



Design and implementation of a web-based platform to support interactive environmental planning

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ARTICLE INFO

Article history:

Received 2 May 2008

Received in revised form 9 May 2009

Accepted 18 May 2009

Keywords:

Web-based interactive analysis
Online environmental planning systems
Web-GIS
Parks and open space
Geospatial data
Southern California

ABSTRACT

A web-based platform to support interactive environmental planning in Southern California is currently being developed, as part of the Green Visions Plan project. The main goal is to provide tools for municipalities and community-based groups to identify candidate project sites that can: (1) promote more equitable park and open space access for local residents; (2) protect and restore biodiversity; and (3) protect and enhance watershed health. The Interactive Park Analysis Tool operates at the parcel level and provides estimates of potential park user demographics in a series of customized reports, as illustrated in this article. The Interactive Park Analysis Tool and supporting map viewer platform (like the other tools) utilizes a client/server system architecture that provides users with access to large, detailed geospatial datasets. The system architecture and implementation is described, and a case study illustrates system functionality. Work is now underway to expand the platform to include additional online tools to facilitate the evaluation of biodiversity and watershed health within the study area.

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1. Introduction

The Southern California metropolitan area is one of the fastest growing urban areas in the United States, characterized by social and economic polarization, and disparities in public service provision. Many older communities, especially communities of color and low income neighborhoods, are in desperate need of new parks for recreational purposes. Some municipalities and community-based organizations have shifted their focus to Geographic Information System (GIS) analytical tools and geospatial data to promote equitable access to parks and open space in the past few years. In addition, the World Wide Web has facilitated and nurtured the use of GIS technologies to support a variety of decision-making tasks at the local and regional scales (see Peng & Tsou, 2003; Rinner, 2003; Sugumaran & Sugumaran, 2005; Bhargava, Power, & Sun, 2007 for examples). Due to the growing needs and interests of environmental planners, many efforts have been launched to develop and implement web-based environmental planning tools.

The development of online environmental planning tools has been reported extensively in the literature. Many of these planning tools have been developed to support different environmental goals such as water management, soil management, ecosystem

and forest management, habitat planning, and native vegetation management. Hence, Zhu, McCosker, Dale, and Bischof (2001) have developed an online information system, VegMan, to support sustainable regional vegetation management in the Central Highlands region of Queensland. The Center for Agricultural, Resource and Environmental Systems at the University of Missouri–Columbia (CARES, 2003) has created several web-based spatial decision support applications to provide users with access to habitat information and hydrologic data, and to help with the management of livestock, woodlands and agriculture. Dymond, Regmi, Lohani, and Dietz (2004) presented a spatial decision support system that integrated hydrologic, economic and fish-health models in a single web-enabled interface. Sugumaran, Meyer, and Davis (2004) proposed a web-based environmental decision support system (WEDSS) to identify and prioritize local watershed environmental sensitivity in the City of Columbia, and Boone County, Missouri. Karnatak, Saran, Bhatia, and Roy (2007) proposed a web-based environmental planning system to promote biodiversity conservation in India that featured multi-criteria spatial decision analysis tools. Rao et al. (2007) described a web-GIS decision support system to assist the USDA in planning and managing Conservation Reserve Program (CRP) enrollment. Culshaw et al. (2006) proposed an Environmental Information System for Planners (EISP) to assist local authorities to deal systematically and efficiently with the land use planning process in the UK. Finally, Simão, Densham, and Haklay (2008) presented a web-based spatial decision support system

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to help planners, stakeholders and the public identify and plan wind energy projects in England. These systems are generally used by environmental planners and managers, environmental analysts, the decision makers within local government, the public and other interested parties.

All of the aforementioned online environmental planning tools are designed based on the client/server technology. With these tools, data querying, geoprocessing, and spatial decision analysis are implemented at the server side, whereas user interaction, data and map display, and report generation are the end processes executed at the client side. Moreover, depending on the distribution of the processes between client and server, the client is either a thin or thick client. A thin client (Dymond et al., 2004) is often limited to data/result presentation with a simple web interface. On the other hand, thick clients (Zhu et al., 2001) support more functionality such as group decision making and multi-criteria evaluation, in addition to data presentation. Various technologies are used to develop the clients and servers with the aforementioned systems. To be specific, clients are implemented using web technologies such as Java applets, Javascript, HTML, ActiveX controls, and browser plugins. On the other hand, server-side processes are mainly implemented on top of ArcIMS server, ArcGIS server, OGC compliant web map services, Java applications, Active Server pages, Java Server technology, and other server-side scripting languages.

In this article, we present a web-based platform to support interactive environmental planning in Southern California. The platform and “Interactive Park Analysis Tool” that is showcased herein are key parts of the “Green Visions Plan for 21st Century Southern California” project, hereafter referred to as the Green Visions project (Wolch, Wilson, & Longcore, 2009). One of the primary aims of this on-going project is to produce a suite of web-based GIS planning tools which can be used to help guide future investments that reduce inequities in recreational open space, promote habitat restoration and conservation, and improve natural hydrologic function in southern California.

Among all multi purpose web-based environmental planning systems reported in the literature, the Green Visions Project Platform (GVPP) described in this article is the first online planning tool which will, when it is completed, support habitat conservation, watershed health and recreational open space planning simultaneously. The GVPP serves regional geospatial datasets, including hydrologic information, land cover and land use, wildlife species, transportation networks and municipal boundaries, demographics and human health risks, to name a few. The GVPP is fully accessible to the general public and is hosted on one of the USC GIS Research Laboratory servers (GVP, 2009). The platform is implemented using the client/server architecture with a thin client, similar to the related work discussed earlier. The implemented system has a four-tiered configuration consisting of a web client (Tier 1), the IIS web server (Tier 2), the ArcIMS Map Server (Tier 3), and ArcSDE in combination with MS SQL Server as the spatial database server (Tier 4).

The innovative part of our system is the ability to work at a very fine resolution. Few studies have developed web-based analytical systems that operate at such a resolution. All of the web tools presented under the related work, for example, are designed for low resolution analysis on user selected study areas rather than high resolution parcel-based analysis. These architectures are such that they cannot afford a very fine resolution for subsequent analysis and decision-making tasks. The presented article describes the development of a web-based platform that supports unique interactive, “on-the-fly” analyses at the parcel level. Using the Interactive Park Analysis Tool, for example, a user can convert one or more parcels into candidate parks and visualize the changes in potential park use or pressure. This tool therefore provides users with an easy way to instantly calculate disparities in park access, and the

effects of adding one or more new parks on such disparities. The intended users are municipalities, community-based organizations and environmental planners who want to identify potential park locations that will reduce the pressure experienced by existing parks in park-poor neighborhoods in the Green Visions Plan study area.

The remainder of the article is organized as follows. The overall design and system architecture of the web-based environmental planning tool will be discussed in Section 2. By simulating the impacts of a new park in Section 3, the characteristics of the Interactive Park Analysis Tool will be presented in detail. Then, the advantages and shortcomings of the developed system will be presented followed by some thoughts for extending the platform in the final section.

