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The Future of GIS in Planning: Converging Technologies and Diverging Interests

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The Future of GIS in Planning

Converging Technologies and Diverging Interests

William J. Drummond and Steven P. French

Problem: Given that geographic information system (GIS) technology is evolving and becoming integrated with allied technologies, how should planners understand and use it to meet the needs of the profession?

Purpose: This article outlines important changes in geospatial technology to initiate a discussion of how the planning profession can best respond to these challenges and opportunities.

Methods: The article is based on a literature review and the authors' knowledge of current technology trends and how these trends are likely to affect planning practice and education.

Results and conclusions: The world of GIS is changing. With the advent of mass-market GIS, the needs of planners are less central than they were previously to commercial GIS vendors. However, there are exciting new opportunities provided by web-based systems and open-source geospatial software. Planners must move aggressively to grasp these new opportunities.

Takeaway for practice: The new web-based systems provide exciting opportunities to create new geospatial applications, especially in the area of public participation. New open-source GIS software will allow planners to assemble geospatial applications from functionality that is distributed across the web. Planning practitioners and academics should form alliances to develop the next generation of urban modeling and planning support software.

Keywords: GIS, geospatial, spatial analysis, web services, planning methods

Research support: None.

Over the past two decades, geographic information systems (GIS) have emerged from university laboratories into the heart of mainstream planning practice. During this period, planners have been aggressive adopters and adapters, and strong advocates for local governments deploying GIS. This is true at least in part because GIS provides spatial analysis and manipulation capabilities that align closely with the professional needs of urban and regional planners. Figure 1 shows that U.S. local governments adopted GIS technology slowly at first and then more rapidly as these systems became more affordable and as higher-resolution, detailed data became more available. As a result, GIS is now a standard item in planners' tool kits.

We have entered an era of ubiquitous data. Demographic, cadastral, and environmental data are now readily available for most metropolitan areas in the United States and many other places around the world. Because planners, public works departments, tax assessors, and others spent much of the 1990s amassing large, highly detailed data sets, GIS projects no longer begin by creating the necessary data from scratch. Data for many projects can be downloaded from state GIS clearinghouses, state or federal agencies, or local governments. While these readily available data may require some manipulation before they will be useable for a particular project, today's planners no more expect to key-in attribute data and to digitize maps than they expect to draw and code them with colored pencils.

GIS technology is currently converging with several other technologies to provide new levels of accessibility and functionality. As GIS use becomes more

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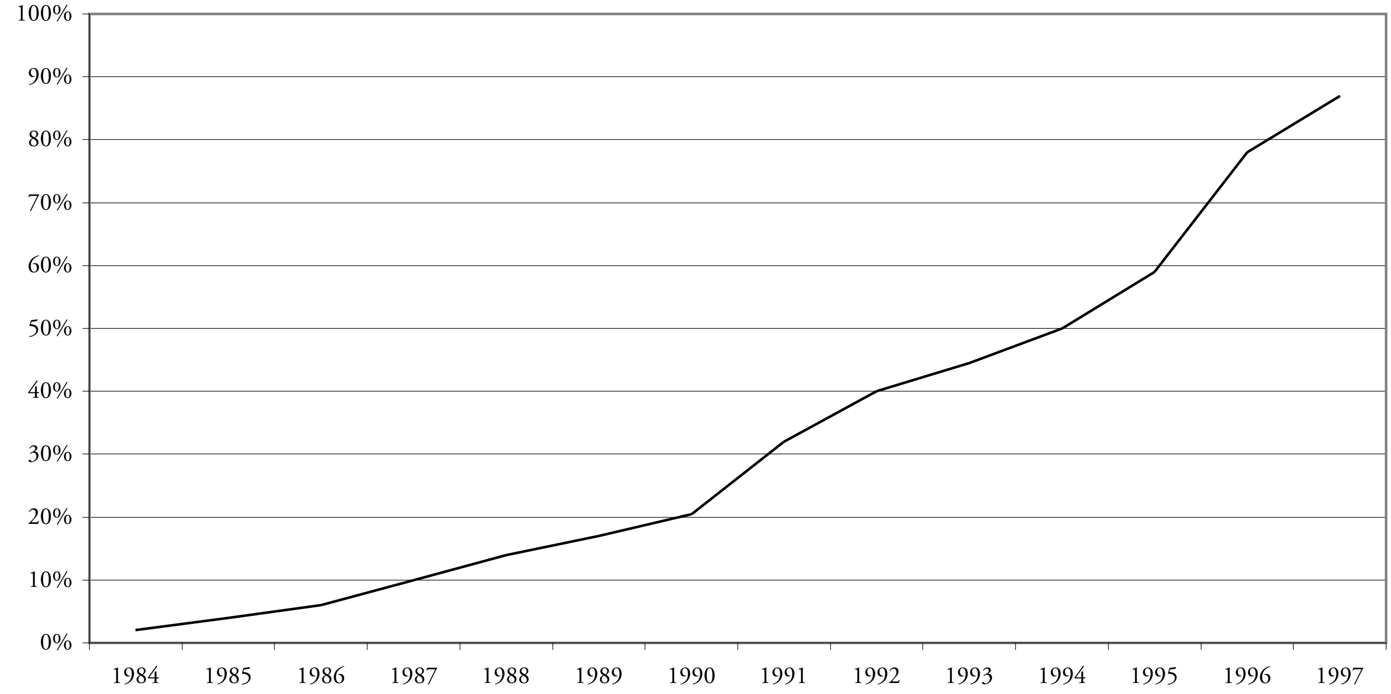

