we need to convert the data sets to a common format. The conversion incorporates these sequential procedures: converting data, verifying information and correcting data, and deriving new data sets. The common format for SiteOne is GIS grid data. The unit size depends on the available data scale, which is no less than a 50 ft. by 50 ft. grid for the case study in this research. Therefore, each housing site with at least two grids is evaluated in terms of its capability and potential for residential development.

An important outcome of the proposed work is to convert data between different computer software packages. A major task is to produce climatic data sets. For those cities that have available TMY files, the converting process is easier than for those that do not have these files. The observation climatic data sets for Reston are collected from the neighboring 45 weather stations. Each data set consists of hourly measurements in the specific station. Then we reconstruct daily values from all stations into hourly data files, ready to derive new data sets (Chapter 5). Since the TMY data files are text files, they can be imported into ArcView GIS directly. Using the location information of the weather stations, ArcView interpolates each hourly data set into the desired maps, such as the hourly temperature map, the hourly relative humidity map, and the precipitation map. In addition, we derive the slope and aspect maps from the elevation map and then assign analysis criteria to the derived maps to generate the result maps in the topography categories. Table 4-6 and Figure 4-17 summarize the original data sets and derived maps in the database module.

Table 4-6 Result maps in each category based on different criteria

	<i>Original data sets</i>	<i>Maps using contemporary principles</i>	<i>Maps using feng shui methods</i>	<i>Map using integrated principles</i>
Climate	temperature relative humidity wind speed & direction radiation	comfort zone map	wind speed map wind direction map elevation map aspect map	overlay comfort zone maps and result map from feng shui
Geology	soil map	soil type map and erosion map		
Hydrology	100-floodplain map wetland map stream map	100-floodplain map wetland map	100-floodplain map result map of distance to bodies of water slope elevation	100-floodplain and result map from feng shui
Topography	elevation map	slope map aspect map	slope map aspect map hillshade map elevation map	slope maps aspect maps
Vegetation	tree coverage map	tree coverage map		