2. Design and implementation of web-based dynamic analysis system

The web-based analysis tool designs are based on a client/server model divided into four levels of functionality (Foote & Kirvan, 2000; Peng & Tsou, 2003; Plewe, 1997; Tsou, 2004), as illustrated in Fig. 1. These four levels consist of a Web Interface, Web Server, Application Server and Spatial Database Server. The Interactive Park Analysis Tool is integrated within the GVPP, which began as a basic map viewer originally created by the California Department of Fish and Game (DFG, 2007). Based on previous experience implementing web mapping projects (i.e. Ghaemi, Swift, Goldberg, & Wilson, 2006; Swift et al., 2004; Zimmermann, Bardet, Ku, Hu, & Swift, 2003), the initial DFG map viewer was customized to deliver a suite of multi-faceted analytical tools and accompanying geospatial datasets.

As an online environmental planning tool to assist environmental advocates, planners, and managers in decision making, the GVPP requires the following features. First, the system needs to provide data querying and extensive native geoprocessing capabilities. Second, it needs to afford a fast online rendering of large vector and raster datasets regardless of user network bandwidth. Third, it needs to support multiple concurrent users and the results from interactive tools like the Interactive Park Analysis Tool should be provided in real time. We describe next how the proposed system architecture and chosen software (ESRI's ArcIMS, ArcSDE 9.2 and Microsoft's SQL Server 2005) satisfy the aforementioned requirements.

2.1. System architecture

The client side is considered the first level within the system, providing a user interface that accepts requests, performs a multitude of map-centric tasks, and dynamically displays the results in tables and HTML formatted popup reports (Fig. 1). The GVPP provides direct access to approximately 80 geospatial vector and raster datasets generated as part of the Green Visions project (Wolch et al., 2009). The client front-end provides a main toolbar that allows users to perform basic GIS operations such as navigating around the map view (zoom in, zoom out, pan map, and zoom to the extent of the active layer), performing queries against layers to retrieve attribute information for download in tabular format (Fig. 2), and printing customized map views. Fig. 2 provides an example view of the GVPP viewer, and shows the available geospatial data layers in the “Layer List” on the left-hand side, and the basic map viewer tool buttons in the main toolbar across the top. The Layer List controls layer visibility and selection, such that the dataset selected by a user is referred to as the “Active Layer”, the layer acted upon by the tools in the toolbar. The client interface also provides metadata and layer properties tools, and allows each user to

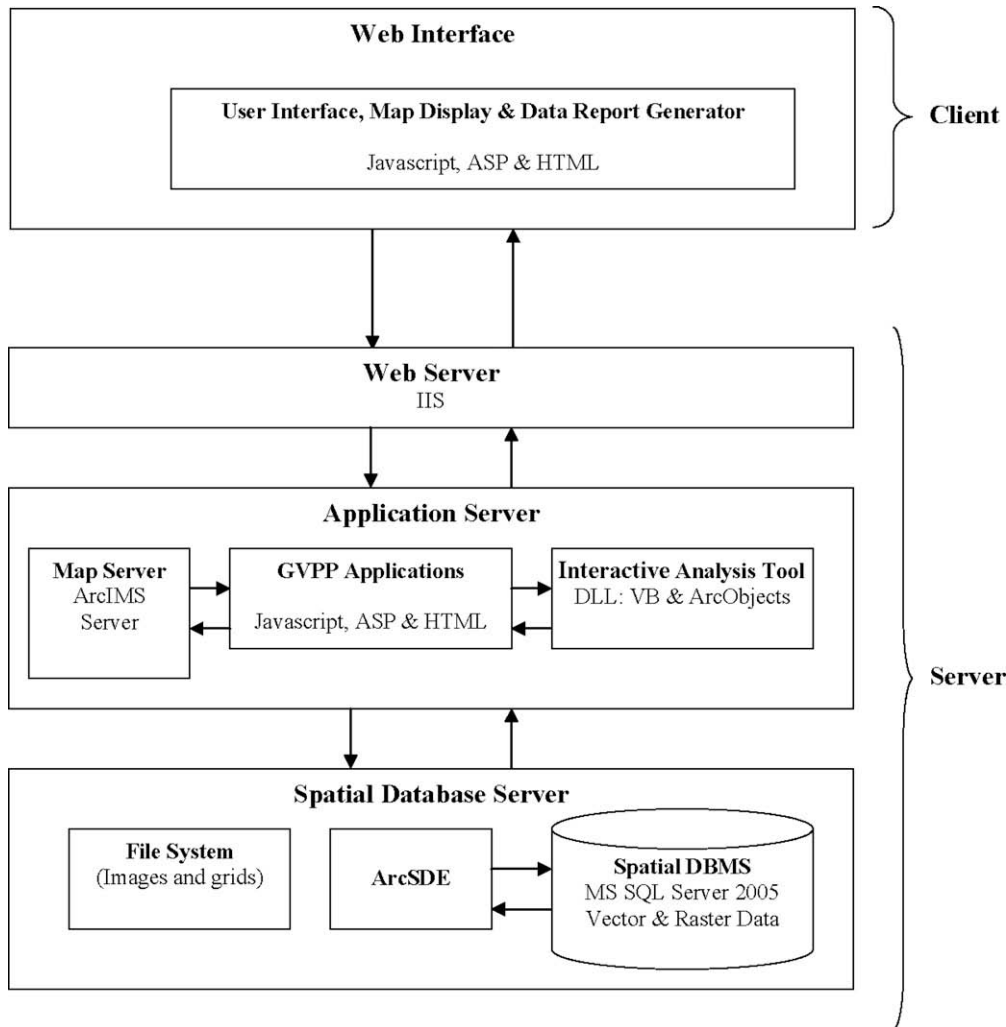


Fig. 1. System Architecture of the GVPP, including the Interactive Park Analysis Tool.

save unique map views as “Bookmarks” to be retrieved whenever the user visits the GVPP. In addition, a convenient “Data Catalog” tool has also been implemented to facilitate searching for and loading project-specific data layers into the map viewer. Data layers are grouped within the Layer List based on data type categories (i.e. Green Visions Project Data layers, Base Layers). The Client side was originally developed using Javascript, Active Server Pages (ASP) and HTML (DFG, 2007).

The server side architecture is a three-tiered configuration comprised of the Tier 1 “Web Server”, Tier 2 “Application Server”, and Tier 3 “Spatial Database Server” (Fig. 1). Microsoft Internet Information Server, IIS V.6 is utilized as the Web Server. When a user initiates a request, the IIS passes the data between the client-side Web Browser and the Application Server. The Application Server currently consists of three main modules (Fig. 1): the Map Server, GVPP applications, and the Interactive Park Analysis Tool. Upon a request by a user, one of these modules is launched in order to execute the client request and return the results to the client’s web browser. These modules are discussed in detail under “Interactive Park Analysis Tool”.

