Adapting Geographic Information Systems to Address Sketch Planning Needs

by

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A. B., Economics
Brown University, 1991

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Abstract

A geographic information system (GIS) has traditionally been used as a way for organizations to create, manage and analyze spatially referenced data in highly structured ways. Many planners, however, avoid GIS because the way they analyze data (or the way they perceive their analytic techniques) is not accommodated by the standard GIS toolkit.

This paper focuses on the needs of urban designers, and argues that what urban design is about—understanding the urban realm by finding patterns in the landscape—is theoretically well suited to the adoption of GIS technology. Therefore, the problem is to create tools that serve this aspect of the planning profession. Two main areas emerge as critical. One is creating a toolkit of standard sketch planning functions that takes advantage of the ability of GIS to integrate numerous and disparate data sources. The other involves building into the system a level of customization demanded by the creative professionals engaged in urban design.

To explore this topic, we begin with a review of analytic techniques espoused by urban designers and architects as well as the latest research in using information technologies to clarify complex spatial environments and relationships. With this information in mind, two urban design applications are prototyped. One is a prototype pattern finding application. The goal of this application is to allow the designer to combine their knowledge of the area with the analytic power of GIS to discover hard to find patterns in the city. The second prototype tests the ability of GIS to answer questions that are important to urban designers by applying the techniques Kevin Lynch espoused in The Image of the City (1960) to the City of Boston, Massachusetts. In particular, we try to find nodes (concentrations of activity) using only digital data.

Finally, the paper looks at how this research could be used in an actual urban design project—the redevelopment of Mission Main, a public housing project in Boston.

Thesis Supervisor: Professor Joseph Ferreira Jr.
Title: Adopting Geographic Information Systems to Sketch Planning Needs
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Biography

The author has worked professionally as a geographic information systems specialist for an environmental consulting firm and as a researcher on environmental cost-benefit analysis issues. He was awarded a degree in Economics from Brown University in 1991.
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I. Introduction

Problem Definition

Urban designers are engaged in the practice of improving urban life by proposing changes in the city's built form. In order to make these proposals, they must have a rich understanding of the place in question. In past centuries, most cities were small enough that a planner could have a good understanding of who lived in the city and what their needs were, but our cities are far too complicated today for this informal system to work. Countless factors affect the inner workings of the city, so in an attempt to gain an understanding of place, planners try to examine aerial photographs, engineering plans, Census data, economic studies, transportation systems, etc. Since one person does not have the mental ability to hold data on all of these subjects in their head at once, we currently employ a system of planning by committee. Many people are directed to study certain aspects of a problem, and then this information is supposed to be synthesized in meetings and joint reports.

This study proposes a different solution to the problem of synthesizing information. Since the urban design issue is mainly one of the storage, analysis and presentation of spatial data, geographic information systems (GIS) have much to offer the field. Scientific disciplines have used GIS for years, but most designers, being involved in work which is a mixture of science and art, have clung to traditional tools. Sketch planning is an activity that requires a great amount of time and effort to do properly. The area under consideration must be understood in great detail, including the physical layout of infrastructure, patterns of activity, crime, demographics, etc. Most cities do not have enough time or money to send planners out into the field to study every area of the city to develop an understanding of these factors through personal observation. This thesis explores ways in which a GIS database can be used to develop this understanding of the urban landscape without a field investigation of every acre of the city.
What is a sketch plan

Urban designers use sketch planning to create a simplified picture of an otherwise complex scene for the purpose of clearly communicating design concepts. Different designers have different ideas of what a sketch plan is, from a highly representative picture to an abstract diagram. In the context of this paper, a sketch plan is a picture drawn in plan view that distills certain key components of a landscape to tell a story about a place that words could not express as succinctly. Sketch plans are often compared with diagrams, but I see a diagram as being a generalized sketch plan because it does not try to capture the spatial relations of a place in as much detail as a sketch plan.

Figure 1: Spatial Description Techniques

As our main form of communication is through words (expressed orally or written down), the information in a sketch plan could be expressed in this way, but it is a fact that, especially in design, a picture often is worth a thousand words. Since sketch plans are often developed from aerial photographs, why isn't the photograph enough? In fact, it is more than enough. The photograph is too rich in information—it tells too many different stories. Like a lawyer uses information from a case, decades of relevant precedent and their own knowledge and training to build a persuasive argument for the court, the designer uses a sketch plan to convey their analysis of a landscape based on the information present in source maps, knowledge about urban design and their own training in the discipline. So the sketch plan tells a story which is unique based upon the individual designer (or designers) and available information sources.
Research Questions

The main question that this research will address is whether GIS can be used to generate sketch plans. As this is a very early investigation into this topic, this must be the initial thrust of the research. If it is possible to produce sketch plans using GIS, then we can decide whether the urban design field can benefit from GIS or whether traditional methods do a better job of describing the urban landscape. If GIS can be effectively applied to urban design problems, we must ask which problems should we address first, and how can future data collection and systems design efforts facilitate the implementation of urban design information systems.

Significance

Zoning (and possibly the comprehensive plan—when adhered to) is one of the only city planning tools that attempts to consider the city as a whole. Subdivision reviews, permitting, design reviews and impact assessments all approach the planning problem from the point of view of a single project. Although zoning is a useful planning tool, we are concerned about more aspects of the city than the simple regulation and segregation of land uses. We must also consider qualities such as safety, ease of transportation, aesthetics, and a sense of place. In order to tackle these problems on a large scale, discussants need a general understanding of the city. This understanding is difficult to achieve, as a city is a combination of thousands of structural and social elements, and people can only consider a few at a time (psychologists believe that we can only hold about five to seven unrelated items in immediate memory).¹

This paper seeks to alleviate the planner’s dilemma, by using GIS and electronic communication tools to increase the amount of information used in the planning process and to allow multiple participants access and input into the construction

¹ Richard Perron and Deron Miller, “Landscape of the Mind,” p. 72.
of an image of the city. If the urban design GIS described here can be implemented, planners will have a powerful new tool for performing more thorough analyses of the city and therefore creating better urban environments.

Research Methodology

There are four steps to my approach at answering the research questions. First, I look at the literature of the leading thinkers on urban design. As there is little precedent for integrating information systems with urban design, the second step is to look at the body of knowledge developed in other fields on applying GIS to planning. With this information, I attempt to prototype and test an urban design GIS based on the concepts espoused by Kevin Lynch in The Image of the City. Boston, Massachusetts is used as a test case as an extensive digital database was available for this city. Fourth and finally, the applications and concepts developed in the prototype are used to critique the design objectives of a current urban redevelopment plan for a public housing project.

This redevelopment project involves a total redesign of an entire neighborhood under the guidance of a central planning body. All elements of the neighborhood are subject to change, including zoning, the configuration of roads, the design of buildings and even the type of tenant mix. The central planning body also would like the design proposal to address inter-agency communication and collaboration. Because of its comprehensive nature, this project provides an ideal test case for using GIS to help synthesize information for planning.
II. Literature Review

Modeling and Design Thinking

The need for the design profession to embrace analytic methods of inquiry has been observed since the 1960s when many people realized that the rate of American urbanization was increasing exponentially, and our institutions were not equipped to deal with the phenomenon. As civilization became more complex, the ability for a single person to understand the full range of issues that affect a given problem dwindled, yet our planning processes did not adapt to this situation—they still depended largely on the belief that the mental faculties of one person, or a small group of people, were sufficient to synthesize all of the pertinent information regarding a problem. Many planning disciples have begun to use computerized information systems to help cope with modern urban processes, but the trend has not been observed in the design profession.

Christopher Alexander saw that, "unable to cope with the complicated information [the urban designer] is supposed to organize, he hides his incompetence in a frenzy of artistic individuality...In this atmosphere the designer’s greatest gift, his intuitive ability to organize physical form, is being reduced to nothing by the size of the tasks in front of him, and mocked by the efforts of the ‘artists.’ What is worse, in an era that badly needs designers with a synthetic grasp of the organization of the physical world, the real work has to be done by less gifted engineers, because the designers hide their gift in irresponsible pretension to genius."¹ The problem as stated here seems as relevant and novel as it must have seemed then. This passage comes from Notes on the Synthesis of Form, in which Alexander begins to formulate a theory on how designers might begin to use formal logic to solve design problems. Very generally, the theory involves finding the entire set of design problems that must

¹ Christopher Alexander, Notes on the synthesis of form, 1964, p. 11.
be solved or conditions to be met and determining which are related to each other and in what order to solve them.

Alexander was not the only one to espouse this approach. In Design Thinking (Rowe, 1987), Peter Rowe states that in European design schools of the 1950s and 1960s, “attempts were made to describe the creative problem-solving process at work in design by way of the logical structure of overt activities that appears to take place. In other words, design was regarded as a series of stages characterized by dominant forms of activity, such as analysis, synthesis, evaluation, and so on” (p. 46). Furthermore, these theories usually incorporated an iterative property, to make explicit the process of designing based upon the information at hand and then refining the design by reevaluating the original set of information with respect to previous design solutions. Asimow (1962), Archer (1963-1964) and later Steinitz (1995) proposed variations on this “operational” model of the design process (Figure 2). Schön (1983) focuses less on the operational aspect of the model and more on its iterative properties, as the designer continuously reflects on the work.

These approaches to design were an attempt to solve “ill-defined” design problems. Rowe describes three types of problems, well-defined, ill-defined, and wicked. Well-defined problems, like $2x + 5x^2 = 29$, have obvious starting and ending points and rules to follow from beginning to end. Ill-defined problems, which Rowe believes encompasses most architecture and urban design problems, usually have desired goals, but the solution which will achieve the goals is unclear as well as the initial conditions. Wicked problems are those for which the goals, starting point and ending point are up for constant debate, like hazardous waste disposal. There is no specific result that can be agreed upon as the best possible solution to the problem.
Figure 2: Operational Models of the Design Process

Archer: Stages of a design process

Asimow: Iconic model of a design process

Steinitz: A Framework for Design as a Verb

1 Peter Rowe, *Design Thinking*, 1987, p. 50.
2 __p. 48.
3 Carl Steinitz, "Design is a verb; Design is a noun," 1995, p. 199.
Many of the ideas in *Design Thinking* are worthy of consideration, but Rowe’s discussion of operational models and modeling is the most relevant to this work. He starts with Echenique’s definition of models, “A model is simply a representation of relevant characteristics of a reality...a means of expressing certain characteristics of an object, or system, that exists, existed, or might exist” (Echenique 1963, p. 1). He then groups models into four categories: descriptive, predictive, explorative and planning. Descriptive models seek to explain what and why something is the way it is and how it works. Rowe would describe Lynch’s city imageability concept as a descriptive model. Predictive models are either extrapolative, in that they predict the future based on what can be expected from looking at the past, or conditional, in that changes in inputs result in different outputs. Explorative models are, “designed to allow the discovery, by systematic speculation, of realities other than the one at hand that may be logically possible. Such speculation usually proceeds by exploiting the systematic variation of basic parameters used in a descriptive model” (p. 167).

