

CHAPTER ONE

INTRODUCTION

From Rousseau's rural utopia to the latest Earth Day activities, it is clear that mankind is working toward achieving a better understanding of his relationship with nature. This concern can be seen in various architectural practices: Frank Lloyd Wright's organic architecture shows the ecological principles of building designs that are integrated with the site and local materials. Similarly, the geologically striated mass and irregularly contoured walls of Alvar Aalto's villa designs reflect his concern of human activities to conform with the intrinsic nature of the site and the modification of the environment. In addition to these attempts in architectural practices, systematic and integrated examination also leads to new ecological movements and disciplines. In the mid-nineteenth century, landscape architecture became a new branch of architecture; it re-discovered the value of nature, and tried to focus on the visual, psychological, and spiritual influences of the natural environment. Unlike building design, landscape architecture design focuses upon planning the entire arrangement of a site, including the location of buildings, grading, stormwater management, construction, and planting.

Both landscape architects and architects are involved in site analysis, while urban design or land development addresses a larger scale, such as cities and regions. Building sites are the smallest units in a broad range of spatial scales. Although buildings are the primary focal point for architectural design, their relationship to sites and other structures should also be a concern. Thus, many professions are engaged in site analysis and planning process. Current curricula of architectural schools and organizational structures of the building industry suggest that there are at least five important components in the design process: aesthetic concerns, culture, environment, structure and materials, and economics and social/political influence. These components are also applicable to the site analysis process.

To ascertain the value of site analysis, it is necessary to consider several definitions. Most definitions divide the process into various steps. Some specify the steps practically, from site selection to building location, and to utility placement (Figure 1-1a). Others consider it as a “systematic, and often iterative, sequence of steps” (LaGro, 2001). These steps include site selection, inventory, analysis, concept development, and design implementation (Figure 1-1b). Figure 1-1c shows Lynch’s definition. He notes that site planning as

the art of arranging the external physical environment to support human behavior. It lies along the boundaries of architecture, engineering, landscape architecture, and city planning, and it is practiced by members of all these professions. Site plans locate structures and activities in three-dimensional space and, when appropriate, in time (Lynch, 1971, p.1).

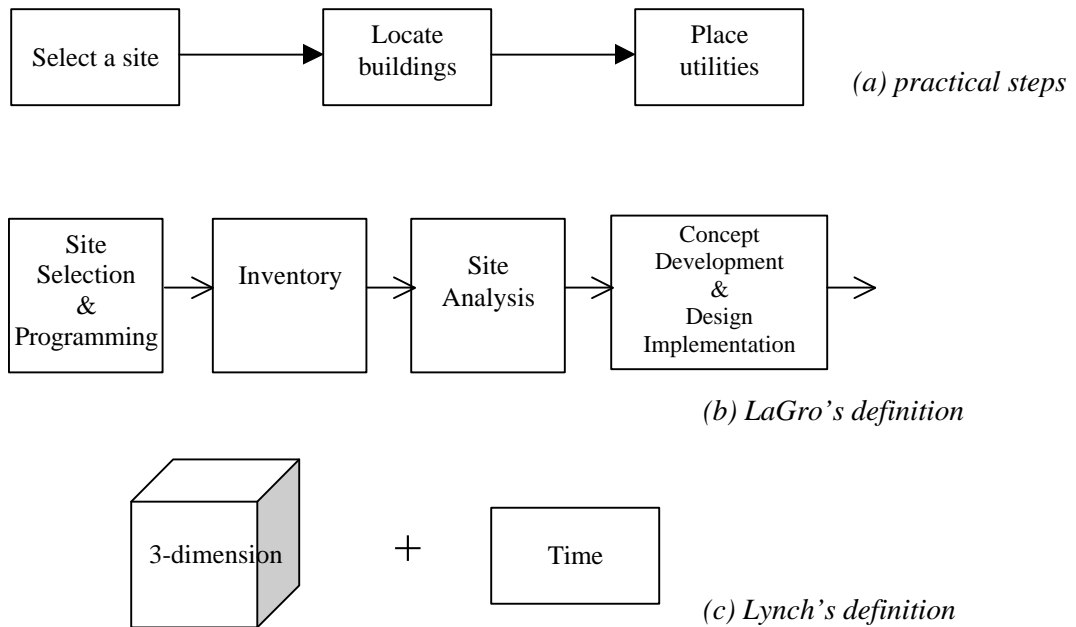


Figure 1-1 Three different definitions of site analysis

Theoretical discussions about the site analysis process are also implemented into design practices and the development of computer tools. McHarg (1969) established