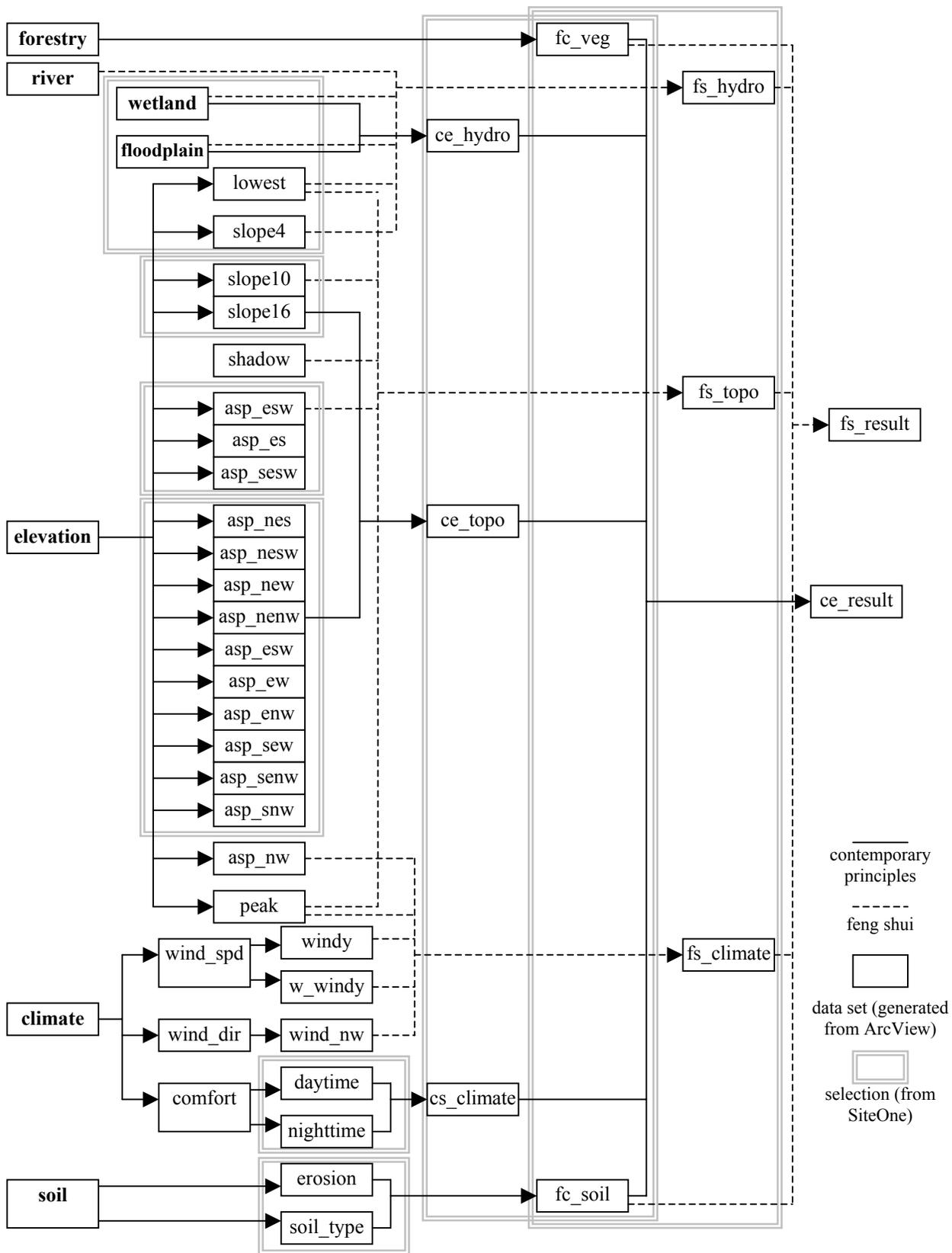


Figure 4-17 Information flow diagram

4.3.3 Result Generation Module

The result generation module shows the most desirable sites in the study area that best fit the set of analysis criteria. It allows the user to customize the decision-making rule structure to fit his or her needs. Output can also indicate advantages, disadvantages, and desirability of the alternatives.

This module selects the primary results from the database module according to the default setting or user inputs, as well as the final result map. A user interface was developed for this purpose using Visual Basic from Microsoft and MapObjects from ESRI. The interface is user-friendly and windows-based. In addition, users can also print out the maps and text that contains recommendations and suggestions from the analysis results. Figure 4-18 shows the interface of the result generation module.

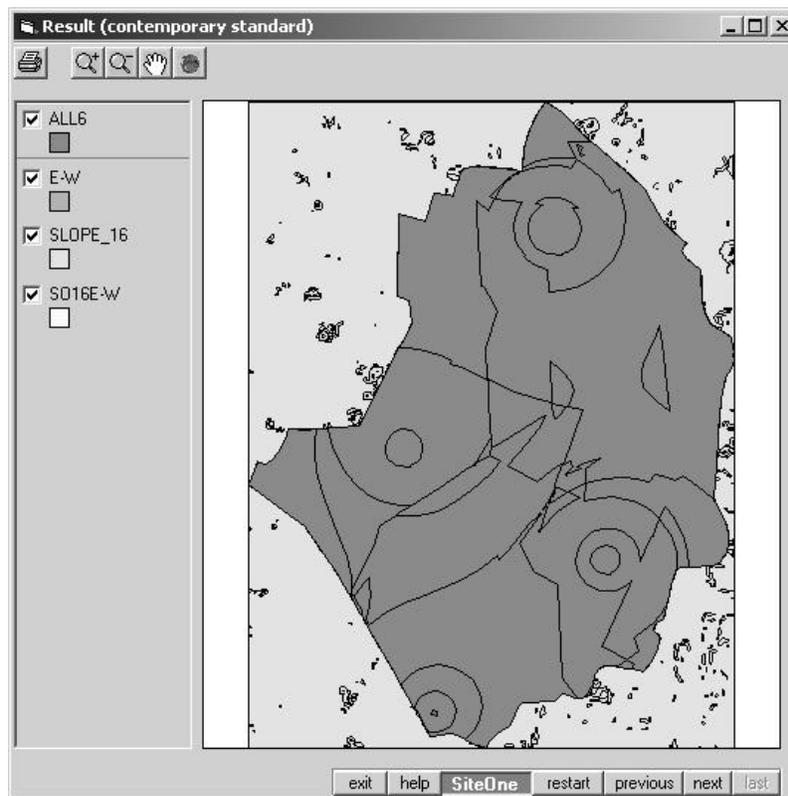


Figure 4-18 Interface of the result generation module