The planning model as Rowe defines it builds upon the other three types. In his planning model, descriptive models are required to understand the current state of affairs. Next, different interventions can be evaluated with a predictive model to generate possible solutions. The solutions are then ranked objectively according to their ability to meet stated goals. Explorative models may be used to generate predictive models, ranking schemes, or other decision support tools.

*Figure 3: A Hierarchy of Model Types (Rowe 1987)*

```
Models

Explorative

Descriptive

Predictive

Planning

Past ———> Present ———> Future

Reality
```
I have avoided allowing the applications developed here to fall into the realm of predictive or planning models because they are intended to be more pure. Those two kinds of models inherently require value judgments that must be made separately as each planning problem is faced. These applications intentionally try only to be descriptive (in the case of the node-finding algorithm) or explorative (the pattern-finding application). Too often the tendency is to create an application that makes decisions, as in Rowe's planning model. This is difficult, and not necessarily wise, as examples from the environmental field show us.

**The environmental field**

Most of the recent environmental modeling literature is geared towards resolving some issue as opposed to simply investigating the "relevant characteristics of an object or process." Landscape Ecology and GIS (Haines-Young et al 1993) and Environmental Modeling and GIS (Goodchild et al 1993) focus almost entirely on planning models in that each model presented is intended more as a decision support tool than a descriptive or exploratory tool. The only descriptive modeling work being published recently involves the classification of satellite imagery. However, the environmental field has been using GIS for decades, so there is still a great deal of literature which addresses the modeling issues of concern here.

Carl Steinitz's basic theory of design is very similar to Rowe, Archer and Asimow (Figure 2). Although much of the work referenced here is from the 1990s, it refers to ideas that Steinitz has worked with for decades. In fact he says, "In 1990, after almost 25 years of applying GIS to many projects, I came to the realization that there was a common structure to this work, and I wrote a short paper entitled, 'A Framework for Theory [applicable to the education of
landscape architects]. This common structure takes the form of "A Framework for Design as a Verb" (Figure 2), where Steinitz illustrates a six-stage method where representation models explain how the landscape should be described, process models explain how it operates, evaluation models explain whether it is working well or not, change models explain how it might be altered, impact models explain what differences these alterations might cause, and decision models help us decide whether and how to act. His feedback loops (shown with arrows) relate these models to one another and shows an iterative pattern where each model can inform others.

Environmental Impact Assessments show how modeling can be abused. It was stated above that a model must start with a decision to choose certain relevant characteristics of a real object or system because it is too difficult to try to model all characteristics. The planning model then ends with a ranking of possible outcomes. These assessments are being conducted throughout the world using the exact same modeling procedure, as if the environmental concerns in, for example, an urban-industrial area like Los Angeles should be ranked the same as those in a mostly rural area like Vermont (where a large part of the economy is eco-tourism). The validity of these techniques has become an issue of general public debate recently as the U.S. Congress has called into question the U.S. Environmental Protection Agency's decision-making techniques. So although the environmental field is very advanced in terms of using GIS as a modeling and decision-making tool, they have perhaps gone too far in relying on analysis to make difficult choices which are as much a product of socio-cultural issues as technical ones. This is not to say that we should not strive to construct good decision making models. I simply want to emphasize that the move from a descriptive model to a planning model is a significant one, and is outside the scope of this work.

The most important descriptive model in the environmental field is presented in *Landscape Ecology* (Forman and Godron 1986), where the landscape is described generally in terms of structure function and change. Structure refers to the distinct elements that make up the landscape. Function refers to how structures interact. Change is the alteration of structure and function over time. It should be noted that all of these elements change with scale, so that a farm might be a structure at one scale, but at a larger scale, the farm structure becomes the separate structures farmhouse, dirt road, cropland, grazing land, hedgerow, etc. Structure can be more generally described as consisting of patches, which are relatively homogeneous areas, corridors, which are places along which living things travel,¹ and a background matrix, which describes the general landscape characteristics of the place. Edges are created where different landscape structures meet. For people, a residential neighborhood is a patch, while a highway is a corridor. At a larger scale, an apartment building could be a patch, which would then make every sidewalk and road a corridor and every stoop part of an edge. At a smaller scale for migratory birds, the chain of wetlands along the Atlantic coast is a corridor.

The patch-edge-corridor theory is similar to Lynch’s district-edge-path, and may not be a coincidence, as Forman mentions Lynch as having “particularly elucidated structure and change in the urban landscape” (p. 29).

**Urban Design**

The body of literature drawn upon most heavily in this work is that which looks at the city as a whole and how the built environment influences its ability to function well. To develop coherent arguments, there must be an understanding of how buildings, roads, sidewalks, rail lines, topography, etc., integrate to form a characteristic place. This field of inquiry is at the heart of what urban design is

¹ The corridor concept is affected by both spatial and temporal scale. Deer may traverse one type of corridor every day in the search for food, while butterflies may use a migratory corridor twice
about, so these concepts are studied in order to be able to create a geographic information system that can support the continued exploration of these ideas.

The Image of the City (Lynch, 1960) examines “the apparent clarity or ‘legibility’ of the cityscape,” and argues that, “a distinctive and legible environment not only offers security but also heightens the potential depth and intensity of human experience.” From this starting point he proceeds to develop a theory that in order for a city to be legible, certain elements must be readily identifiable by its inhabitants; these elements are nodes, paths, districts, edges and landmarks. Nodes are transportation junctions or concentrations of activity. Paths are channels along which people (in vehicles or not) customarily travel. Districts are sections of the city that have some common character. Edges are boundaries between areas. Landmarks are points of common reference, like the Empire State Building in New York City, the Citgo sign in Boston, or the Space Needle in Seattle.

Working from this theory, Lynch tells us how a poor city image can be found (through sketch planning and input from residents) and how it can be corrected. The resulting ‘highly legible’ cityscape will then be a much more interesting and satisfying place for people to live and work. In order to define a city’s imageability and later correct it, the designer must be able to find the nodes, paths, districts, edges and landmarks as they are perceived by the city’s inhabitants. This work shows how a geographic information system could begin to support this process by finding nodes. The use of GIS is important here because Lynch’s method involves field investigation to find nodes, which limits the area he is able to study to the amount of highly trained human labor he is able to muster behind the effort. My method focuses on strategic use of digital data in order to create an algorithm which finds nodes and is field-checked in a small area, but can then be used to find nodes over any area.
A Pattern Language (Alexander 1977), gives a much better analytic framework for urban design than Alexander's previous Notes on the Synthesis of Form, and it has influenced an entire field of inquiry concerned with 'shape grammars.' These shape grammars have been explored mainly within the discipline of architecture, but the pattern language also deals with the urban scale. There are 253 'patterns' which descend in scale from the pattern 'Independent Regions,' which describes how human civilization on the planet should be organized, to the pattern 'Things from your Life,' which talks about what you should hang on the walls of your home.

Alexander believes that a designer may use the framework by deciding which pattern best fits their task, and then use that pattern and a few patterns above and below that main one. As an example, if we were involved in economic development for 'blue-collar' workers, we might start with pattern 42, 'Industrial Ribbon.' This pattern would tell us that although industry is smelly, noisy, dirty, etc., it must be placed in or near neighborhoods so that people may understand the connection between the things they use in their daily life and the process of
making them. Also as a practical consideration, proximity is important so that people do not have to drive to work and spend a great deal of time in travel to and from work. In situations where the industry requires too much land for their placement in the general urban fabric to be practical, they should be placed in an industrial ribbon, which would be near ring roads (pattern 17) and have truck and train access.

**Figure 5: Pattern 42, Industrial Ribbon**

In planning this industrial ribbon, it would be important to take into careful consideration the idea of work communities (pattern 41), old people everywhere (pattern 40) and housing on hills (pattern 39). Descending in scale, we must consider the university as a marketplace (pattern 43), local town halls (pattern 44) and necklaces of community projects (pattern 45). More patterns may be considered, with each likely to be less important to the project as they get farther removed in scale. So this is a comprehensive guide to urban design, though it’s organizing principles are distinct from Lynch’s.

*The Next American Metropolis* (Calthorpe 1993) is an example of the latest trend in urban design, “the new urbanism,” which advocates high-density walkable towns with a greater mix of land uses than current zoning policies generally allow, narrow urban streets which allow the street to be used as public space as well as transportation and buildings that relate to that public space instead of to parking lots. Calthorpe has expanded the theory to include a regional design scheme termed “transit-oriented development,” (Figure 6) in which these new

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urban areas (which are designed to be small towns) are connected to each other and to a larger metropolis by public transportation.

These high-density, dispersed small towns are supposed to satisfy the American desire to live in a small town while still having easy access to the city. This type of development pattern is also intended to be ecologically sustainable by concentrating human populations in the least environmentally sensitive areas and encouraging people to use public transportation. As urban planners expand the scope of their work to regional planning, the need for information management and analysis strategies becomes even greater.

**Figure 6: Transit-Oriented Development (Calthorpe 1993)**

GIS in Planning

Now with an understanding of modeling has developed in respect to urban design, we may take a critical look at initial, recent attempts at integrating design and GIS. A number of researchers are now beginning to explore the potential of computerized information systems for planning with limited success. Their concepts seem to be so theoretical as to be of little practical use at this point, or so specific and data-intensive that the cost to set up the system is prohibitive.
One area of research involves making analytic tools accessible to non-technical planners and the general public. This requires new kinds of interfaces to the information system as well as new kinds of information visualization techniques. Linsey and Raper have experimented with the provision of spatial analysis functions through a graphical user interface (Linsey and Raper 1993). The focus here is on allowing a user to create their own analysis by attaching a graphical front-end to Arc/Info’s map display, database query, buffering and spatial intersection functions. Shiffer focuses more on visualization techniques than spatial analysis. His work seeks to create tools that allow the outcomes of complex processes to be better understood by the general public (Shiffer 1995). One example is that instead of debating the possible deleterious effects of airplane noise by explaining the decibel levels of planes, he presents a system that can play back the actual sound an airplane would make and allows it to be varied depending upon the type of plane and the observer’s distance from the plane.