guidelines for choosing sites for urban development in various geographic locations, especially in metropolitan areas. Using mapping and measurement techniques, he identified eight natural processes related to land use. The basic information includes data on climate, geology, physiography, hydrology, pedology, vegetation, wildlife habitats, and land use. Then, after establishing a quantification system to interpret the data, he mapped the relevant factors to show the results. Landscape architects and architects widely used McHarg's methods, which are also shown in state-of-the-art computer mapping tools (Chapter 4).

A large number of systems have been developed to analyze building sites and buildings. These often focus on the environment; more specifically, they introduce, promote, and guide the principles of sustainability. One good example is the Leadership in Energy and Environmental Design (LEED) rating system promoted by the US Green Building Council (USGBC). The LEED uses prerequisites and a performance-based credit system tailored to individual regions, site locations, and building types. When rating the sustainable sites, there are eight credit sections: "site selection, urban redevelopment, brownfield redevelopment, alternative transportation, reduced site disturbance, stormwater management, landscape and exterior design to reduce heat islands, and light pollution reduction."¹ Similar analysis tools for smaller residential buildings are also available and can be referenced on the Department of Energy (DOE) website.

Other group of tools is based on geographic information systems (GIS). For example, Scenario Constructor in CommunityViz² can model several options for a proposed building project at different locations. It offers quantitative impact analysis capabilities and performs a "spatial spreadsheet" with numerical computations on geographic data in real time. It also allows the project team to sketch alternative land-use scenarios and evaluate their implications for the community objectives and constraints (Chapter 4).

1.1 Limitations of Existing Methods and Tools

However, the methods and tools for analysis as described above suffer from several limitations. Today's architectural design process involves many participants, including

¹ More information can be found at the US Green Building Council website: <http://www.usgbc.org>.

² For more information, please check the website of CommunityViz at <http://www.communityviz.com>.

architects, engineers, governmental agencies, developers, clients, and the general public. The information and knowledge involved in this process have become increasingly complex, and have a wider spectrum. Thus, integrated systems and effective management methods within a guided framework are urgently needed. For designers, this requirement not only suggests buildings as integrated systems, but also leads to an extended design process, starting with site selection and evaluation. A similar paradigm shift has already happened in the broader field of environmental planning. Both the Ecosystems Approach and Landscape Ecology models signify the advancement from a general systems ecological framework. These are two examples of the recent integration of natural, physical, and biological dimensions with historical, cultural, and socioeconomic aspects. However, the integration of different analysis tools in the design process in general, and in site analysis and selection in particular, does not have a specific formulation.

The comprehensive connection between different design stages is also hard to achieve in terms of using computer tools. A wide range of professionals, technicians, and builders participate in the development process over time. Professionals contribute to the project based on their own expertise, but often fail to communicate and coordinate with others. Therefore, their mismatched computer data formats and terminology become problematic.

It is also hard to find a tool based on existing projects that has been proven useful over time. The situation is severe for problems and issues that relate to social and cultural factors, because these issues are complex and difficult to analyze using computer programs. The uniqueness of particular projects also makes developing a general computer program even more challenging. Almost all tools only “support” site selection; they do not make final decisions for users. With the development of high-speed and high capacity computers, modern expert systems may use knowledge modules and inference engines to account for both human activity and natural process models, and support complex decision-making (Brail and Klosterman, 2000).

Additionally, the environmental aspects are defined ambiguously in the complex site analysis and selection process. Since the 1950s, various publications have presented issues and design approaches aimed at environmental integration. Several frequently used terms, such as ecology, sustainability, green architecture, and renewable energy, are defined as follows:

- Ecology, according to Webster's New Collegiate Dictionary, is defined as a branch of science concerned with the interrelationship or pattern of relations of organisms and their environments. It studies resource and energy management in the biosphere and its sub-categories. Zeiher (1996) argues that the balance of ecology can be influenced by the design and construction of architecture whether or not people respect the ecological concept.
- To understand sustainability, the most widely quoted definition should be introduced first: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brudtland, 1987, p.43). The sustainable design is an architectural approach to environmental, social, and economic issues of the individual and to communities that requires all three to work together now and in the future.
- Green architecture is a term used to describe energy-efficient, environmentally-friendly buildings and developments by effectively managing natural resources. Green building principles encourage resource conservation, consider environmental impacts and waste minimization; build a healthy and comfortable environment, reduce operation and maintenance costs, and address community infrastructure issues³. The LEED program developed by USGBC not only defines the green building idea but also measures the concept, the "greenness of a building."
- Renewable energy refers to energy resources that occur naturally and repeatedly in the environment and can benefit human activities. Renewable energy systems include solar, wind, and geothermal energy. Trees and plants, rivers, and even garbage are also considered renewable energy resources.