Figure 1. Cumulative percent of U.S. local governments adopting GIS, 1984 to 1997.

Source: This figure was originally published in Warnecke, Beatie, & Lyday (1998). The copyright belongs to the Urban and Regional Information Systems Association (URISA), and it is reprinted with permission. It was originally titled “First year of GIS software use (cumulative).”

widespread, planners make up less of the market. In this article we will describe these trends and suggest what they mean for the planning profession. Table 1 lists many of the terms and acronyms that we will use and their meanings.

Exactly how the relationship between planning and GIS will evolve over the next decade is, of course, highly debatable. We hope this article will catalyze that debate by providing an overview of current technology trends and proposing a reasonable strategy for adapting to this rapidly changing environment. Others may disagree about the importance of the trends we choose to highlight, or how planners should respond to them, but surely all planners agree that it would be better to actively shape our future with GIS than to be swept along by the wave of technology change.

In a classic article, Michael Teitz (1974) argued that planning methods are more than techniques; they can also be viewed as social phenomena. GIS methods are no exception. Advances in computing technology certainly proscribe or expand what is possible, but broad trends in social demand direct the development of GIS and other methods. GIS methods in particular have historically been applied in the relatively narrow social context of specific professions, which include city and regional planning, natural resource management, civil engineering, criminology, and public health among others.

Figure 2 shows the most important relationships among the factors that govern the development of GIS technology. A rapidly expanding technology base is transforming GIS, but this change is shaped by demand for particular functionalities, initially by planners and other professional users, but increasingly by a much wider group of users. For the most part, GIS has only limited effects on its own technological base and on the broader trends in social demand, but individual professions adopt and modify GIS methods, and are themselves partially shaped by the methods they embrace and use. Certainly planning practice today has been shaped by the widespread adoption of GIS technology. Some notable planning scholars even argue that GIS has distracted planners from developing more important and useful methods (Harris, 1989; Harris & Batty, 1993).

The Evolution of GIS

GIS was originally developed as an environmental technology. Roger Tomlinson (1998) coined the phrase

Table 1. Glossary of terms.

AAG (Association of American Geographers)	The professional society for U.S. geographers.
API (application programming interface)	A well-specified interface that defines how a software program can request services from a program or operating system.
CAD (computer-aided design)	A set of computer tools that partially automate the drawing and design process.
CIR (color-infrared)	A type of color film that records the photographic infrared radiation just beyond the range of human vision as red and is most often used to map or evaluate growing vegetation.
GPS (global positioning system)	A global navigation system created for the U.S. Department of Defense that uses 24 or more satellites orbiting the earth at an altitude of 12,000 status miles to provide very precise, worldwide positioning and navigation information 24 hours a day, in any weather.
IKONOS	The world's first commercial satellite to collect black-and-white images with 1-meter resolution and multi-spectral imagery with 4-meter resolution.
KML (keyhole markup language)	An API that allows users to add geo-referenced data layers to Google Earth.
LIDAR (light detection and ranging)	A type of aircraft-based remote sensing using laser-driven pulses of light and multi-spectral cameras to scan and process digital information about a landscape and to determine distance and position of the material from the return signal.
NSGIC (National States Geographic Information Council)	The organization that provides communication and coordination among state GIS agencies.
OGC (Open Geospatial Consortium)	An organization that advocates the development of non-proprietary GIS software and data formats.
ortho-rectified image	A satellite or aerial photographic image that has been digitally corrected to ensure ground features are depicted to scale using a specific spatial reference system. Other georeferenced layers, such as roads and streams, can be readily overlaid on top of the rectified image.
SAR (side aperture radar)	A coherent radar system that generates high resolution remote sensing imagery.
UCGIS (University Consortium for Geographic Information Science)	A consortium of leading universities engaged in GIS teaching and research.
URISA (Urban and Regional Information Systems Association)	A professional organization that includes GIS users from planning, geography, and other professions.
WFS (web feature service)	An Open Geospatial Consortium (OGC) protocol that uses formatted URLs to share vector data across distributed platforms.
WMS (web map service)	An Open Geospatial Consortium (OGC) protocol that supports data sharing and interoperability across distributed platforms.