Dave and Schmitt (1994) have prototyped an information system that is tailored to the needs of designers, but their definition of urban design in the context of this project is very architectural. They decide that the traditional GIS model is inappropriate for urban design needs and instead use computer aided design (CAD) programs as their base system. This decision reflects their focus on three-dimensional rendering and visualization as opposed to spatial analysis. Although it is true that traditional GISs have weak three-dimensional visualization tools, by using the computer only as a tool to produce pictures of the urban environment, all analysis must still occur in the mind of the designer. This paper will argue that Dave and Schmitt’s system, while having focussed applications, ignores the main benefit of using computerized information systems, which will be to create new analytic techniques that a person is able to conceptualize but not execute in their mind.

The National Physical Planning Agency of the Netherlands has been taking an approach to integrating GIS and design similar to the one put forth here (Schuur
1994), with a critical difference. They are working on using GIS for understanding the *existing* state of the physical world and having designers use thematic maps as base maps to draw on and design *potential* states of the physical world. GIS is then employed once again to rank and evaluate the potential designs. The critical stage where GIS and design is integrated still involves the intuition and skill of the designer to synthesize GIS information in their head instead of with the help of the computer, which is the same problem Alexander discussed in 1964 in his previously mentioned *Notes*. Since the designer’s contact with the GIS database is still through printed maps, he or she can only see a certain amount of information at one time—with the pattern-finding application presented in this work, I endeavor to enable the designer to take into account more data than can be plotted coherently on paper.

*Figure 7: Designing on a GIS base layer (Schuur 1994)*

*NOTE: some design elements are exaggerated from the original*
III. Functional Prototype

Theoretical Scope

The functions offered here are novel only in the way they ask the user for input and in the way that the computer delivers answers to the user. The focus here is not to suggest new algorithms, but to define which algorithms are useful for urban design and to adapt the traditional GIS interface so that designers can make use of GIS for spatial data analysis.

In all fields, GIS research should focus on exploiting the ability to synthesize disparate data themes. The single variable thematic map is one of the most common GIS outputs, but decision makers rarely want to know how one variable varies across space. They want to know about the interaction of many different variables. This type of analysis lies at the heart of GIS, but the way software is currently configured, the user must be familiar with a plethora of software-specific commands to perform an analysis, which means that the help of a GIS specialist is usually required.

An environmental sensitivity analysis is one example of this kind of study. Data on vegetation, soil type, elevation, slope and aspect are synthesized to come up with some measure of environmental sensitivity for every point in the study area. Generally, scientists define the study parameters and then the GIS work is performed by a technician who applies those parameters to a data set and then generates a map.
The need for better GIS interfaces is currently being addressed by individual users who develop “modules” using the GIS package’s scripting language (the fact that all major GIS packages have a scripting language is an acknowledgment of their weak user interface). Modules have been developed for forest management, political redistricting, bus routing, etc. This section can be thought of as an effort to build an urban design module.

There are five components to the construction of this system. First, it must be decided what are the important things to know about a city in order to understand it (Kevin Lynch proposed that a city’s edges, nodes, paths, districts and landmarks must be known). Second, we must create computable algorithms for the identification of these “important things”—Rowe’s descriptive model. Third, the user interface must strike a balance between simplicity and flexibility. Right now, GIS user interfaces err on the flexible side, allowing a multitude of operations if the user can figure out how to perform them. A GIS for urban design should be easily employed by an urban designer, so beyond the creation of functions with specific application to the urban design field, an interface should be created which maximizes the ability of the designer to explore the study area.

Fourth, an urban design module must be flexible in terms of the definition of algorithms. Urban design is different from most disciplines that use GIS in that there are few generally accepted procedures that are implemented the same way in every situation. Defining the “important things” that must be known about a place is an issue that many people have an opinion about, but no official body, like the American Planning Association, has set down any rules or even guidelines on this question. For example, we may think that an algorithm to find the shortest path from one place to another is an important tool, but a designer may think that the time or distance between two places is relatively unimportant to the design of an urban area when compared to issues such as safety, a feeling of home, etc. “Although attempts have been made to reduce design to completely explicit systems of search or synthesis, it remains an art, a peculiar
mix of rationality and irrationality. Design deals with qualities, with complex
c connec tions, and also with ambiguities" (Lynch, 1981). So an urban design
module must allow the user to create their own analysis tools, but in an easier
way than simply providing a scripting language that is closer to programming
than using an existing program. This last aspect will not be developed in the
context of this work because of the extensive programming required. Instead,
this work develops the system the way Lynch might have, and leaves the
creation of a flexible interface to further research.

Fifth and finally, an urban design or planning GIS must incorporate some
method of receiving input from the general public and organizing and
synthesizing this information graphically. The importance of including the
public in the planning process has been well documented, but decision makers
often exclude the public from the process by arguing that it is too expensive and
time-consuming to hold numerous public meetings and try to come to some sort
of group consensus. Information networking technology offers a forum for the
public which could overcome these arguments. A general framework for this
part of the system would include the provision of information to the public, a
way for people to make comments with text and pictures (possibly also video
and audio), a way for people to browse the comments of others and a way of
synthesizing the input to get an idea of the collective view on the issue.

The scope of this work is to lay out all of the issues concerned with GIS and
urban design, but to only go into depth on a small number of them. This section
presents a prototype of the descriptive component of an urban design GIS. More
specifically, it looks at how patterns in the landscape could be explored, it takes a
detailed look at how to model Kevin Lynch-type nodes and discusses in broader
terms how the other elements of Lynch’s legible city might be modeled.

1 Lawrence Susskind and Mike Elliott, “Paternalism, conflict, and co-production: learning from
citizen action and citizen participation in Western Europe,” 1983.

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The Database

The database used for this project consists mainly of basic information that is usually readily available to city planners and consultants. Streets, parcels, building footprints and aerial photography are crucial data sources for municipal engineering and planning activities and are increasingly being maintained in digital format. Many states have already implemented programs to produce digital, high resolution, georeferenced aerial photographs of the entire state, so this will increasingly be an inexpensive and rich data source for local planning efforts. To complement these data that describe the physical properties of the city, Decennial Census data is used to gain insight into the demographic characteristics of the city. These data are made available by the U.S. Census Bureau in digital form on CD-ROMs and on the Internet,¹ but even more significantly, many institutions have begun offering preprocessed versions of the data,² making the data source much easier to use by more people.

A short description of the key data layers is presented here while detailed source information can be found in Appendix B: Data Dictionary. The data layer used to represent street areas here actually consists of the area comprised of streets and sidewalks. No more detailed data set covering the entire city could be found for these features. The building footprints data layer represents the outlines of buildings as they would appear from an aerial view. No height information was included and in many cases, multiple buildings are represented as a single shape because of their proximity to one another. Parcels were obtained from the City of Boston, who created this data set for tax assessment purposes. Parcel-based data included land use, building value and land value. Aerial photography came from MassGIS, the Massachusetts agency responsible for compiling and disseminating state digital data. The photographs have a half-meter resolution and are geographically referenced and orthorectified, meaning that the picture has been

¹ U.S. Census Bureau data is at http://www.census.gov/cdrom/lookup

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adjusted to compensate for elevation and the angle of the photograph. This is done so that the viewer seems to be looking straight down on the scene and to maintain accurate sizes and shapes. Census data was simply downloaded from the Internet using the U.S. Census Bureau’s service. All 1990 Census data is available in this way.

These five databases—streets, parcels, building footprints, aerial photographs and Census data—will be used in conjunction with local knowledge to generate an “understanding” of the urban environment. This understanding will be different depending on the needs and personal characteristics of each individual planner. In this work I use Kevin Lynch’s model of understanding the urban environment as described in Image of the City. Although I use this model as an example, the real strength of this application will be its ability to be customized to process any designer’s model of the city.

**Pattern Finding**

Landscape abstraction should transcend traditional human understanding of the physical world, and most importantly extend the limit of our perception of reality.

Perron and Miller, 1991

I consider pattern finding to be a key aspect of any sketch planning GIS. Every designer will want a slightly different set of tools, but the ability to recognize and explore spatial patterns will be included in some way. This function, in its simplest form, takes thematic data sets and allows the user to combine them in various ways. For example, the user can quickly calculate and view all places that are predominantly residential, urban, run down, with a high rate of unemployment and comprised largely of non-native English speakers. This is accomplished by combining demographic, land use and city assessor’s data. The utility of finding patterns is not the main focus here, but rather the ability to

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quickly process pattern finding requests that bring together multiple data sources.

“Blind” pattern finding

One of the most important functions of this system is to be able to find patterns and trends that a person might miss because the pattern is too subtle or because it is based on the synthesis of many data sources. Thematic maps only clearly show how one variable changes across space. In Figure 8 we can see how unemployment clusters and disperses, but we don’t see how it relates to other spatial and social factors, such as roads, power lines, education, etc. We could draw some of these elements on the map, but it would quickly become too cluttered to be of any help in understanding the environment. The thematic map’s strength is breadth, while the site visit’s strength is depth. A planner visiting a site would quickly synthesize many types of information in their head. The planner might be in a neighborhood with housing in poor repair, from which he might assume that the properties were mainly owned by absentee landlords. Seeing many working age people on the streets the planner might infer that unemployment was high. Although a great amount of detail is gained by being on site, the big picture is lost. This person can only have a very general idea about the proximity of public transportation, the percentage of non-English speakers, or the number of banks within walking distance.

So then the goal here is to create a tool which offers the designer more depth. The obvious way to accomplish this is to add multimedia elements to the GIS such as pictures, video, etc., but the amount of time and effort required to put develop that type of audio/visual database is too great. Instead, I try to create a greater depth of knowledge by allowing the user to quickly find areas that meet any number of conditions from any number of data layers.

This is a task to which GIS is well suited because of its ability to overlay spatially referenced data sets and contrast and compare their attributes. The way this is often done in GIS analyses is to choose a number of data sets, perform the
overlay, and then classify the resulting data set’s values into a thematic map. I did not want to use this method because it seems to presuppose a knowledge of which data sets to overlay and what value will be important in the end. Instead, I start with a place of interest. The user can find out everything about the place (limited only by what data sets are available). Then the user can find other similar places throughout the city. All of the intricate overlay commands are transparent to the user, so that they can concentrate on the exploration process.

In order to combine these ideas into a prototype pattern finding application, it was necessary to predict certain modes of operation for the hypothetical user—two are presented here. The first assumes that the planner has in-depth knowledge about one place—usually an street corner or a parcel, and wants to find out the underlying characteristics about this place as well as other places that have similar characteristics. The second is not based upon any one place. The user is allowed to enter any characteristics of interest and see how they compare.

The place-based method is modeled by having the user select a building in the area of interest. The program then allows the user to select any of the themes present in the database that is of interest to the analyst. In Figure 9a the user has selected population density. The next step is to decide what range of population density is important. The value at the location of the building (109.98) is given as a starting point, but the user decides that 100 is a better minimum value. The maximum value is chosen in the same manner, and then additional themes may also be added to the pattern. After all of the parameters are entered, the program finds all areas in Boston that meet all of the criteria.