Environmental integration touches on all the above-mentioned aspects and integrates elements from each of them. Its fundamental principles emphasize the basic aspects of the natural environment, including climate, physiography, hydrology, vegetation, and the lives of the inhabitants.

Some researchers also look to ancient philosophy as both an alternative and complement to contemporary environmental design. Indigenous people used land to define

³ See DOE's Smart Communities Network Project at <http://www.sustainable.doe.gov/buildings/gbintro.shtml>.

their existence and identity. For them “the trees, plants, animals, and fish, which inhabit the land are not ‘natural resources,’ but highly personal beings which form part of their social and spiritual universe” (Davis, 1993, p.1). Similarly, the ancient Chinese developed feng shui, an evaluation system that examines the sites of cities and determines the desirable layouts of buildings. It has been practiced for more than three thousand years in China. Currently, architects of several major projects in Western societies consider input from the feng shui experts on architectural and interior design. However, even the Chinese, who are familiar with ancient Eastern literature and philosophy, often have difficulty understanding basic feng shui concepts and methods of application. Furthermore, the comparison between contemporary and traditional environmental design principles and the possible incorporation of the two are still not a common concern.

1.2 Objective Statement

A review of existing methods and computer tools shows that an integrated framework for site analysis and selection is currently needed, so that preferable building sites can be automatically selected and a detailed analysis report generated. Any new methodology should consider the drawbacks of existing methods and computer tools. After a careful reviewing of the related research, this study will answer the following questions:

1. Can a framework be defined to analyze site conditions in the design process?
 - a. What are the commonalities for the understanding of the world through architectural design?
 - b. What are the major components in the framework? What are the relations among these components?
 - c. What is the relationship between site analysis and the entire architectural design process?
2. What are the environmental factors that should be considered?
 - a. In what ways do feng shui and contemporary environmental design theories intersect?
 - b. What insights would a comparison between feng shui and contemporary environmental theory yield?

- c. How can the environmental component in a site be implemented?
- d. How will the changes of the environmental factors influence other factors and the structure of the framework?

Thus, the purpose of the research is to develop a framework for the evaluation and selection of the most desirable housing sites – those sites achieving a balance between man and nature, the building and its surroundings. Within the structure of this framework, the environmental components will be explored in detail. We will identify the major factors, compare feng shui and contemporary principles, and emphasize the integration of environmental factors into architectural design. This framework will help designers and developers recognize the importance of the site as part of a holistic design process.

The proposed methodology is based on several existing site analysis and selection models. On one hand, the research presented in this dissertation attempts to define a framework that can expand those models and incorporate each component in an organized structure. Thus, the framework will be a comprehensive structure, but will remain flexible and open in terms of its components. Impacts that are currently hard to define or estimate could also be added into the framework in the future. A quick analysis for a small site may only involve a few components; a sophisticated estimate for a complicated project may include more analyses. On the other hand, the implementation of the environmental component supports the proposed framework. Research on major factors within the component can help to clarify the definition of the environmental issues related to site analysis and building design. The component combines the environmental knowledge with an interface design. The computer simulation will demonstrate the decision-making process, as well as provide useful information for designers and decision-makers.

The following tasks will be needed to fulfill the research objective:

1. A study of the design method and process;
2. A review of principles and theories related to environmental design;
3. Development of an integrated site analysis framework;
4. A review of existing methods and tools;
5. Implementation of the framework with a computer simulation program;
6. Demonstration of the framework through data collection and analysis for the study site;

7. A discussion on results generated from the computer program.

1.3 Scope of Research

This research proposes a holistic site analysis framework for residential development. A review of related literature shows that site analysis for program-determined projects includes physical inventory, biological inventory, cultural inventory, and analysis (LaGro, 2001). Common methods for programming, such as document analysis, behavioral observation, historical and current aerial photographs, and zoning maps, may also support decision-making. Figure 1-2 shows the overall framework of a site analysis model and the scope of this research. The highlighted boxes are the focal points. Among the many components of the overall framework, this research concentrates on environmental aspects, as is shown on box one of Figure 1-2. Regarding the environment, the research collects and analyzes climatic, geologic, hydrologic, topographic, and vegetation information (boxes two and three, Figure 1-2). More detailed analyses address the four correlated factors of bioclimatic design (box six, Figure 1-2), as well as four landform components: slope, aspect elevation, and hillshade (box seven, Figure 1-2).