When a user chooses a tool from the toolbar and clicks on the map view, for example to generate or manipulate it, the Web Server interprets this as a user request and directs the request to the Map Server. The Map Server executes the mapping request, launches the available map service in the service registry and

sends a picture of the map in JPEG format to the Web Server. ESRI’s ArcIMS functionalities comprise the core Internet Map Server in the GVPP. ArcIMS Server provides built-in standard GIS tools that support the serving of GIS data, advanced querying, focused GIS application development via open Internet protocols, and powerful map visualization capabilities. More importantly, ArcIMS Server provides functionality beyond 2D map visualization, such as advanced geoprocessing services, since these geoprocessing services were required to implement the interactive analysis tools like the Interactive Park Analysis Tool showcased in this article.

The GVPP Database Server handles the Green Visions Plan geospatial datasets or “layers” which include:

- Base layers such as 3-D digital elevation models, trails, roads (local streets and highways), natural and man-made landmarks (schools, hospitals, airports, etc.), and municipal boundaries.
- Hydrologic data (updated stream networks, watersheds, sub-watersheds, and catchments; Sheng & Wilson, 2008).
- Parcels.
- Land use/land cover.
- Parks (including forests and beaches).
- NDVI images.
- Census 2000 demographics.
- Target species habitat layers (including amphibian, bird, insect, invertebrate, mammal, reptile, and aquatic species, target spe-

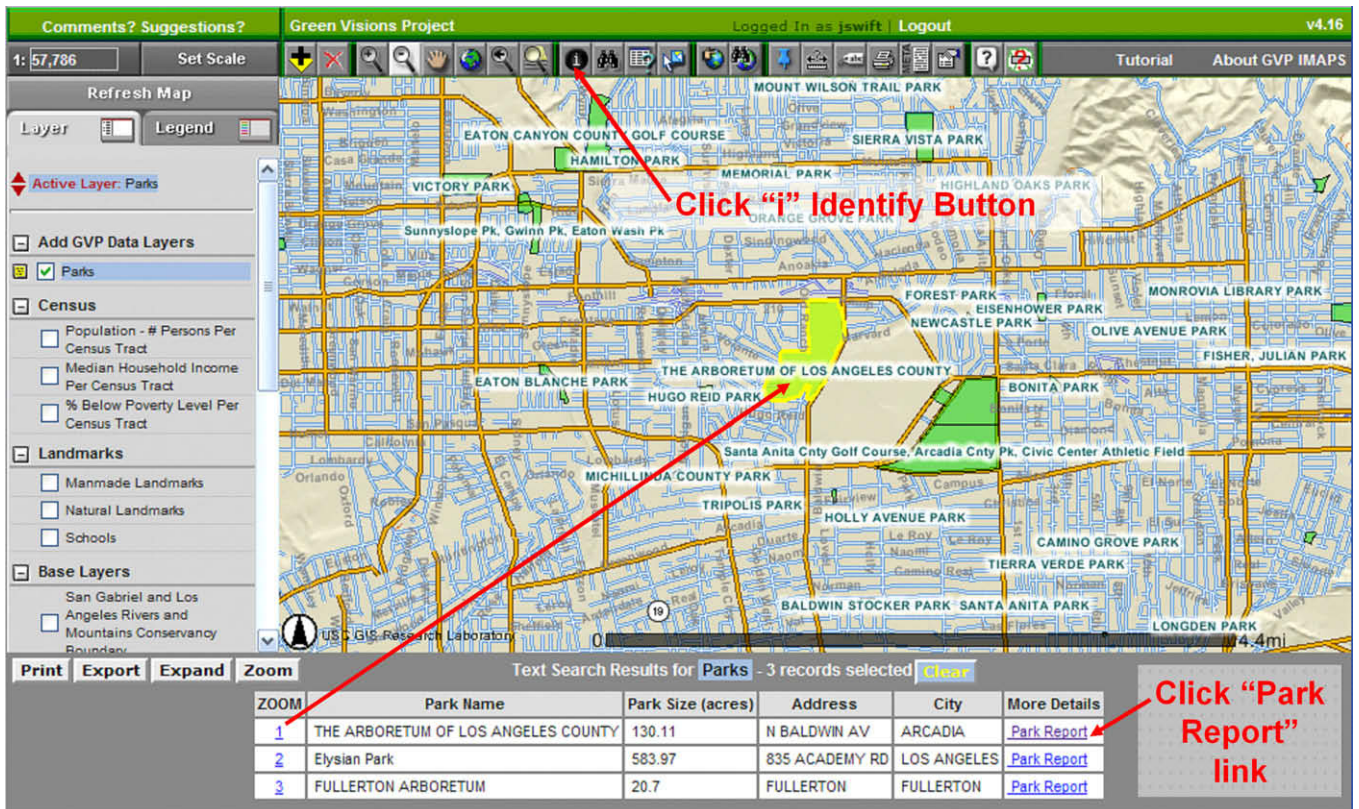


Fig. 2. Tabular data that appears in the bottom panel below the map following the use of the Identify tool and the link used to generate a custom pop-up data report (for one or more selected parks in this example).

cies density, and measures of cost-distance that capture the ease of moving across the landscape for a subset of urban-adapted target species).

Most of these georeferenced vector and raster datasets are stored in Microsoft SQL Server 2005, while some larger grids are stored in server disk space. ArcSDE 9.2 is basically a gateway between the Application Server and the Database Server. It efficiently manages spatial data in the form of tables. ArcSDE provides some key benefits such as the ability to serve many concurrent users and no limit to the size of the SQL Server database which supports the multiple concurrent users, one of the main requirements of GVPP. In addition, the basic and customized GIS tools that work directly with database tables rather than other formats such as shapefiles, greatly improves the system performance of the interactive elements like the Interactive Park Analysis Tool and makes it a real-time service.

2.2. Customized GIS tools

To support investigation of existing conditions captured with the GVPP data layers, a set of data reports was needed which was not available in the initial setup of the DFG map viewer. Therefore, we have developed a custom reporting mechanism in ASP. These reporting applications allow users to generate dynamic pop-up data reports from GVPP data layers. At present ASP report modules are linked to the parks, park service areas, quarter mile network buffers around parks, stream networks, subwatersheds, and watersheds.

A user may select one of these layers, choose the Identify tool button (“i” button, Fig. 2), then click on any feature of interest. Data “features” are represented as polygons (i.e. parks),

lines (i.e. stream segments) or points (i.e. schools). Clicking on a feature will automatically display a list of one or more records (polygons, lines or points and corresponding attributes) associated with the selected layer in the panel beneath the map view (Fig. 2). For example, if a user selects the Parks layer and then the Identify tool button, clicking on a park of interest will generate a list of one or more parks closest to the point or geographic location of the click (Fig. 2). A pop-up data report formatted in HTML can be generated for any park in the list by clicking on a “Park Report” link under the attribute heading “Feature Details”. The generated park report includes some information about the park such as community and cultural facilities, active and passive recreation facilities, landscape features, park condition, safety features, and target species as well as a photo gallery.

While many of these reports simply afford users an opportunity to query existing data layers, others report the results of some form of interactive analysis that enables users to ask “what if” kinds of questions related to park provision and pressure along with habitat and watershed conservation and restoration. The Interactive Park Analysis Tool is showcased in the next section to illustrate these types of capabilities.