In this way, information about one place can be used to help the user find other places that are likely to be similar without having to study every acre of the city in detail. This proves to be a very stimulating method of analysis, especially when places with similar characteristics turn out to look quite different “on the ground.”
The non place-based method is similar to the place-based method, but the conceptual goal is quite different in that the user's interest is not focused on one specific place, but on a specific set of characteristics. The GIS aids the user in choosing a range of values for each characteristic by reporting certain statistics such as mean, maximum, minimum, standard deviation and quantiles.

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These explorations become iterative when the designer takes the results of an analysis (which the program allows to become another data layer) and refines or expands that exploration path by further restricting the limits of a query or adding another query element or intersecting two separate analysis paths. As all the query results can be saved as spatial layers, they are all available for use as inputs into subsequent analyses. For example, the result of an analysis that finds areas that are sensitive to real-estate speculation might be important in studies of economic development zones, road and utilities upgrades, rent control, etc.

**Inverse Analysis**

This section focused on creating diagram-like representations of a complex reality so that the urban landscape would be more easily understood. It would also be useful to be able to start with a diagram and have the computer compare that abstraction to a real place. This could be used as an evaluation test of how well a plan was implemented, or a way to measure how much work it would take to go from the present situation to the urban form suggested by the diagram.

Blind pattern finding can be a powerful exploratory tool, but the designer often wants to start with a certain geographic boundary and understand what makes the area within the boundary different from the area without. This is not really pattern finding but pattern understanding, because what you want to know is why the pattern that has been observed exists. The amount of programming necessary to prototype this concept is beyond the scope of this work, but it is
important to keep in mind because it represents the beginnings of a predictive, or planning model which would go beyond simply describing a place.
Figure 9: Place-based pattern finding

(a) the user interface

(b) Places similar to a building in the Mission Main public housing development
Figure 10: Blind Patterns
Horizontal hatching: Areas vulnerable to commercial real-estate speculation
Cross-hatching (lower right): The same areas with over 50% Black population
Designing like Lynch

This section presents a prototype of how an urban design GIS might look for a particular designer, Kevin Lynch. The pattern finding applications discussed above are functions that most designers would consider a boon to sketch planning. Here we look at a specific group of functions based on the ideas Lynch presents in *The Image of the City*. The purpose is not to recommend Lynch’s theory over any other designer, but to show that design techniques that currently are developed using the designer’s “intuitive ability to organize physical form”¹ can be implemented in a GIS where they can be informed by the data, knowledge and experience accumulated by others. Some aspects of Lynch’s model have been developed more than others, but a great deal has been operationalized. Sometimes the desired data does not exist (a notable omission is mentioned under the section on Paths) and sometimes the algorithms needed are very complex (see Nodes), but this prototype shows that there is no longer a technological barrier to creating a GIS that would benefit urban design.

Kevin Lynch, in *The Image of the City*, looks at the city as a place where many aspects of physical form and land use are controlled by individuals and not by centralized government, resulting in an environment which is constantly changing over time. Within this framework, however, there is a function for the city planner, and that function is to create an environment where residents can take emotional ownership over a large part of the city. Outside of this area that they think of as “theirs,” there should be no consternation associated with navigating around the rest of the urban landscape. This vision of the city contains familiar, private home neighborhoods, lively commercial and civic centers, and navigable and easily identified paths between all of these districts. These building blocks of the urban environment are called nodes, paths, districts, edges and landmarks.

¹ Christopher Alexander, *Notes on the synthesis of form*, 1964, p. 11. Also see page 11 here.
Lynch argues that understanding the city in this way will help planners be able to plan cities that work better for their inhabitants, but in his 1985 reflection on the book’s impact, he is disappointed with the way his work was used. With his work in hand, planners felt that they could find these patterns on their own, with no resident input, when Lynch’s theory was that the location of these nodes and boundaries of these districts must be ultimately defined by the public. This is why a system of sharing experience (discussed at the end of this section) is critical to the success of this model. While the physical environment will offer clues to the image of the city, the computer can not know how safe people feel on their street, or how many neighbors and shopkeepers they can identify by face. This information must come from individuals having input into the system, and this issue will continue to be discussed throughout the paper.

Nodes

Nodes are points, the strategic spots in a city into which an observer can enter, and which are the intensive foci to and from which he is traveling. They may be primarily junctions, places of a break in transportation, a crossing or convergence of paths, moments of shift from one structure to another. Or the nodes may be simply concentrations, which gain their importance from being the condensation of some use or physical character, as a street-corner hangout or an enclosed square. Some of these concentration nodes are the focus and epitome of a district, over which their influence radiates and of which they stand as a symbol. 

*The Image of the City*, pp. 47-48

So nodes are either notable intersections of paths or concentrations of activity. In fact, these two definitions are self-reinforcing, as centers of activity often develop at important intersections, and paths are often created to service major nodes.

In Boston’s South End, the Boston Center for the Arts (BCA) intersection (Figure 21B) is a neighborhood node. The BCA is a multi-purpose facility where art classes and exhibitions are held and artists lofts and studios are located. The block containing the BCA is on the north side of Tremont Street, with a small theater next door and a music school and a parking lot behind. Across from the
BCA and along Tremont heading southwest are a number of small businesses including coffee shops, restaurants and antique stores. The Tremont/Berkeley Street intersection is a heavily traveled automotive path, with commuters on their way to and from the Massachusetts Turnpike and Interstate 93. Pedestrians from the surrounding residential areas use Tremont Street as a destination (for its cultural and commercial offerings) and as a path to downtown Boston, located north and east of the node. Many children are also seen in the area, as a number of schools are within a three block radius.

It is easy to picture a typical day in this node, with people hurrying to work and school in the morning, adults grabbing coffee and breakfast along the way and everyone avoiding the cars speeding along the streets towards the downtown office buildings. Mid-day is quieter. Those who are fortunate enough not to have to work visit the art exhibitions and stop in for a long lunch at a local café and maybe browse the antique stores, hoping for a great find. The afternoon brings a flurry of street activity as school lets out, and before you know it dinner is being served at the restaurants. The area may remain lively well into the evening if there is an art opening or a play that night.

This knowledge is a result of many visits to the area over the course of a three-month investigation of the neighborhood. The task here, however, is to identify this node solely through the use of our database (local resident input will be added to the system later). Earlier, nodes were defined as intersecting paths and/or centers of activity. Every street is a path—although paths do not have to be streets, but there are too many street intersections for this to be an unqualified definition of a node. Each may be a node in a micro reading of a site, but here we are concerned with neighborhood/city scale. Therefore, the following conditions will lead to a more accurate attribution of the term node for urban planning.

A place may be a node if it is situated along a major street. Major may be defined in an urban setting as a street of at least four car widths. This translates at the minimum into one lane of traffic in each direction, with parking on both sides.
Sidewalk width is also important, as it influences people's ability to interact with each other in this public setting (sidewalk data is unfortunately often neglected in the construction of an urban database).¹ The node is further strengthened by having a nearby intersection with another active street, Berkeley Street. Street activity may be difficult to define in a database because narrow streets like Berkeley Street can be very active. Adding traffic count data to the street network would greatly enhance our ability to understand street dynamics with a GIS.

Nodes are also defined as concentrations of activity. This concept can be applied to a GIS by finding areas where multiple land uses come together. Ecologists have found that the areas of greatest diversity in animal and plant species occur where different land uses meet.² Wetlands are so important because they are the transition area between forests, fields and water. Being rich in food sources they also attract animals from the land, air and water. The same theory can be applied to the human species. Because of the varied needs of people, the greatest level of activity will be found in areas that service the greatest number of needs. The BCA is coded as commercial land use with institutional uses found to the west and east. Residential areas surround these public uses, which is crucial because public areas without nearby residential districts become ghost towns at night and on weekends.

One important characteristic of the area which is not reflected in the data is that the buildings on Tremont Street generally have commercial uses on the ground floor and apartments above (Figure 21A). The 1:25,000 land use database, however, codes these buildings simply as residential. A mixed use classification or a data structure which supported more than one classification for a given location would be more appropriate here, as is supported by the parcel-based land use data set. Agencies have resisted mixed use classifications because if you have 20 classes and you allow for each to be crossed with every other, there are

400 possible combinations. With 400 classes, the land use map is no longer significantly less complex than the real world, so once again you may need a GIS specialist in order to make sense of it. Agencies that create the database should be able to build in multiple levels of detail into a database either with a different data model than currently exists\(^1\) or with a different interface to the data than currently exists. The end user then has the freedom to choose the level of detail they need to complete the task at hand. The parcel-based land use data set offers a rich classification scheme (see Appendix B: Data Dictionary), but any aggregation must be performed by the user.

So this node can be generally defined as follows:

- it is on a major street
- the sidewalks on the major street are wide
- it is near the intersection of two busy streets
- many land uses meet in this small area
- residential areas are nearby
- commercial and institutional uses are present

**Finding nodes in the GIS**

The above specifications serve to define a general idea of the kinds of conditions that the GIS must identify. The next step is to create an *operational* definition of node which will lead to the formulation of an algorithm that will allow the designer to tell the computer, “find nodes!” The form of this algorithm, as stressed throughout this paper, is something that is unique to each user. Using the above specifications as a guide, a number of algorithms are tested here in an attempt to simulate the *modus operandi* of an urban planner.

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\(^1\) One GIS application, Arc/Info, has implemented a new data model called the REGION data model, which attempts to address this issue.
Starting from the assumption that the area around urban nodes must include commercial, residential and institutional uses, I use an algorithm (Figure 11) that searches the land use data set (Figure 12) in a 500-foot radius around every cell for different land uses. If the aforementioned three land uses are not present, then the point can not be a node. If they are present, the point is ranked in comparison to other nodes based upon how many different types of land use are present in the area. Next, since I am in the experimental stage (i.e. not yet at the point where I have decided upon only one way to find nodes), I perform the same analysis again using a 260 foot search radius (Figure 16), and then once again using a 1,000 foot search radius. I see that the 1,000 foot radius is to be too large because it searching an almost half-mile diameter area, which is too large to be considered a single place in this urban context, but the other two searches seem to hold promise.