1.4 Research Limitations

The work utilizes knowledge and skills from multi-disciplinary subjects, a case study using Reston, Virginia, and computer programming implementation. Time restrictions and technical limitations are raised through the research. In general, the longer the collection time for data such as the climatological data, the more comprehensively and reliably the data will reflect particular building sites. For this research, 45 weather stations⁴ are located in 240,000 acres, 32 times bigger than Reston, the study area, which is located in the center of the weather stations. However, only a half of these weather stations were installed and operated in 2001, which affects the interpolation⁵ accuracy. Thus, the collected climatic data

⁴ Weather stations were provided by AWS, Inc.

⁵ Interpolation is a term used in mathematics and GIS. It estimates unknown values by taking an average of known values at neighbouring points.

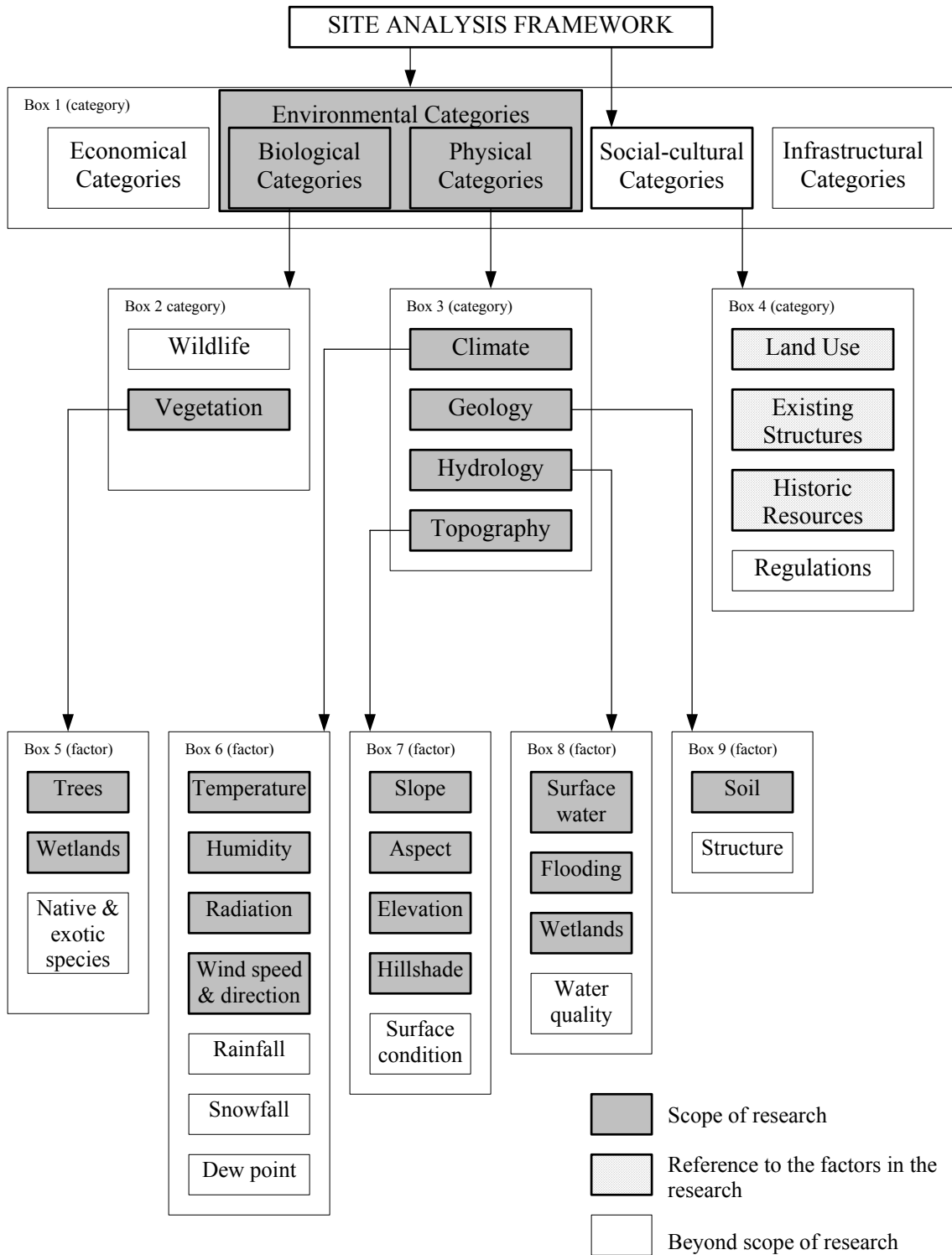


Figure 1-2 Site analysis framework and scope of Research

covers different weather conditions throughout a year, from April 2002 to March 2003. Although the data only presents the weather conditions in a specific year, enough data was collected to successfully calibrate the analysis framework and computer program implementation.

Technical limitations were experienced in three areas. First of all, the collected data should give a comprehensive representation of the physical conditions of Reston. However, data collected from the weather stations does not contain solar radiation information. The available radiation information is produced by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy⁶. It compiles solar radiation data from five stations in Virginia. One of these, the Sterling station, is nine miles away from Reston; and the Richmond station is 114 miles away. Therefore, hourly radiation data sets from the Sterling station are used to complete the data sets from these 45 stations.

The second limitation is the mapping size. The topography data provided by the Fairfax county GIS and Mapping department uses five-foot contour intervals. Because of the limited calculation time and capacity of current computer technology, it is difficult to interpolate the climatic data using the same grid size. Therefore, the climatic data is interpolated in a 50 ft. by 50 ft. grid. It is fine enough to analyze lot sites for single-family houses in Reston, which range from 5000 sq.ft. to 87000 sq.ft.⁷.

Finally, feng shui is historically applied to site selection of cities, towns and villages, buildings, and tombs. However, this research only addresses the application of feng shui to buildings. The implementation of feng shui is also based on the findings of other researchers, which summarize the fundamental feng shui principles and survey of historical buildings. Thus, the feng shui criteria used in this research will be limited in certain areas.