2.3. Interactive Park Analysis Tool

This tool is an elaboration of the work of Sister, Wolch, et al. (2007), wherein a methodology was developed for characterizing potential park and open space congestion in the Green Visions Plan area. Sister, Wilson, Wolch, Swift, and Ghaemi (2007) provide a compelling picture of the disparities between the location of park resources and the locations of disadvantaged populations, such as people of color and the poor, which essentially

laid the groundwork for this phase of the Green Visions Plan project.

A park analysis geoprocessing tool was developed outside the main shell of the basic DFG (2007) map viewer application reproduced in Fig. 2. The new Interactive Park Analysis Tool assists community organizations and municipalities (planners, engineers, politicians, etc.) in identifying new park sites within the Green Visions Plan study area that would reduce existing disparities. Using this tool, users can select specific parcels (e.g. brownfields or vacant lands) as candidate sites and convert them into new parks. Consequently, they can instantly quantify how the new configuration resulting from the conversion of the parcels to parks changes potential use or pressure (i.e. demand) for existing park in the immediate neighborhood of the candidate site(s). The rich demographic dataset within this tool facilitates exploration of the spatial relationships between park facilities and socio-economic characteristics of populations (i.e. income, race/ethnic composition, and age distribution).

The overall design of the online tool is based on the “Park Service Area concept” that was described by Sister, Wolch, et al. (2007) and can be summarized as follows. A Park Service Area is defined as the area (polygon) surrounding a park (Fig. 3). Assuming that everyone uses the nearest park at some uniform rate, we can assign each person in the region to a park by generating Thiessen polygons (similar to what Pearce (2000) did when defining school catchment areas for comparison with census data in the UK). The Thiessen polygon of a park is the area surrounding the park such that every point inside the area is closest to the corresponding park (Burrough & McDonnell, 1998; Gahegan & Lee, 2000). Considering that residents are more likely to utilize parks in closer proximity on a more regular basis, each Thiessen polygon can be viewed as a Park Service Area (PSA), with each park at the center servicing the population within the bounds of the polygon. Since a park, in itself, is a polygon (and not a point), we utilized the vertices around the perimeters of the parks as the points from which the Thiessen polygons would be generated (Fig. 3c and d). Since this step results in multiple Thiessen polygons for each park (given that each park polygon is composed of multiple vertices), the polygons belonging to the same park are then aggregated (Fig. 3d). The geometric result is a lattice of PSAs with every space in the region assigned to the park closest to it. The potential level of park congestion for each park service area is then estimated as the total number of residents per park acre (or hectare) inside a given PSA.

The total number of residents per PSA was established by intersecting the LandScan (Bhaduri, Bright, Coleman, & Dobson, 2002; Bhaduri, Bright, Coleman, & Urban, 2007) population raster with the PSA polygons. The LandScan population raster was generated using a variety of layers describing the “built” environment and dasymetric mapping techniques to reassign 2000 census totals. The veracity (i.e. reliability) of this approach has been demonstrated in several studies (e.g. Cai, Rushton, Bhaduri, Bright, & Coleman, 2006; Patterson et al., 2007, 2009). The LandScan product gives population estimates for grid cells measuring 300 m on a side. The populations within these grid cells were allocated the demographic characteristics (i.e. number of children aged 0–17 years, percent African-American, percent Latino, and percentage of households below the federal poverty thresholds) of the source census blocks. Weighted averages were used when PSAs split the LandScan grid cells into two or more components and when the LandScan grid cells inherited demographic characteristics from two or more Census 2000 tracts or black groups. Further details on how these approaches were handled for the interactive park analysis is provided in the section entitled “Simulating the Impacts of Adding a New Park”.

The aforementioned approach relies on numerous assumptions. No effort was made to distinguish parks based on their size or their facilities present because the latter is largely unknown and there is

a weak relationship between park size and characteristics (i.e. facilities) based on the subset of parks that the GVP research team audited (see Sister, Wolch, et al., 2007 for additional details). Similarly reliance on Euclidean distance when building the PSAs ignores the potential impact of the road network on proximity to parks. However, both approaches are problematic since road network coverages seldom include walking and bicycle paths that people might use to travel to and from neighborhood parks, and we made no attempt here to link park use to specific facilities (i.e. presence/absence of safe playground equipment, basketball courts, soccer fields, tennis courts, etc.) that draw people of different ages to specific parks. These aspects and what we know about them in the GVP study area are discussed in detail by Sister, Wilson, et al. (2007) and Sister, Wolch, et al. (2007).

To summarize the park pressure analysis approach, any parcel may be converted to a candidate park site by adding the parcel to the Parks layer (Fig. 3a and b). Utilizing the vertices of the parks and the added parcel, Thiessen polygons are created for each vertex along the perimeters (Fig. 3c). After aggregating all polygons belonging to the same park, a new PSA is created for the candidate park and the surrounding PSAs are redrawn (Fig. 3d). The geometric result is a lattice of PSAs with new boundaries delineating the service area for each park, including the candidate park site. Park attributes (i.e. facilities present) and demographic information are then assigned to each PSA in a series of GIS overlays. Potential park use (i.e. demand) in the new PSA configuration is then estimated to show users how the candidate park would reduce park use (demand) in the area of interest and the immediate vicinity.

A step-by-step illustration of the Interactive Park Analysis Tool model is provided in Fig. 4. The process consists of a series of geoprocessing modules programmed in Visual Basic and ESRI ArcObjects and it is implemented as a Dynamic Link Library (DLL). The tool is designed “outside of the box” to employ dynamic linking, which conserves server-side memory. The server-side DLLs perform geoprocessing functions much more rapidly than client-side web pages coded in ASP, dramatically speeding up the performance of the Dynamic Park Analysis Tool.

This service can be used to simulate the impacts of creating parks from existing parcels in 30 to 40 s, regardless of the user’s level of GIS experience. The analysis run time varies slightly depending on the number of parcels selected by the user and the resulting number of neighboring PSAs involved in the analysis, as well as the number of concurrent GVPP users and network bandwidth.

Implementing the approach shown in Fig. 3 in the form of a web-based tool presented numerous technological challenges. Although the Interactive Park Analysis Tool follows the overall methodology of Sister, Wolch, et al. (2007), the online implementation required numerous work-arounds or adaptations to best accommodate server-side processing capabilities, the goal being to provide a real-time service. For example, due to limitations in server resources, the number of parks included in any one analysis was restricted to a 4 km buffer around the selected parcel(s) and all parks outside this radius are excluded. At first, we expected this exclusion would have a negative impact on the validity of information provided by the Interactive Park Analysis Tool. However, we came up with an approach which is described in detail in the next section that protects the validity of the information provided by this tool regardless of the limitation caused by buffer size. The following discussion focuses on one example of how the Interactive Park Analysis Tool can be used, and thereby highlights the functionality implemented with the tool via the GVPP.