During the course of this research (as often happens in real life) a more detailed source of land use data became available, so I am able to run the same 500-foot and 260-foot search radius analyses using parcel-based land use with an intermediate classification (Figures 17 and 18) and with a highly detailed classification scheme (Figures 19 and 20). The difference between the intermediate and detailed classification schemes is not only the number of categories, but also the purpose for which the categories were created. The intermediate scheme was one that came with the database (Figure 13)—it could have been geared towards tax assessment, utility maintenance, or something else. The detailed scheme was developed specifically for this study (Figure 14). This can be seen in the category labels to the left of the maps.
Figure 11: The Node finding algorithm

DESCRIPTION: The key function in the node algorithm is “focalvariety”, an ARC/INFO GRID function which finds the number of different values in the given radius of a point (illustrated below). GRID is the Arc/Info GIS’s raster spatial analysis module. Shown here is the flow chart for creating nodes from the coarse land use data.

† Description of the FOCALVARIETY algorithm

<table>
<thead>
<tr>
<th>input</th>
<th>output</th>
</tr>
</thead>
<tbody>
<tr>
<td># = land use code</td>
<td># = number of uses within a 1 cell radius of cell</td>
</tr>
<tr>
<td></td>
<td># = NODATA</td>
</tr>
<tr>
<td></td>
<td>NODATA</td>
</tr>
</tbody>
</table>

```
find variety of uses in a 500' radius
find variety of uses in a 260' radius
find variety of uses in a 260' radius
find variety of uses in a 500' radius
```
The process I used to evaluate the success rate of finding nodes at this initial stage was to simply see if the found nodes coincided with Lynch’s study (Figure 4) and my knowledge of downtown Boston. The area of the city most Bostonians are familiar with consists of the Fenway/Kenmore, Back Bay/Beacon Hill, South End, and Central neighborhoods (Figure 23: City-defined Districts). There were three nodes here that I used as benchmarks, Kenmore Square, The BCA corner and Newbury Street.

Kenmore Square is a major city-wide node (Figure 21C). The roads coming together here are eight lanes wide in some sections. The effect of this is mitigated by a strip of useable area separating the two directions of traffic. Most of this strip is used as a park, but near the actual intersection there is a bus and subway station in this zone. The many diverse businesses include restaurants, music stores, a funeral parlor, the Boston University Bookstore, nightclubs, convenience stores, clothing stores and coffee shops. These are supported by Boston University, apartments and hotels, the baseball park, and a nearby street that serves as “nightclub row.”

The BCA corner is a more subtle, neighborhood node. Only people who live or work in the South End are likely to frequent this area. Exceptions are those who are coming to the BCA for an event or in their car cutting through the South End on their way to the highway. The nature of the stores reflect this. They are mostly convenience stores, small restaurants and dry cleaners. Newbury Street is another major node, but it is different in that it is linear. The street is lined with shops that appeal to tourists and the wealthy, as well as eating places for locals.

The areas found with the 1:25,000-scale land use and a 500-foot search radius included the three test nodes mentioned above, but many other areas were also

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1 I weighted my experience greater than Lynch’s because his sketch plan reflects the city in the late 1950s. This area is still the heart of the downtown though, so his analysis has relevance today.
found. These did appear to be more active than the areas that were not found, but there was not enough of a distinction between places for the operation to be useful. Also, although the test areas were found, they were ranked lower than areas that are actually less active. Searching a 260-foot radius reduced the amount of area selected, but did not help in better identifying actual nodes. Similar problems resulted from the analysis using parcel-based land use and the intermediate classification scheme. Too much of the city was identified as “node-like” and the ranking of areas did not correspond well to the actual distribution of activity. This is a result of the classification scheme having little relation to urban design issues (Figure 13). The only category that was not residential, commercial or institutional is industrial, and what this categorization scheme emphasizes is the differing densities of residential areas. Although it may seem obvious that this description of land use would not be useful, I wanted to run the analysis with it to show how important the base data and categorization is to obtaining useful information.

The detailed classification scheme includes a number of important disaggregated land use categories. Institutional use is separated into schools, hospitals, library/museum/galleries, religious and other. Industrial use is separated into light industry, manufacturing and utilities. Commercial use is separated into retail, hotels, restaurants/bars and offices. These important differences in land use allow the node finding function to create highly descriptive and useful nodes (Figures 19 and 20), although this data set did not identify the BCA node. The major difference between the 500-foot and 260-foot detailed land use nodes is the size of the area identified. It seems that concentration of activity is better represented by the 260-foot search radius, but the data is not accurate enough (or the node finding function is not fine-tuned enough) for this search to work as well as the 500-foot radius search. In other words, the 260-foot radius is closer to the actual size of a node, but we must find larger, more general areas because even the parcel-based land use data set has drawbacks. For example, the BCA node was not found in large part because the land use data does not classify the
buildings along Tremont Street. For some reason these areas were left out of the data set.

Once the algorithm was fine-tuned and studied in the lab as described above, I was ready to investigate the nodes that had been found in other parts of the city. This two-step process of building theory and associated algorithms in the office and then field-checking the theory reflects the general idea that the GIS should allow the designer to apply their knowledge about a small area to the entire city. I used my knowledge of downtown Boston to formulate an algorithm that would identify areas I consider nodes and then the algorithm applied that concept to the rest of the study area. In fact, the algorithm was extremely successful in performing this task, although this success is difficult to prove because design methods are inherently difficult to quantify. A photographic presentation (Figure 21) of the nodes is the best way to describe them without labor-intensive pedestrian and traffic counts or video. All photographs were taken between 9:00AM and 5:00PM on weekdays.

**What this means to the designer**

The nodes study shows that information regarding how people move about the city can be obtained from seemingly static data. The data has been transformed from a description of land uses with their associated areas and spatial relationships to a story telling where people frequent and how busy certain places are in comparison to others. Operational analyses of the concepts of district, path, edge and landmark are not developed fully here but the basic theory is the same. The digital data sets that are currently being developed hold a wealth of information for urban designers—the functionality needed to transform raw data into objects useful to designers, like nodes, just has not yet been invented.

The difficulty in creating the node finding algorithm had more to do with data and computing resources than with conceptual issues. Without the parcel-based land use data set, this study would not have been successful. This is significant
because very few cities have developed digital data sets at this level of detail, but
detail is crucial to studies of the urban environment. Computing power is also an
issue. This analysis would not have been possible with the kind of computing
power currently available in personal computers. UNIX workstations were used,
and even then it was only feasible to analyze a portion of the city, which itself is
only a portion of the metropolitan area. Progress in the detail of data sets and
computational power will make experimentation in this area much more
practical in the future.
Figure 12: The BCA node as described by the 1:25,000 land use data set
Figure 13: The BCA node as described by the parcel-based land use data set with an intermediate classification scheme.
Figure 14: The BCA node as described by the parcel-based land use data set with a detailed classification scheme.
Figure 15: Nodes derived from 1:25,000-scale land use and a 500-foot search radius.
Figure 16: Nodes derived from 1:25,000-scale land use and a 260-foot search radius

LEGEND
- 4-5 land uses
- 5-6 land uses
- Buildings
- Streets

Scale 1:18000
0ft 1000ft 2000ft 3000ft
0km 1km
Figure 17: Nodes derived from parcel-based land use with an intermediate classification scheme and a 500-foot search radius.
Figure 18: Nodes derived from parcel-based land use with an intermediate classification scheme and a 260-foot search radius.

LEGEND
- 3-6 land uses
- 7-12 land uses
- 13-14 land uses
- Buildings
- Streets

Scale 1:18000

Legend values:
- 3-6 land uses
- 7-12 land uses
- 13-14 land uses
- Buildings
- Streets
Figure 19: Nodes derived from parcel-based land use with a detailed classification scheme and a 500-foot search radius

LEGEND
- 4-8 land uses
- 9-13 land uses
- 14-17 land uses
- Buildings
- Streets

Scale 1:18000

0ft 1000ft 2000ft 3000ft

0km 1km
Figure 20: Nodes derived from parcel-based land use with a detailed classification scheme and a 260-foot search radius.

LEGEND
- 3-6 land uses
- 7-10 land uses
- 11-14 land uses
- Buildings
- Streets

Scale 1:18000

N

0ft 1000ft 2000ft 3000ft

0km 1km
Figure 21: Photographs of nodes around the city

(A) Dudley & Warren
(B) The BCA (Tremont & Union)
(C) Kenmore Square (Commonwealth Avenue)
(D) Downtown Crossing
(E) Centre and Buckford
(F) Uphams Corner
Figure 22: Key to the Nodes Photographs
District

Districts are medium-to-large sections of the city, conceived of as having two-dimensional extent, which the observer mentally enters "inside of," and which are recognizable as having some common, identifying character. Always identifiable from the inside, they are also used for exterior reference if visible from the outside. Most people structure their city to some extent in this way, with individual differences as to whether paths or districts are the dominant elements. It seems to depend not only upon the individual, but also upon the given city.

*The Image of the City*, p. 47

The easiest way to explain the concept of district is by example. In Boston, the South End, the North End, Back Bay and the Financial District are obvious districts. New York has Greenwich Village, Soho, Wall Street, Harlem and countless others. Although specific boundaries may be hard to agree upon, the general existence and location of most districts are easy for residents to acknowledge.

A useful distinction can be made here between a neighborhood district and a physical district. Defining neighborhood districts using digital data is difficult because the boundaries may be based on historical events, informal gang (south-central Los Angeles) or politician-controlled areas, elevation (Beacon Hill, Boston), etc. Some of these factors have some physical form and can therefore be captured in a GIS, but some will not. Furthermore, physical form may lead the designer into misclassifying a neighborhood. For example, Boston’s South End crosses over Massachusetts Avenue, a street so wide that planner unfamiliar with the area would assume that no neighborhood could cross that barrier.

The issue of defining districts for Boston was aided by the fact that one of the data sets available specifically addresses this issue by outlining and naming the eighteen neighborhoods of the city (Figure 23: City-defined districts). An interesting use of the inverse pattern finding application described at the end of this paper would be to take one of these neighborhoods and ask what is different about it as compared to the rest of the city, or adjacent neighborhoods. In this
way the accuracy and usefulness of the neighborhood data set could be evaluated. Districts are an important macro-level concept of neighborhood, but micro-districts are also crucial to a sense of comfort in the city. These districts would be a number of blocks, rather than a section of the city. This is the area in which many of the faces should be familiar. Christopher Alexander describes this as Pattern 14: Identifiable Neighborhood, which says, “People need an identifiable spatial unit to belong to.”\(^1\) The district as Lynch defines it would be a closer match to Pattern 12: Community of 7000, which states, “Individuals have no effective voice in any community of more than 5000=10,000 persons.”\(^2\)

Alexander’s definition of community is reflected in the dividing up of Boston into wards, the smallest political unit in the city. Neighborhood boundaries can be explored using traditional thematic mapping techniques. The three districts generated in Figure 23 are shaded by taking the minimum and maximum values for the attribute in question (median family income, percent Asian and percent Black) and dividing that range into four equal ranges. The Back Bay/Beacon Hill area is home to the only city residents whose average income is more than the city’s average of $35,532 (Figure 23: A high income district). Boston’s Chinatown district appears clearly by classifying the city by percentage Asian population. Only the small Chinatown area has a greater than 50% Asian population in each block group (Figure 23: An Asian district). Similarly, Blacks seem to be concentrated in Roxbury and Mattapan.