1.5 Organization of Dissertation

The dissertation is presented in seven chapters. This chapter, Chapter One (Introduction), lays out background information, reviews existing methods and tools, and

⁶ More information about solar radiation data can be found at http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

⁷ The number is calculated from the zoning map of Reston with the residential district regulations from Fairfax country government (http://www.co.fairfax.va.us/dpz/PDF_files/Ordinance/art03.pdf)

addresses research questions and objectives. It also discusses the scope and limitations of the research.

Chapter Two (Design Methods and Process) reviews the basic concepts of design problems, methods, and process. It also presents the pertinent research on site analysis, and discusses its position in the design process.

Chapter Three (Feng Shui and Contemporary Environmental Design Principles) reviews contemporary environmental design principles and feng shui theories and applications. It also compares feng shui to contemporary environmental design principles. Finally, it outlines the major environmental factors that should be considered.

Chapter Four (A Site Analysis Framework) discusses the concept, components, and structures involved in an integrated site analysis model. This chapter also highlights the environmental factors in the framework, and describes implementation strategies. Then, it reviews existing methods and tools. Finally, this chapter introduces the implementation of a computer simulation tool, SiteOne.

Chapter Five (Case Study Using SiteOne in Reston) presents the different collection and analysis methods for climatic, topographical, hydrological, and vegetation data. The analysis procedures of the climatic data include deriving overall hourly data from individual local weather stations, generating temperature and relative humidity data sets, interpolating point data to grid data, and finally, applying comfort zone criteria to these data sets. This chapter also presents the analysis results from single categories as well as the overall outcome, which is based on SiteOne.

Chapter Six (Proof of Concept: Site Analysis by Professionals) demonstrates how professionals can use the proposed framework in site analysis. This study also uses the results from the interviews to validate the SiteOne results. It summarizes the differences between the interview results and the SiteOne results and analyzes the possible causes of these discrepancies.

Chapter Seven (Conclusion and Discussion) discusses the results presented in the previous chapters, and summarizes general concepts and guidelines for a comprehensive site analysis framework. It also suggests future research that may extend the concept and implementation of the integrated site analysis framework.