2.4. Simulating the impacts of adding a new park

Fig. 3 provides an example of the flow of the Interactive Park Analysis Tool applied to a specific parcel. In this example, a user se-

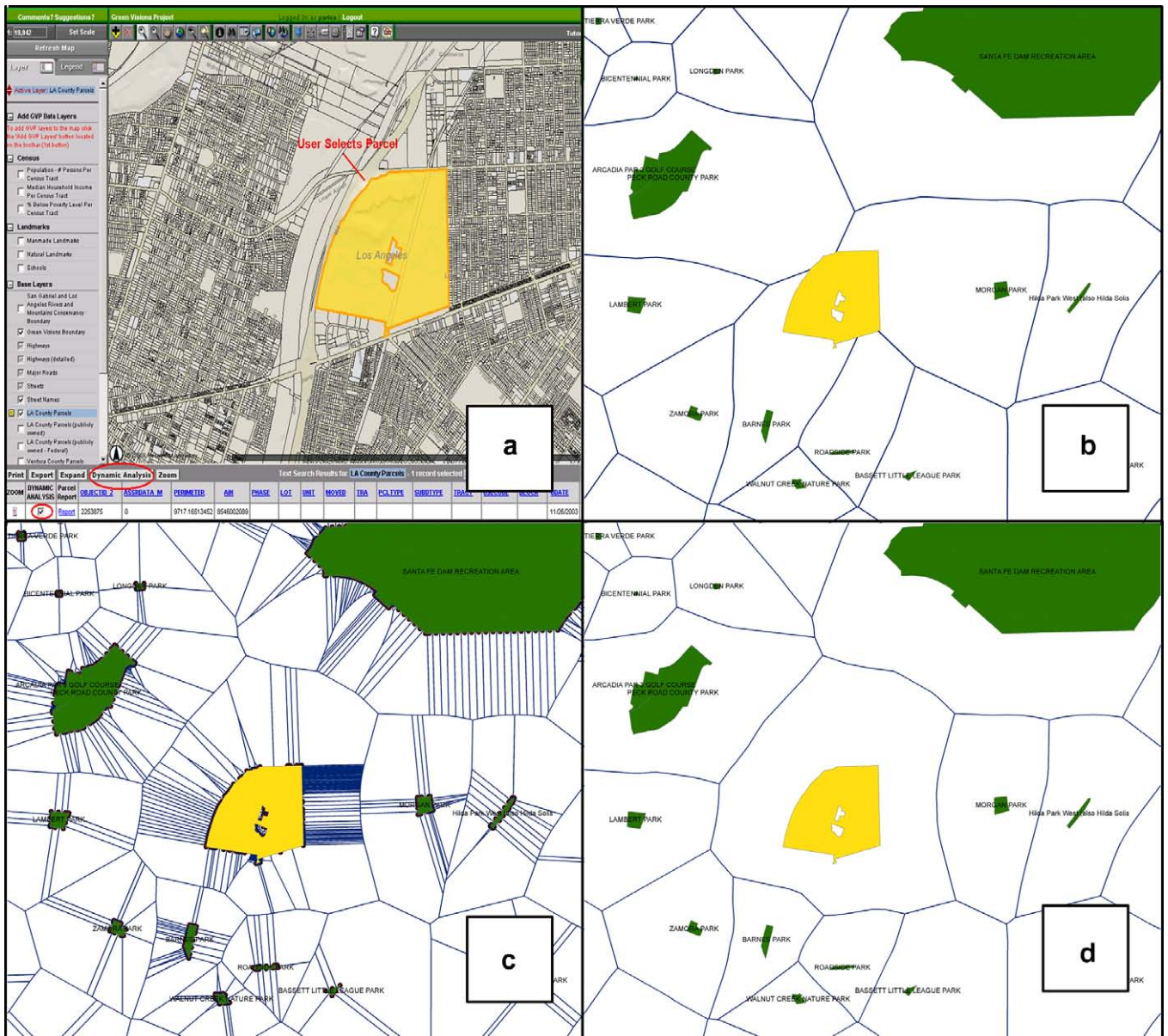


Fig. 3. Example of a Park Pressure Analysis conducted using the Interactive Park Analysis Tool via the GVPP. (a) User selected Parcel AIN# 8546002089. (b) Selected Parcel showing existing parks and accompanying park service area boundaries. (c) Regeneration of vertices around perimeters of parks and corresponding park service areas (Thiessen polygons). (d) Compilation of new park service areas for user selected parcel and surrounding parks.

lects the parcel from the map by clicking on it (Fig. 3a). The analysis is initiated by checking the appropriate box under “Dynamic Analysis” in the list of parcels and then clicking the button “Dynamic Analysis” located between the Expand and Zoom buttons in the panel below the map. Fig. 3b–d illustrates the steps involved in generating the PSAs (Thiessen polygons). Fig. 5 provides the corresponding example output data report. Careful examination of the results of online analyses with previous analyses conducted by Sister, Wolch, et al. (2007) using ESRI’s ArcGIS desktop software showed identical outcomes.

One additional challenge faced in implementing this analysis online lay in ascertaining to what extent creating a new park from an existing parcel affects the geometries of the neighboring PSAs. In the PSA layer displayed in Fig. 6a, it is assumed that the polygon containing the parcel being analyzed is labeled 0, the polygons adjacent to the parcel are labeled 1, and the remainder of the polygons are assigned the integer 2 or higher. The sequence of steps shown in Fig. 4 shows how each polygon in level 1 lost a portion

of its geometry when the Thiessen polygons and the demographic characteristics of the PSAs were recalculated. Fig. 6 shows how the affected polygons were regenerated and then integrated into the description of PSAs. Hence, the polygons labeled uppercase A, B, C, D, E, F, G, and H in Fig. 6b are the adjacent Thiessen polygons of the selected parcel. After running the dynamic analysis, the polygons labeled lowercase a, b, c, d, e, f, g, and h represent subsections or portions of the same polygons which are included in the new Thiessen polygon surrounding the proposed park site. Each of the polygons a, b, . . . , h were individually intersected with the population data layer in order to correctly calculate the demographic metrics associated with each polygon subsection.

Function DMG (a) is defined as any demographic information within polygon ‘a’, such as the total number of persons or median household income of persons living in this area. Thus in general, following an Interactive Park Analysis, the changes in demographic information in the PSAs neighboring the parcel of interest can be calculated using the following equation:

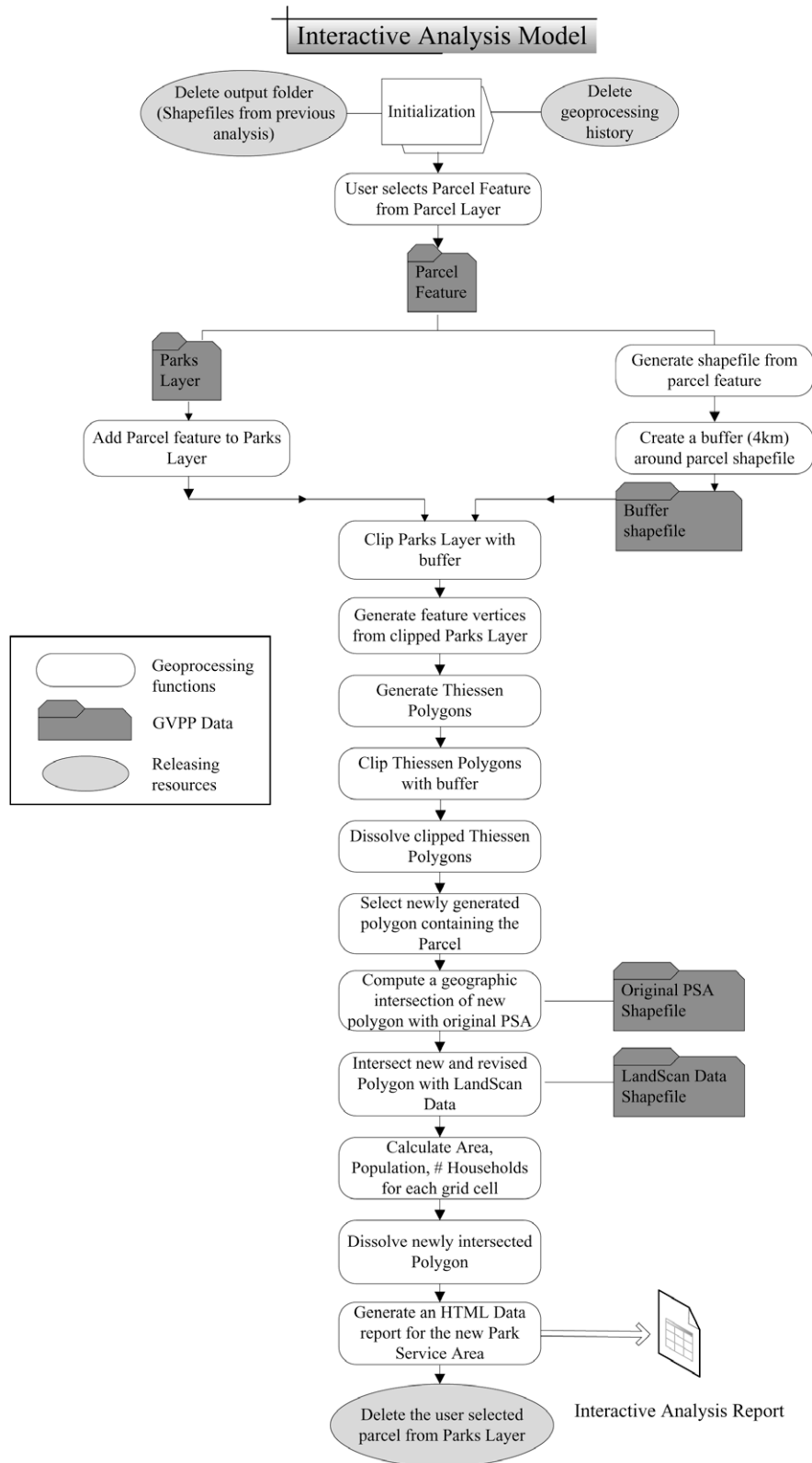


Fig. 4. Interactive Park Analysis Tool process model, including all the steps required to implement a Park Pressure Analysis online.

$$DMG(A - a) = DMG(A) - DMG(a) \tag{1}$$

in which (A - a) represents the Thiessen polygon A after running the interactive analysis tool. In other words, the population served by park service area (A - a) equals the population served by park service area (A) minus the population served by park service area (a).

It is important to note that this approach accommodates special situations which arise due to limitations of the online implementation, such as the limited size of the analysis buffer area. The aforementioned approach of dividing the landscape into multiple subsections successfully handles new park sites and park service areas that affect very large green spaces such as National forests

Proposed Parcel									
Parcel AIN#:	8546002089								
Parcel Area in Acres:	326.28								
Park Service Area in Acres:	2261.41								
Population Served by Park Service Area:	22229								
Children Under 18 Served by Park Service Area:	7481								
Population Served per Parcel Acre:	68								
Children Under 18 Served per Parcel Acre:	23								
Population Density per Square Mile:	6291.11								
Median Household Income:	\$ 43931								
Percent of Population Below Federal Poverty Threshold:	15.96								
Park Pressure Reduction									
Park/PSA Name	Persons served per park acre			Children served per park acre			Total Park Service Area in Acres		
	Before	After	%Change	Before	After	%Change	Before	After	%Change
PECK RD CNTY PK, ARCADIA PAR 3 GOLF COURSE	86	78	-9.96	23	20	-11.35	2084.88	1609	-22.82
SANTA FE DAM RECREATION AREA	8	7	-6.76	3	3	0	4973.12	4759	-4.31
BARNES PARK	1511	1083	-28.31	522	381	-26.99	952.42	404	-57.63
ROADSIDE PARK	2674	1839	-31.22	954	661	-30.72	536.48	342	-36.18
BASSETT LITTLE LEAGUE PARK	6732	6490	-3.59	2189	2104	-3.87	962.07	925	-3.83
ZAMORA PARK	3060	2967	-3.06	1078	1048	-2.79	707.9	685	-3.21
MORGAN PARK	2879	1942	-32.54	984	661	-32.87	1563.79	887	-43.26
LAMBERT PARK	1286	1132	-11.97	407	360	-11.45	861.4	769	-10.7
Total	60	50	-16.24	20	17	-16.5	12642.07	10380.66	-17.89

Fig. 5. Summary HTML format pop-up data report on Parcel #AIN: 8546002089, produced using the Interactive Park Analysis Tool.

(as is the case for polygon A in Fig. 8) for example. This particular analysis takes into account the effect of the small buffer size which cannot encompass the larger parks, yet correctly calculates the demographics of the affected PSAs.

3. Advantages and disadvantages of the current system

The implementation of this web-based tool provides several advantages. First and foremost, the web tool extends the availability of this type of analysis to community groups and municipalities, which in turn affords these stakeholders the capacity to quickly build the rationale supporting proposals for new or improved park sites. In 2007, representative groups of potential tool users were convened for several workshops in order to introduce the tools and provide basic guidance. Since then, the workshop participants and other stakeholders have manipulated the tools and offered feedback on responsiveness and functionality that has been addressed in subsequent versions of the system.

Second, the Interactive Park Analysis Tool provides non-GIS users as well as GIS-savvy professionals a real-time service. This service can be used to simulate the impacts of creating parks from existing parcels in 30 to 40 s, regardless of the user's level of GIS experience. Another advantage of implementing the Interactive Park Analysis Tool as a web tool is the fact that it can be utilized in a distributed fashion via the Internet. In other words, a geographically distributed group of users, such as environmental planners affiliated with the same agency or company but spread across different office locations can concurrently run this tool. It is also

possible to compare the expected results of turning multiple parcels into parks in a single analysis session.

There is a shortcoming with the current version that needs to be addressed in future versions, in order to provide users with greater flexibility. Multiple concurrent users cannot simultaneously utilize the Interactive Park Analysis Tool implemented by a single DLL in the current version whereas they can utilize all of the other tools implemented in GVPP concurrently. However, the current DLL is programmed as a COM component and as such, it does not allow users to share the GIS data layers stored in ArcSDE and perform their park analysis at the same time. To resolve this problem, we need to migrate the developed system from the ArcIMS server to ArcGIS server. When working with ArcGIS Server, each user by running the interactive analysis tool, will make a connection to a server, obtain a server context and use it to access resources on the server. In this circumstance, multiple users will be able to run the Interactive Park Analysis Tool simultaneously since they can access GIS data layers located on the server from different server contexts.