\(^1\) Christopher Alexander, *A Pattern Language*, p. 81.

\(^2\) ——, p. 71.
Figure 23: Identifying Districts

City-defined districts

A high income district

An Asian district (Chinatown)

A Black district

Median Family Income ($)

0 - 17705

50 - 70
70 - 100
100 - 175
175 - 250
250 - 375
375 - 750
750 - 1,000

25 - 50
50 - 75
75 - 100
100 - 125
125 - 175
175 - 250
250 - 375
375 - 750
750 - 1,000

Districts:
- High income
- Asian (Chinatown)
- Black
Path

Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads. For many people, these are the predominant elements in their image. People observe the city while moving through it, and along these paths the other environmental elements are arranged and related.

The Image of the City, p. 47

Roads and transit lines are easily included in a GIS, the difficulty comes in classifying them according to use. Road width is one way to obtain a rough idea of how heavily used a street is for vehicular traffic, but this is only one type of path. Jacobs suggests that the number of intersections one street has with others is a good indicator of how busy and interesting a street will be because more intersections implies a greater potential to be part of the route to more destinations. For example, one would only find people who are going somewhere on that street on a long street with no intersections.

Since paths are channels along which people customarily move and nodes are places at which people customarily meet, it is logical that people will customarily move from node to node. This suggests a different method of defining paths. Instead of going back to the original data sources to model the path concept, it can be constructed from the nodes model. This theory works particularly well for Newbury Street (along the northeastern portion of Figure 20). This street is used by many go from the western part of downtown Boston to the financial district in the northeast. It is more frequently used than the completely residential streets to its north because it offers the opportunity to see more people, have a snack or window shop.

Apart from being a connection of nodes, the classification of paths proved to be the most difficult concept of Lynch's to model. Transportation data is rarely very detailed, due to the time and expense associated with pedestrian and traffic

1 Allan Jacobs, Great Streets, 1993.
counts and classifying a street as a single unit when its name may change along its route. Because of this lack of helpful data sources, this is one area in which I do not foresee GIS being immediately helpful to urban design.

Edge

Edges are the linear elements not used or considered as paths by the observer. They are the boundaries between two phases, linear breaks in continuity: shores, railroads cuts, edges of development, walls. The identification of hard edges may clearly be aided by GIS. Many times a district will be constructed using one type of data (demographics) and the edge will be formed by another (streets, rail lines, water features). The overlay and intersection capabilities of GIS allow this type of analysis to be performed in a straightforward manner. That addresses the question of hard edges, but Lynch also identifies soft edges, which he calls seams. Soft edges separate distinct regions but have no easily observable edge element.

Soft edges can be roughly identified with GIS because edges must be defined in the creation of any vector-based data set. For instance, the Census data used was based on block groups. These are usually two to four city block areas that U.S. Census Bureau researchers have decided are similar enough to aggregate into a block group. The 1:25,000 land use data set also required a trained professional to decide where one area ended and the next began. This was not a problem with the parcel-based data because lot lines served as the edges.

Landmark

Landmarks are another type of point-reference [like nodes], but in this case the observer does not enter within them, they are external. They are usually a rather simply defined physical object: building, sign, store, or mountain... They may be within the city or at such a distance that for all practical purposes they symbolize a constant direction... They are frequently used clues of identity and even of structure, and seem to be increasingly relied upon as a journey becomes more and more familiar.
Finding landmarks would be one of the most difficult tasks for a traditional GIS. As directional guides, they are often taller than other landscape features, which makes them difficult to distinguish with data sets that rarely include object heights. Many objects become landmarks because they stand out from their surroundings in other ways, like appearance, and this characteristic is also rarely captured in a database.

The best way to identify landmarks is through resident input. In fact, one of Lynch’s main points is that all of the preceding elements of the city should be identified using the experience of the people that define them through their daily activities.

**Information Sharing**

The reader may have noticed that in the references to the text of *The Image of the City*, Lynch usually defines the elements of the city in terms of an observer. The point is that the designer can not understand an urban landscape only through his or her own observation—it is an understanding of how residents observe their city that counts. Urban design and planning differs greatly from many other sciences in this way. Environmental scientists can not ask herons whether they are comfortable with the current size of their habitat, or whether the construction of a proposed road would keep them from using a nearby wetland. The input of residents has long been considered crucial to the formulation of good design plans, but decision makers rarely get this valuable information because it is perceived to be too time-consuming to get the opinions of a large number of people.

Lynch put forth the effort to interview individuals, but each interview took at least two hours, so his technique could not be considered an implementable model in the context of a city government working within a limited budget. Advances in networking technologies and electronic communication should
make the collection and analysis of public opinion on local issues more common, but research on integrating GIS and public input is still in its infancy.

Lynch asks four questions of his interviewees. Draw a sketch map of the area showing interesting and important features, sketch the route and events along an imaginary trip, list parts of the city felt to be most distinctive, and describe where a few objects are located. Instead of sitting down with a person and asking these questions, they can now be asked and answered with a computer. As we may soon reach the point in America where a large and diverse portion of the citizenry could be reached through electronic networks, Lynch's technique should be revisited with these new tools in mind.
IV. An Application to Urban Redevelopment

A concept of how an urban design GIS might work to help build a descriptive model of the city has now been presented. The question of what this means to the formation of policy and design interventions has not been addressed intentionally because those questions are beyond the scope of this model. As mentioned in the literature review of environmental modeling, I feel that too often models are constructed as decision making tools instead of decision support tools. The actual decisions must be made by the individual planner or planning agency, and any attempt by the GIS to guide the final decision is risky, as it may lead to a narrowing of possible options too early. This section will look at a current redevelopment proposal for a public housing project and describe what can be learned about the housing development using the model that has just been built.

Redevelopment Objectives

The objectives of the design guidelines are:

1. Build a minimum of 535 public housing units within a larger mixed income community. These units must be built to a high standard of quality and designed to current standards for family housing.

2. Reorganize the site to create a typical urban family housing neighborhood, one which cannot be readily recognized as “public housing”, one in which design promotes sustainable safety, and one which is integrated into the urban fabric surrounding it.

3. To the largest extent possible, this redevelopment must address edge conditions around the site which could compromise or threaten the long term viability of the new community.

4. Maximize this unique opportunity to coordinate the efforts and resources of different city departments and non-profit agencies including, but not limited to the BHA, MMTTF, BRA, Public Facilities Department (“PFD”), Police Department (“BPD”), Parks and Recreation Department, Community Centers, School Department, Department of Public Works, Transportation Department, Public Library, MBTA, the Mission Church, Medical Academic and Scientific...
The design guidelines are presented here by the owner, the Boston Housing Authority (BHA), to prospective developers. Although they are for a specific housing project, they reflect the current thinking in how to make public housing work. Major design issues center around supporting mixed incomes, making appearance similar to private housing, and encouraging safety through design (this concept has been put forth by Jane Jacobs as "eyes on the street").

Site analysis

Design objective one

Here the BHA requests that a large number of public housing units coexist with market rate units. Since public housing is only made available to very low income families, this means that people with incomes that allow them to purchase market rate housing will live next to people who have almost no income. Incomes are detailed in census data, but the lowest level of aggregation is the block group, which covers at least a few city blocks. A unit by unit analysis is therefore not possible with census data. The parcel database affords a better resolution for analysis, but the only data available is land use, land value and building value. An analysis can be attempted by looking at residential building values and finding places where a wide range of values are near each other (Figure 24), but building value is still a poor surrogate for income, which is the stated criteria.

Ideally, the urban design GIS could offer the planner insight into creating mixed communities with the pattern finding application if unit by unit income data were available. One procedure would be to find neighborhoods in which the desired range of incomes were present. The planner could also specify what percentage of the community should fall within certain income sub-ranges. After places that met the criteria were identified, other household characteristics could be studied such as rent, education, place of birth, length of occupancy, building age, parking, distance from public transportation, etc. to further develop an understanding of the composition of a viable mixed income community. As mentioned, this analysis can not be performed well given the current level of detail in census data, but it may be redundant anyway, as the fulfillment of objective two may be the catalyst for the fulfillment of objective one.

**Design objective two**

The main thrust of this objective is to create a development in which urban form and demographic characteristics blend into the larger community (the safety objective will not be addressed here because safety-related information is not part of the database). Most public housing projects currently follow the design ideology in fashion during their construction in the 1960s and 1970s. They are developments consisting of large, tall, unornamented, multi-family buildings with a great deal of public open space around them. Organic neighborhoods in Boston are townhouses with back alleys that can be used for parking or gardens and façades that come right up to the sidewalk, with a small zone for a stoop and landscaping. Units face streets, which are used by the general public. The streets are narrow, which slows down vehicular traffic and makes the street safer for pedestrians. Most residential buildings are three to four stories tall with none being higher than four and one half stories.

Understanding the difference in urban form is straightforward. Simple visual observation shows a marked difference in building form in plan (Figure 25) and in perspective (Figure 26) between public housing developments and
neighborhoods that have formed organically. The planned developments are the antithesis of the organic ones. Residences rarely face the street and public areas relate to the entire development instead of to any one residence. There are few streets in the developments (Figure 27), so no one passes through except people connected to them. South of Mission Main, organic development takes a less dense form as we move away from the city center. There are many neighborhoods of single family homes of one and two stories along with triple-deckers.

Although visual analysis works well here to identify the difference in urban form, an urban design GIS should be able to quantify and operationalize this difference so that the designer gains a another understanding of the difference and so that their methods can be applied over larger areas. The difference in building form might be quantified using an area to perimeter ratio (area / perimeter). The mean of this ratio is twenty-eight for the group of institutional buildings to the northwest of Mission Main, nine for the residential area to the southwest of the development and twelve for the development itself. At first glance, this seems to suggest that a lower building to area ratio would better match the neighborhood, but once again, scale, resolution and the richness of the data set are important because a townhouse can have the same general shape as a public housing tenement, with the major differences being in the architectural detail, building quality, upkeep, number of units and location.

Contrasting the relationship of streets is more straightforward. The public housing developments rarely have streets in them, and when they do, these streets often dead end in the development. Organic neighborhoods contain more streets and they usually culminate in intersections instead of dead ends.