geographic information system in the early 1960s when he led a project to map Canada's natural resources. During the same decade, Edgar Horwood, a professor of civil engineering and planning at the University of Washington, wrote some of the earliest computer mapping software, founded the Urban and Regional Information Systems Association, and conducted a number of highly influential short courses and conferences (Chrisman, 1998, 2006; Tomlinson, 1998).

The creation of modern GIS coincided with the environmental revolution of the early 1970s, and land suitability analysis was one of the primary applications. Manual techniques for analyzing land suitability can be traced back to the 19th century (Carr & Zwick, 2007). However, McHarg (1969) popularized the technique widely with his book *Design with Nature,* leading others to convert his physical method into computer-based, nascent GIS. Early applications of this method to planning problems

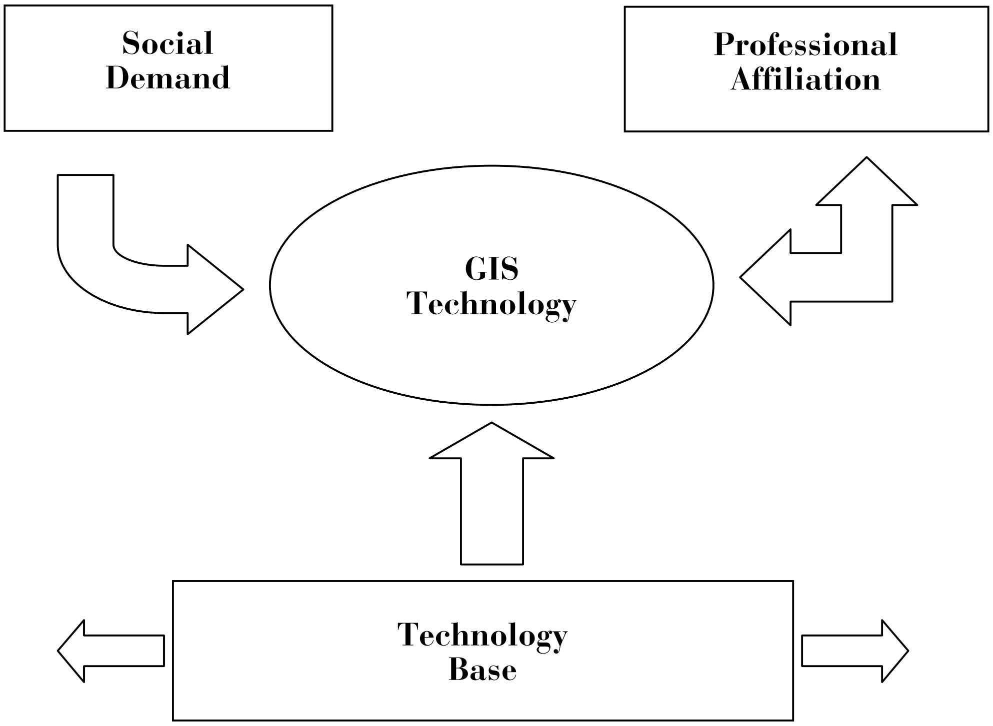

Figure 2. Factors shaping the evolution of GIS technology.

were demonstrated by Ingmire and Patri (1971) and Lyle and von Wodtke (1974).