4. Conclusions and future directions

The GVPP includes a full suite of basic GIS mapping tools and utilities, as well as customized report generation applications and the specialized Interactive Park Analysis Tool. All of these tools facilitate the viewing and analysis of map data layers. The Interactive Park Analysis Tool provides a quick and easy way for users to look carefully at the different options by converting parcels to

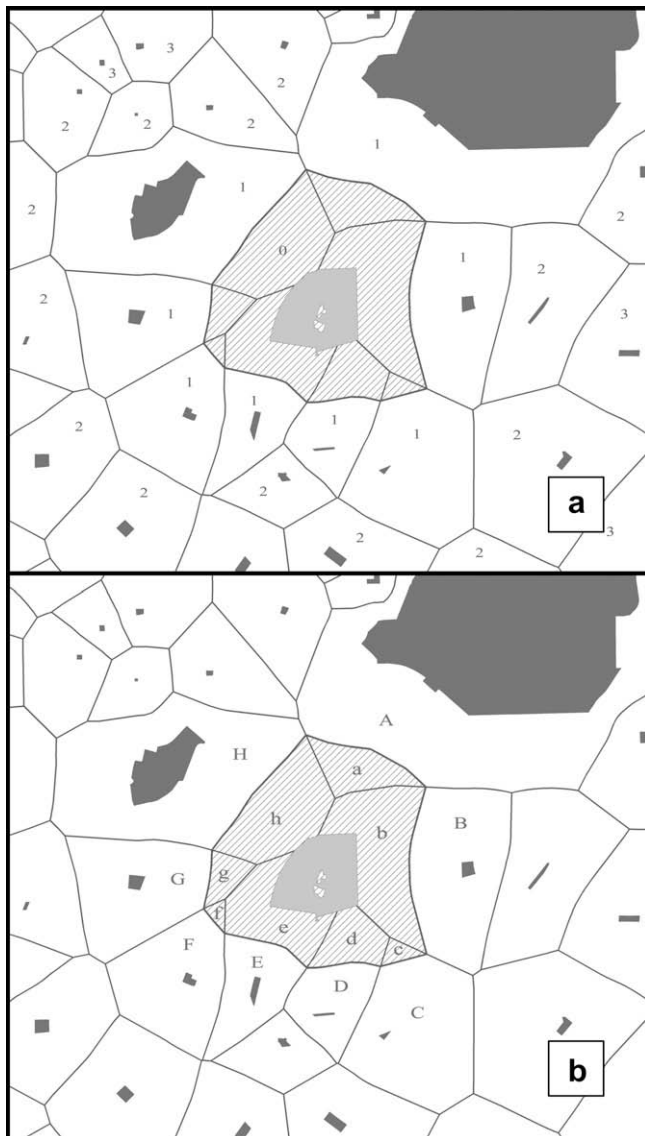


Fig. 6. (a) Diagram of polygons resulting from an Interactive Park Analysis. (b) Approach applied to accurately compute demographic information of neighboring Thiessen polygons.

parks on-the-fly and comparing the various impacts of such investments.

The Interactive Park Analysis Tool affords a consistent and easily understandable language for policymakers and funding organizations to compare alternative candidate park sites. Public access web-based tools support municipalities and community-based groups, especially those with otherwise limited resources, to lobby for candidate park sites and/or park development that can lessen the pressure on existing parks in specific jurisdictions and regions. The adoption of online tools in decision-making will have the effect of leveling the playing field for municipalities and community groups vying for park funds, by minimizing the unfair advantage that currently accrues to those who have more resources to submit the most convincing proposals (Wolch, Wilson, & Fehrenbach, 2005). The platform has already been used to help prepare and evaluate proposals submitted to the Lower Los Angeles and San Gabriel Rivers and Mountains Conservancy (RMC) requesting funds for park, open space, habitat and watershed conservation and restoration projects in a series of regular grant competitions. The RMC lists the use of the platform and accompanying tools in their pro-

posal requirements and the USC GIS Research Laboratory has been contracted to offer training workshops to support proposal preparation.

As a future work, the same scenario building capability will also be built into interactive habitat and watershed tools, which are, given their inherent characteristics, more complex. Additionally, web-based decision support tools, because they use GIS layers, can easily be designed to address the large number and variety of possible benefits of multi-purpose projects. For example, there is a growing need to increase and/or sustain existing rates of groundwater recharge, as well as improve the quality of urban stormwater runoff (Sheng, 2007; Sheng & Wilson, 2008; Sheng, Wilson, et al., 2007). These concerns can potentially be addressed along with the issue of park and open space provision. Utilizing the decision support tools, the GIS park layer can be overlaid with hydrography and watershed layers, and candidate park sites can be evaluated in terms of their potential as groundwater recharge sites in addition to their potential for alleviating existing park congestion. Another example involves habitat restoration and/or conservation needs that, again, can be addressed together with park provision, by overlaying a habitat layer on top of the park layer. The layers can be queried such that locations of potential park sites that can also serve as suitable habitats for native wildlife or links (i.e. stepping stones) in an urban wildlife corridor can be identified and prioritized. Future work will also involve migrating the GVPP from the ArcIMS server to the ArcGIS server. The advantages of upgrading to ArcGIS include the ability to support multiple users simultaneously (as noted earlier) and greater stability for the GVPP website as a whole.

Currently, the developed system enables the user to convert a candidate park site into a park and observe how much this conversion would impact variations in access to parks in the neighborhood surrounding the selected parcel(s). Our future work will concentrate on growing this analysis system. In the extended approach, users will have the capacity to pick many candidate park sites and rank them based on their capacity for reducing inequities in access to parks. Some decision-makers and/or advocates may view the top-ranked parcels as the best candidate site (s) in their neighborhood. We will also need to update GIS data layers as new ones become available – this need is perhaps best illustrated by the current reliance on the 2000 Census for demographic information in a rapidly growing and changing urban area like the Los Angeles Metropolitan Region.

Acknowledgments

The Green Visions Plan Project has been funded by a consortium of public agencies led by the San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy and implemented by the USC Center for Sustainable Cities and USC GIS Research Laboratory. We also thank the California Department of Fish and Game for permission to use the basic map viewer and the technical guidance they provided as the GVPP was constructed.

References

- Bhaduri, B., Bright, E., Coleman, P., & Dobson, J. (2002). LandScan: Locating people is what matters. *Geoinformatics*, 5, 34–37.
- Bhaduri, B., Bright, E., Coleman, P., & Urban, M. (2007). LandScan USA: A high-resolution geospatial and temporal modeling approach for population distribution and dynamics. *Geojournal*, 69, 103–117.
- Bhargava, H. K., Power, D. J., & Sun, D. (2007). Progress in web-based decision support systems. *Decision Support Systems*, 43(2007), 1083–1095.
- Burrough, P. A., & McDonnell, R. A. (1998). *Principles of geographical information systems*. New York, NY: Oxford University Press.