Small nodes seem to be another characteristic of organic neighborhoods, like the BCA node in the South End, but they are absent from the immediate Mission Main area. Two minor nodes can be found south and west of the development, but these are associated with other neighborhoods (Figure 27). If the “home
zone” of Mission Main residents could be expanded to include this area, this might not be a concern, but as it is, residents only seem to consider the development as familiar territory.¹

So three conditions have been identified whose spatial characteristics differ markedly in planned neighborhoods versus organic ones, building form, streets and nodes. Many others probably exist and each designer should be able to use the GIS to develop and quantify their own individual ideas.

**Design objective three**

Objective three addresses edge conditions. This will be a difficult task as land use data shows that the development is bordered mostly by non-residential uses, except to the south (Figure 28). The development is surrounded by colleges, hospitals, and their associated parking lots. This makes it hard to create a neighborhood environment as there are few existing neighborhoods with which to integrate. Street data shows that the site is also cut off from neighborhoods to the east by a wide transportation corridor.

A designer might begin to look at solving this “wicked” design problem² with the tools and methodology developed earlier. Nodes address the problem of the edge between residential and more public areas well, so here is one way in which the edge condition might be addressed. For argument’s sake, we begin with the assumption that the designer feels that it is important to create a node in the Mission Main neighborhood. There are presently no nodes in the area because land uses are largely limited to institutional buildings, their associated parking lots and public housing. The designer might explore the possibility of creating a node by inserting commercial, recreational and mixed uses in certain areas of the neighborhood, most likely addressing the edge condition by placing these uses

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¹ Statement of the Boston Housing Authority’s Mission Main coordinator.
² page 13.
on the northern and western edges of Mission Main (commercial establishments could attract the business of workers in the institutional areas).

By doing this in the GIS and running the node algorithm, a relatively objective judgment regarding the likely success of the design intervention can be generated. With these new land uses in place, the planner can say that given the development of certain areas in the manner described, a certain size node will be created. Other nodes of this size look like place X, place Y and place Z. There are a lot of assumptions in this scenario. Most significantly, the node finding algorithm must be accurate and nodes of certain sizes must be comparable, but at least a design methodology has been created which can be challenged, debated and refined, instead of a design proposal which seems to coalesce in the mind of the designer.

**Design objective four**

Objective four is to coordinate the activities of all government and private agencies that are working with Mission Main. I included the list of the agencies who would need to be involved to illustrate what a difficult task this would be. In order to accomplish this goal using traditional techniques, meetings would be needed with all of these agencies on a periodic basis. In practice, the coordination of activities is a rare event. This would probably require a great portion of someone from each agency's time every month, and then this person would still have to disseminate the information to the rest of the agency. The knowledge sharing functionality described in the previous section (III. Functional Prototype: Information Sharing) is perfectly suited to address this issue. This functionality was described as it would apply to the situation of a planner organizing input from the general public, but as agencies are only a subset of the general public, the theory is still the same.

The benefits of using GIS to address this objective are numerous. Everyone in each agency would have immediate access to everyone else’s latest updates to the database, the need for time and effort-consuming face-to-face meetings
would be reduced, and all the information would be accessible on any desktop with a computer and a network connection. In addition to these efficiency issues, sharing information in this way allows the designer to integrate everyone's information into analyses of the kinds described above. Using this system, more information is likely to be considered as part of the project, and the actions of agencies is more likely to coordinated.

Policy and design implications

In order to complete the picture of how these tools might be used, here are a few insights that the above study would support. This cursory site analysis leads to a few definite recommendations. First of all, in order to attract a mixed income clientele, Mission Main buildings should look similar to townhouses in the downtown area. It was mentioned that there is also a precedent for a less dense pattern of single family homes and triple-deckers. Although the argument could be made that the site is outside of the downtown area and therefore more similar to less urban parts of Boston, following this example would make it difficult to accommodate the required number of units on the site.

It will be difficult to integrate the development into the larger community because the site is largely isolated from other residential neighborhoods. Any efforts in this area should focus on connecting Mission Main to areas south of the development, the only direction which offers an opportunity for connection to a larger neighborhood. As the non-residential areas surrounding the development consist of major institutions (hospitals and colleges), there is little that can be done towards addressing edge conditions by changing the physical form of these places. It would make more sense to emphasize that edge and focus energy on connecting the development to southern and western neighborhood areas.
Figure 24: Identifying "Mixed" Communities
Figure 25: Urban Form in Plan View
Free Market vs. Public Housing (arrows point to public housing)
Figure 26: Urban Form In Perspective View
Free Market vs. Public Housing

(a) 1960s/1970s-era public housing (Orchard Park)

(b) A highly desirable pre-World War II-era high density free market neighborhood (South End)
Figure 27: Nodes around Mission Main
Figure 28: Land Use around Mission Main
V. Conclusions

_Sketch planning like Lynch with GIS_

It has been shown here that the data sources currently available for a major metropolitan area can be used to perform studies of interest to urban designers. Using one designer, Kevin Lynch, as a test case, a GIS was modified so that its basic functionality could be applied to modeling the spatial concepts Lynch presented in _The Image of the City_. Although every one of Lynch’s concepts was not fully prototyped, the work progressed far enough to prove that this area of research holds great promise.

It was shown how Lynch’s nodes, paths, districts, edges and landmarks could begin to be identified using structural clues and GIS, but the most important idea Lynch put forth in his work is that the people who live and work in a place have the best answers to many design questions. This part of his theory has been the most neglected by planners—Lynch says that his model was used as a way of further distancing people from the design process instead of making them a part of it. We have another chance to test his theory using new information sharing technologies that can integrate the designer, the design process and the citizenry. What is needed is an information system that can gather information from people on issues of concern to the design process, synthesize this input into some kind of shared understanding of the city and report back the results and allow for comments on these results (like the design process, the information sharing process should be iterative).

The premise of this paper was that if design concepts could be integrated into a GIS two benefits emerge. First of all, the designer can analyze a larger portion of the landscape because once their methods are operationalized and integrated into the GIS, computing power allows a relatively quick processing of as much of the landscape as exists in the database. This benefit was seen in the nodes prototype, where a GIS function for finding concentrations of activity was
developed based on familiarity with a small area of a city and then applied to the rest of the city database. Second, having a computerized information system will lead to new kinds of studies and working methods. The pattern finding prototype suggests a new way for urban designers to take a comprehensive look at how areas are similar and how they are different.

Designers should add GIS to their arsenal of analysis tools. However, new spatial analysis interfaces will be needed to attract this group of professionals to GIS, because their modes of thought are often non-linear and less rigidly structured than those who have already adopted GIS technology. Although progress was made in creating a "sketch plan" of the city, detailed data relating to the movement of people and vehicles would have been valuable because it could have helped to explain how people move from home to node and from node to node. It also could have helped answer some interesting questions that were raised regarding how similar areas in the city relate to one another.

This study has shown, however, that GIS analysis can play an important role in urban design. The pattern finding application stimulated a great deal of exploration and discussion among the planners that tested it. The node finding application proved to be a powerful tool, as it accurately located the busiest areas in the city using only a detailed land use coverage and a well thought out algorithm.

**Creating an urban design GIS**

This paper has looked at ways to improve the quality, speed and information base of urban design using GIS. Of more concern to further research is advancing past this point and looking at ways in which the basic design process can be enhanced. In order to create information systems for designers, three issues must be addressed: data access, user interface and model development.

Model development is concerned with the construction of, as Rowe puts it, descriptive, explorative, predictive and planning models, as well as the ability to
go back and forth between design concepts/models and make refinements. For example, in the nodes model, after developing the nodes and using them in an analysis, I might want to go back and remove the constraint that institutional uses be a requirement or make the node radius smaller. The GIS must accommodate this kind of refinement easily. The construction of models is also an important element of the system. The models presented here were constructed with GIS scripting languages which are almost as complicated as generic programming languages. A more visual-oriented model building system would be necessary for designers.

Interface issues fall into two categories, hardware and software. The standard GIS interface currently consists of a keyboard and mouse for input (digitizing tablets are usually used only for data entry), and a monitor for visual output. It would be more natural for the monitor (visual interface) to rest on a table and tilted only slightly to mimic the orientation of a map or reading table. Regarding input, it would be best to use a stylus that wrote directly on the screen because people are used to drawing on the place they want a mark to be, not twelve inches away. These recommendations would not be made if their purpose was only to make the computer interface more like one to which designers are more accustomed. If there were significant advantages to be gained from the current interface, then the designers should adjust—for example, most people can type faster than they can write freehand, so perhaps the keyboard should stay—but the current interface only exists because it was easy to create, not because moving a mouse on a flat surface is better than moving a finger across the screen.

The software issue is concerned mainly with text-based input versus more graphical methods. As software packages (and the hardware to run them) are evolving, their interfaces are becoming more graphical and less text-based due to user preferences, and urban designers share this preference. It was mentioned above that scripting/model building should become more graphical, and this is the main extension of the general argument that graphically-oriented user interfaces are preferable to text-based ones. A less obvious software issue is inter-
application communication. Communications, word processing, database, spreadsheet and GIS software should work together seamlessly in order to promote maximum work efficiency.

One glimpse at the way this might look in practice is the Netscape Navigator software package with "helper" applications, "plug-ins" and the Java scripting language. Navigator is a piece of software that provides Internet networking capabilities. When the network software accesses text or graphics, it simply shows the text and graphics to the user. When it accesses a kind of data that it does not recognize, it uses a helper application, a plug-in, or Java to process it. The idea is that the user simply tells Navigator what he or she wants and lets that one piece of software figure out what other software might be needed to complete the task. This may soon be the model for operating systems and that would be a boon to the development and adoption of information systems by all disciplines.

**Integrating GIS into the institutional setting**

The final issue to be addressed is data sharing. The technology described here is impractical without institutional support at a variety of levels. First of all, the urban planner needs a very detailed data set in order to analyze the city properly. Data on Boston is approaching the level where it can be used in this way, but many shortcomings were identified throughout this paper. More importantly, data needs to be made more readily available to interested parties. Local, state and federal governments must focus on increasing and simplifying data access. Until a spatial data standard exists, data should be made accessible in the native formats of all of the most common GIS packages to minimize the costs of using GIS data—hard drive space is cheaper than specialized labor and data conversion can be performed once instead of by each user.

As for private firms, their should be a change in policy regarding digital data. Often when a government project is done by a private firm, the firm retains the
rights to the data, meaning the government can not distribute it. This is a complicated issue to solve legally and financially, but it would be in society’s interest to create a system where all data created by public and private entities could be accessed from a centralized place (so that everyone knew where to find data). This system does not have to only contain spatial data sets. Maps, reports and other sources of information can be in digital form and be accessible through the network.