Land suitability analysis is a specific instance of the general problem of integrating data by location. Over the next decade, researchers at the Harvard Laboratory for Computer Graphics and Spatial Analysis developed two different solutions to address this problem. The raster approach divided a study area into a matrix of regular grid cells and stored information for each grid cell. Programming a raster data structure was relatively simple, and developing overlay and buffer techniques was not difficult. The raster was also the native structure of data generated by the new Landsat satellites. The second, and competing, solution was the vector approach. Vector maps stored geospatial information as individual points, lines, and polygon objects linked to a database of attribute information rather than as information about every cell in a grid. This approach was much more difficult to program, and techniques such as overlay and buffer analysis were complex and difficult to run in a reasonable amount of computer time. However, these difficulties were eventually overcome with the use of topological data structures (Chrisman, 2006). Whenever today's internet users generate maps that combine street centerlines and aerial photography they are benefiting from decades of behind-the-scenes GIS data structure development.

The raster and vector approaches were developed at Harvard, and then commercialized by landscape architects who had the business acumen to form successful software companies. The early environmental applications of GIS are memorialized in the names of several of those companies. ESRI stands for Environmental Systems Research Institute, and ERDAS for Earth Resources Data Analysis System. However the commercial market for GIS as an environmental technology was limited.

GIS could not be sold to landscape architects, who found CAD (computer-assisted design) systems better suited to their design needs. GIS technology did find a home in several natural resource organizations, particularly the U.S. Geological Survey (USGS), the U.S. Forest Service, and a number of private timber firms. But the first really large-scale market for GIS software was provided during the 1980s by the country's 3,000 counties and 19,000 municipalities, in particular the tax assessors, city planners, and engineers within those governments. The fit between GIS and the needs of local planners was excellent. Planners had professional interest in environmental issues, long-term commitments to particular geographic areas, and access to governmental computing resources. They also understood maps and had pressing needs to conduct complex geospatial analyses that were beyond the capabilities of simple computer mapping programs (Dueker, 1987). Beginning with the 1979 edition, the standard land use planning textbook included land suitability analysis as a fundamental land use planning method, essentially replacing the previous recommendation to conduct a vacant land survey (Chapin, 1965; Chapin & Kaiser, 1979). Significant numbers of GIS systems were also sold to state and federal government agencies, but these markets were more limited than that of local governments.

Based on work begun in the 1960s, the U.S. Census Bureau developed the Geographic Base File-Dual Independent Map Encoding (GBF-DIME) file, which was fully deployed to support the 1980 census. It was comprised of street segments (and other linear features) that defined census blocks and all larger statistical reporting areas. Each line segment included address ranges, allowing address-based census responses to be located in their appropriate blocks. The DIME file was replaced by the Topologically Integrated Geographic Encoding and Referencing (TIGER) file for the 1990 and subsequent censuses. This basic topological data structure underpins the address matching, routing and direction applications available on the internet, global positioning system (GPS) devices and cell phones today.

In the early 1990s, GIS began expanding into the business market, and as GIS became available on personal computers it became viable for a much broader spectrum of business users (Castle, 1993). Industries with deep pockets and clear geospatial needs, such as public utilities, transportation companies, and logistics firms, were early adopters. However, GIS technology has not yet followed an accelerating S-curve penetration of business like the one it displayed in the government sector (Pick, 2005).

GIS software was originally developed as a specialized, proprietary application, with its own arcane scripting and programming languages (e.g., the Arc/Info macro language, AML) which isolated it from mainstream information technology (IT). In many local governments and universities, central IT departments focused on mainstream database management systems and office automation applications (e.g., word processing and spreadsheets) leaving those with geospatial needs to support their own applications. This severely limited the pool of potential GIS managers, developers, and programmers. However, in the last five years commercial GIS software has been moving toward more mainstream software development platforms. The speed, performance, and staffing benefits of merging GIS with mainstream IT dictate that large organizations store their data in relational database systems like Oracle and SQL Server. This also facilitates the integration of GIS with the large customer and inventory databases maintained by most firms and agencies.

In the 1990s, GIS was most often deployed as a stand-alone application on a single personal computer (PC) or workstation, but GIS has now moved to client-server architecture. In this configuration the programs that provide the GIS functionality reside on a central server and users access this server through client machines that submit their processing requests and receive the results back for display. The newly evolving web-services architecture is even more decentralized, in that its spatial analysis software functions can reside on machines that are distributed across the web. Common protocols for data exchange are necessary for this model to reach its full potential.