- Cai, Q., Rushton, G., Bhaduri, B., Bright, E., & Coleman, P. (2006). Estimating small-area populations by age and sex using spatial interpolation and statistical inference methods. *Transactions in GIS*, 10, 577–598.
- Culshaw, M. G., Nathanail, C. P., Leeks, G. J. L., Alker, S., Bridge, D., Duffy, T., et al. (2006). The role of web-based environmental information in urban planning—The environmental information system for planners. *Journal of Science of the Total Environment*, 360(1–3), 233–245.
- Dymond, R. L., Regmi, B., Lohani, V. K., & Dietz, R. (2004). Interdisciplinary web-enabled spatial decision support system for watershed management. *Journal of Water Resources Planning and Management ASCE*, 130(4), 290–300.
- Gahegan, M., & Lee, I. (2000). Data structures and algorithms to support interactive spatial analysis using dynamic Voronoi diagrams. *Computers, Environment and Urban Systems*, 24(6), 509–537.
- Ghaemi, P., Swift, J. N., Goldberg, D. W., & Wilson, J. P. (2006). Prototype geographic search and query tools for a library digital archive. *ArcUse*, 9(2), 30–32.
- Karnatak, H. C., Saran, S., Bhatia, K., & Roy, P. S. (2007). Multicriteria spatial decision analysis in web GIS environment. *Geoinformatica*, 11(4), 407–429.
- Patterson, L., Urban, M., Myers, A., Bhaduri, B., Bright, E., & Coleman, P. (2007). Assessing spatial and attribute errors in large national datasets for population distribution models: A case study of Philadelphia County schools. *GeoJournal*, 69, 93–102.
- Patterson, L., Urban, M., Myers, A., Bhaduri, B., Bright, E., & Coleman, P. (2009). The effects of quality control on decreasing error propagation in the LandScan USA population distribution model: A case study of Philadelphia County. *Transactions in GIS*, 13(2), 215–228.
- Pearce, J. (2000). Techniques for defining school catchment areas for comparison with census data. *Computers, Environment and Urban Systems*, 24(4), 283–303.
- Peng, Z.-R., & Tsou, M.-H. (2003). *Internet GIS. Distributed geographic information services for the internet and wireless networks*. John Wiley and Sons (p. 336).
- Plewe, B. (1997). *GIS online, information retrieval, mapping, and the internet* (p. 336). Santa Fe NM, OnWord Press.
- Rao, M., Fan, G., Thomas, J., Cherian, G., Chudiwale, V., & Awawdeh, M. (2007). A web-based GIS decision support system for managing and planning USDA's conservation reserve program (CRP). *Journal of Environmental Modelling & Software*, 22(2007), 1270–1280.
- Rinner, C. (2003). Web-based spatial decision support: Status and research directions. *Journal of Geographic Information and Decision Analysis*, 7(1), 14–31.
- Sheng, J. (2007). Evaluating hydroclimatic systems across large metropolitan areas. Unpublished Ph.D. Dissertation, Department of Geography, University of Southern California.
- Sheng, J., & Wilson, J. P. (2008). *The green visions plan for the 21st century. 16. Watershed assets assessment report* (p. 98). Los Angeles, California: University of Southern California GIS Research Laboratory and Center for Sustainable Cities.
- Sheng, J., Wilson, J. P., Chen, N., Devlinny, J. S., & Sayre, J. M. (2007). Evaluating the quality of the national hydrography dataset for watershed assessments in metropolitan regions. *GIScience and Remote Sensing*, 44, 1–22.
- Simão, A., Densham, P. J., & Haklay, M. M. (2008). GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites. *Journal of Environmental Management*. doi:10.1016/j.jenvman.2007.08.032.
- Sister, C., Wilson, J., Wolch, J., Swift, J., & Ghaemi, P. (2007). *The Green Visions Plan for the 21st Century. 15. Park Congestion and Strategies to Increase Park Equity* (p. 31). Los Angeles, California: University of Southern California GIS Research Laboratory and Center for Sustainable Cities.
- Sister, C., Wolch, J., Wilson, J., Seymour, M., Linder, A., Byrne, J., et al. (2007). *The Green Visions Plan for the 21st Century. 14. Parks and Open Space Resources in the Green Visions Plan Area*. Los Angeles, California: University of Southern California Center for Sustainable Cities and GIS Research Laboratory.
- Sugumaran, R., Meyer, J. C., & Davis, J. (2004). A Web-Based Environmental Decision Support System (WEDSS) for Environmental Planning and Watershed Management. *Journal of Geographical Systems*, 6, 307–322.
- Sugumaran, V., & Sugumaran, R. (2005). Web-based spatial decision support system (WebSDSS): Evolution architecture and challenges. In *Third annual SIGDSS pre-ICIS workshop designing complex decision support: Discovery and presentation of information and knowledge*, December 11, Las Vegas, Nevada (p. 22).
- Swift, J. N., Stepp, J. C., Bobbitt, J., Futrelle, J., Tiwana, S., Ali, M., et al. (2004). Information technology issues in the development of the pilot COSMOS/PEER-LL (Pacific Earthquake Engineering Research Institute (Berkeley) Lifelines Program). Geotechnical Virtual Data Center. Geo-Trans 2004, ASCE, UCLA, July 27–31.
- Wolch, J., Wilson, J. P., & Fehrenbach, J. (2005). Parks and park funding in Los Angeles: An equity-mapping analysis. *Urban Geography*, 26(1), 4–35.
- Zhu, X., McCosker, J., Dale, A. P., & Bischof, R. J. (2001). Web-based decision support for regional vegetation management. *Computers, Environment and Urban Systems*, 25(6), 605–627.
- Zimmermann, R., Bardet, J. P., Ku, W. S., Hu, J., & Swift, J. (2003). Design of a geotechnical information architecture using Web Services. In *Proceedings of the seventh world multi-conference on systemics, cybernetics and informatics*, Orlando, Florida, July 27–30.

Web references

- CARES (2003). A decision support system for planning and management of sustainable livestock production in the Midwest. <<http://cares.missouri.edu/Projects/Default.aspx>>. Accessed May 2009.
- DFG (2007). BIOS biogeographic information and observation system. California: Department of Fish and Game. <<http://bios.dfg.ca.gov>>. Accessed May 2009.
- Foot, K.E., & Kirvan, A.P. (2000). WebGIS. Unit 133. NCGIA core curriculum in geographic information science. <http://www.ncgia.ucsb.edu/giscc/units/u133/u133_f.html>. Accessed May 2009.
- GVP (2009). Green Visions Project Website. Green Visions Plan for the 21st Century. <http://gv-server.usc.edu/GVWebTools_public_v2/viewer4.16/signIn.asp>. Accessed May 2009.
- Tsou, M.-H. (2004). Present realities and the future of internet GIS. GIS development. <<http://www.gisdevelopment.net/magazine/years/2004/july/29.asp>>. Accessed May 2009.
- Wolch, J., Wilson, J.P., & Longcore, T. (2009). The green visions plan for the 21st century. <<http://www.greenvisionsplan.net/html/welcome.html>>. Accessed May 2009.