Once these technical issues are resolved, a designer should have access to any information for any place without leaving their office. This is not to say that doing urban planning without leaving the office is a good thing, but rather to emphasize that the overhead involved with the current system of identifying, obtaining and converting data severely limits its use, and government can play an important role in alleviating this problem.
Bibliography


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Appendix A: Scripts written for this project

The following scripts were written in Avenue, the scripting language of ArcView version 2 (Environmental Systems Research Institute, Redlands, CA). To install these pattern finding applications, copy these five scripts into your project and create two new buttons in the View button bar called ‘Find Same’ and ‘Blind Pattern.’ Select ‘View.FindSame.ave’ as the script for the ‘Find Same’ button and ‘View.FindSameUpdate.ave’ as the update script for the button. Select ‘View.BlindPattern.ave’ as the script for the ‘Blind Pattern’ button. These names may be shortened for a DOS-based operating system.

********************************************************************************
'View.BlindPattern.ave
'Raj Singh, 1996

theView = av.GetActiveDoc
theThemeList = theView.GetThemes
dontstop = true
usedThemeList = List.Make

while (dontstop = true)
  'Have the user choose a theme
  themeChoice = MsgBox.Choice (theThemeList,"Select a theme of
  interest","Theme Select (Cancel when done)"
  usedThemeList = usedThemeList.Add(themeChoice)
  'if the user hits cancel, then they are done and we send
  'the list of used themes to the calling script
  if (themeChoice = nil) then
    dontstop = false
    returnVal = av.Run ("FS.IntersectThemes",usedThemeList)
    exit
  end

  'Have the user choose a field from the chosen theme
  themeChoiceFTab = themeChoice.GetFTab
  themeChoiceFieldList = themeChoiceFTab.GetFields
  themeChoiceName = themeChoice.GetName

  titleName = themeChoiceName+" Attribute Selection"
  fieldChoice = MsgBox.Choice (themeChoiceFieldList, "Select a field of
  interest",titleName)
  if (fieldChoice = nil) then
    MsgBox.Error("No field chosen",""
    exit
  end

  'get summary info, so far mean, maximum, minimum
  fieldsum = 0
  fieldmin = 0
  fieldmax = 0
for each recno in themeChoiceFTab
  fieldVal = themeChoiceFTab.ReturnValue(fieldChoice, recno)
  if ( fieldVal >= 0 ) then
    fieldsum = fieldsum + fieldVal
  end
  if ( fieldVal < fieldmin ) then
    fieldmin = fieldVal
  end
  if ( fieldVal > fieldmax ) then
    fieldmax = fieldVal
  end
end
numrecs = themeChoiceFTab.GetNumRecords
fieldmean = fieldsum / numrecs
statString = "MAX="+fieldmax.AsString+" MEAN="+fieldmean.AsString+
            "MIN="+fieldmin.AsString

'shows the user min & max and asks for user min & max
minString = fieldChoice.GetAlias+" statistics: "+statString+"."+"What
            is the MINIMUM value you are interested in?"
maxString = fieldChoice.GetAlias+" statistics: "+statString+"."+"What
            is the MAXIMUM value you are interested in?"
minVal = MsgBox.Input(minString, "Minimum Value", fieldmean.AsString)
maxVal = MsgBox.Input(maxString, "Maximum Value", fieldmean.AsString)

'select all the objects that meet the requirements
queryStringy = "(["+fieldchoice.GetAlias+"]>="+minVal+") and
              (["+fieldChoice.GetAlias+"]<="+maxVal+")"
isOK =
      themeChoiceFTab.Query(queryStringy, themeChoiceFTab.GetSelection,
                           #VTAB_SELTYPE_NEW)
      themeChoiceFTab.UpdateSelection
      av.GetProject.SetModified(true)
end 'while

returnVal = av.Run ("FS.IntersectThemes", usedThemeList)
This script finds the values of the selected fields of selected themes which underly the selected polygon. Then based on those values, the user can expand their range a bit and find all other areas on the map that fall within the range of values chosen for the selected themes.

'the update script should make sure only one theme is active and only one polygon is selected when this script is called

theView = av.GetActiveDoc
theObjectTheme = av.GetActiveDoc.GetActiveThemes.Get(0)
theFTab = av.GetActiveDoc.GetActiveThemes.Get(0).GetFTab
themeFieldList = List.Make
theThemeList = theView.GetThemes
themeFieldList = themeFieldList.Empty

usedThemeList = av.Run("FS.SelectThemes","")

usedCount = usedThemeList.Count

returnVal = av.Run("FS.IntersectThemes",usedThemeList)
select objects from themes of interest

theView = av.GetActiveDoc
theObjectTheme = theView.GetActiveThemes.Get(0)
theThemeList = theView.GetThemes
dontstop = true
usedThemeList = List.Make

while (dontstop = true)
  'Have the user choose a theme
  themeChoice = MsgBox.Choice (theThemeList,"Select a theme of interest
  or Cancel to quit","External Theme Select")
  usedThemeList = usedThemeList.Add(themeChoice)
  'if the user hits cancel, then they are done and we send
  'the list of used themes to the calling script
  if (themeChoice = nil) then
    dontstop = false
    return usedThemeList
  end

themeChoiceFTab = themeChoice.GetFTab
themeChoiceFieldList = themeChoiceFTab.GetFields
themeChoiceName = themeChoice.GetName
  'Select the record of interest in this theme
  themeChoice.SelectByTheme(theObjectTheme, #FTAB_RelTypeIntersects, 0,
  #VTAB_SelTypeNew)
  av.GetProject.SetModified(true)

if (themeChoiceFTab.GetSelection.Count = 0) then
  MsgBox.Error("The themes do not intersect",""
  exit
end

'there is one and only one object selected, so only one record
for each recno in themeChoiceFTab.GetSelection
  fieldVal = themeChoiceFTab.ReturnValue(fieldChoice,recno) 'only one
 carrots selected, so only one record
end

'means the user min & max and asks for user min & max
minString = fieldChoice.GetAlias + " equals " +fieldVal.AsString + " at the
location of the object. What is the MINIMUM value you are
interested in?"
maxString = fieldChoice.GetAlias + " equals " +fieldVal.AsString + " at the
location of the object. What is the MAXIMUM value you are
interested in?"
minVal = MsgBox.Input(minString,"Minimum Value",fieldVal.AsString)
maxVal = MsgBox.Input(maxString,"Maximum Value",fieldVal.AsString)

'select all the objects that meet the requirements
queryStringy = "(["+fieldchoice.GetAlias+"]>"+minVal+") and
(["+fieldChoice.GetAlias+"]<="+maxVal+)")

isOK =
themeChoiceFTab.Query(queryStringy,themeChoiceFTab.GetSelect
ion,#VTAB_SELTYPE_NEW)
themeChoiceFTab.UpdateSelection
av.GetProject.SetModified(true)
end 'while

return usedThemeList

'*******************************************************************************
'View.FindSameUpdate.ave
'Raj Singh, 1996

SELF.SetEnabled(false)

theView = av.GetActiveDoc
activeList = theView.GetActiveThemes

if (activeList.Count = 1) then
    searchTheme = activeList.Get(0).GetFTab
    if (searchTheme.GetSelection.Count > 0) then
        SELF.SetEnabled(true)
    end
end
end
'FS.IntersectThemes
'Raj Singh. 1996
'intersects selected objects in the used theme list

theView = av.GetActiveDoc
usedThemeList = SELF.AsList
usedCount = usedThemeList.Count
theTheme = usedThemeList.Get(0)
lastItem = usedCount - 1
usedThemeList.Remove(lastItem)
i = 1

while (i <= (lastItem - 1))
    selectTheme = usedThemeList.Get(i)
    theTheme.SelectByTheme(selectTheme, #FTAB_RELTYPE_INTERSECTS, 0, #VTAB_SELTYPE_AND)
    av.GetProject.SetModified(true)
    i = i + 1
end 'while

if (File.Exists("xxselect.shp".AsFileName)) then
    File.Delete("xxselect.shp".AsFileName)
end
if (theView.FindTheme("xxselect.shp") <> nil) then
    theView.DeleteTheme(theView.FindTheme("xxselect.shp"))
end

newFTab = theTheme.GetFTab.Export("xxselect.shp".AsFileName, Shape, true)
theSrcName = SrcName.Make("xxselect.shp")
if (theSrcName = nil) then
    MsgBox.Error("invalid SrcName","")
    exit
end
newTheme = Theme.Make(theSrcName)
newTheme.SetVisible(true)
theView.AddTheme(newTheme)
av.GetProject.SetModified(true)
Appendix B: Data Dictionary

Descriptive Name: MassGIS land use
File Name: landuse.shp (ArcView)
Source: MassGIS
Date: 1985 and 1975
Resolution: 1:25,000
Attributes: land use, area

Descriptive Name: Parcels, Boston
File Name: parcels (Arc/Info)
Source: City of Boston
Date: 1988
Resolution: unspecified
Attributes: land use, building value, lot value, total value

Descriptive Name: Buildings, Boston
File Name: bldgfp.shp (ArcView)
Source: Boston Edison
Date: 1996
Resolution: unspecified
Attributes: none

Descriptive Name: 1990 Census block groups
File Name: msabg90.shp (ArcView)
Source: U.S. Census Bureau
Date: 1990
Resolution: 1:24,000
Attributes:
<table>
<thead>
<tr>
<th>Table (matrix)</th>
<th>Title</th>
<th>Total number of data cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1.</td>
<td>PERSONS(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2.</td>
<td>UNWEIGHTED SAMPLE COUNT OF PERSONS(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3.</td>
<td>100-PERCENT COUNT OF PERSONS(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3A.</td>
<td>PERCENT OF PERSONS IN SAMPLE(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4.</td>
<td>FAMILIES(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Families</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5.</td>
<td>HOUSEHOLDS(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Households</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P7.</td>
<td>SEX(2)</td>
<td>2</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P8.</td>
<td>RACE(5)</td>
<td>5</td>
</tr>
<tr>
<td>Universe: Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian, Eskimo, or Aleut Asian or Pacific Islander</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P10.</td>
<td>PERSONS OF HISPANIC ORIGIN(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Persons of Hispanic origin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P57.</td>
<td>EDUCATIONAL ATTAINMENT(7)</td>
<td>7</td>
</tr>
<tr>
<td>Universe: Persons 25 years and over</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 9th grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9th to 12th grade, no diploma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school graduate (includes equivalency)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some college, no degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associate degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduate or professional degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P80A.</td>
<td>MEDIAN HOUSEHOLD INCOME IN 1989(1)</td>
<td>1</td>
</tr>
<tr>
<td>Universe: Households</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median household income in 1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P81.</td>
<td>AGGREGATE HOUSEHOLD INCOME IN 1989(2)</td>
<td>2</td>
</tr>
<tr>
<td>Universe: Households</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than $150,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$150,000 or more</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>