The new distributed software architecture has staffing implications that are likely to profoundly affect the relationship between the planning profession and GIS technology. The client-server model depends on expert IT professionals who work directly with the GIS software and data on centralized servers. These professionals create application programs that allow users to access and manipulate the server-based geospatial data. They must have advanced database management skills to configure, operate, and maintain the client system, and programming skills to create applications to support user needs. Typical users fall at the other end of the spectrum. They use the application programs developed by IT professionals to perform basic analysis functions, but have little influence on the design of the underlying databases, and may have only rudimentary GIS knowledge.

As GIS technology has become more complex, we have seen the emergence of a new class of practitioners: the GIS professional (GISP). A GISP focuses on the technology and its uses rather than a particular application of this technology, such as city planning. In 2002 the Urban and Regional Information Systems Association (URISA) created the GIS Certification Institute (GISCI), with education requirements that currently draw heavily on the University Consortium for Geographic Information Science (UCGIS) model curriculum. Since then the American Association of Geographers (AAG), National States Geographic Information Conference (NSGIC), and UCGIS have joined the certification institute. In February 2008 there were 1,920 certified GISPs practicing in the United States (GISCI, 2008). Many large enterprise GIS operations now employ specialists who combine knowledge of a particular field, such as planning or tax assessment, with GIS expertise. We believe organizations staffed with such domain experts, who understand GIS data and geospatial analysis as well as a substantive field such as planning, are well equipped to implement GIS successfully.

In another major change occurring over the past few years, GIS has moved directly into the mass consumer market. Car-mounted GPS units were one of the most popular Christmas gifts in 2007. These systems calculate location to within 10 meters to take advantage of GIS databases that include a very detailed street network, the ramp geometry of complex freeway interchanges, and location information on gas stations, restaurants, banks, stores, and major points of interest.

Internet-based map display and routing services, such as MapQuest, have been available since 1996, but over the last two years the major internet companies Google, Microsoft, and Yahoo! began providing free, web-based mapping services that include more GIS functions, such as aerial photography, three-dimensional views, and the ability to add user-produced data. Google Earth combines a stunning three dimensional interface with an elaborate keyhole markup language (KML) that allows individual users to publish their own vector and raster data on top of the standard Google Earth layers of aerial photography, satellite photography, roads, and political boundaries. Yahoo! Maps was the first major provider to offer a free web service allowing users to geocode up to 5,000 addresses at a time.

Underlying these achievements is fierce competition among these providers of location-based services. The combination of GPS, GIS, and wireless technology has created an immensely powerful advertising medium because it allows a person to use a cell phone or GPS to determine his or her location, report it over a wireless network, and then receive information specific to that location. This creates a huge potential market for advertising to users in specific locations. Mass-market applications have focused on a subset of GIS functions, emphasizing geocoding, routing, simple user interfaces, and visualization of data, but ignoring overlay analysis, buffer analysis, and other functions that were important to earlier environmental applications. We do not expect future demand will lead mass-market GIS to incorporate these latter functions.

The Expanding Technology Base

The early development and practical application of GIS was severely constrained by the need for processing power and storage sufficient to handle the large volumes of geospatial data associated with these systems. This required a mainframe or minicomputer platform into the 1980s. PC-based systems, such as Atlas*Graphics, provided thematic mapping capability that matched the scale and data resolution (e.g., census tracts) available at that time. In the late 1980s, PC ArcInfo offered limited GIS functionality on a PC platform (Levine & Landis, 1989; Wiggins & French, 1990). Fully functional GIS that supported polygon overlay and complex buffering, and was robust enough to handle municipal-scale parcel databases, still required a workstation with a UNIX operating system. Robust GIS became widely available on personal computers in the 1990s. Today, GIS functionality is available not only on desktops and laptops, but also on tablet and handheld devices, and is finding its way onto cell phones, personal data assistants (PDAs), in-car navigation systems, and other specialized devices.

While the increase in personal computing power has been important in making GIS available to a wider audience of users, even more important, a number of related technologies are rapidly converging to strengthen and extend GIS capabilities. These converging technologies include GPS, remote sensing, wireless communications, and the internet. The resulting combination of technologies is making GIS available to ever wider audiences and broadening the set of problem areas to which GIS can effectively be applied.

GPS

The GPS was originally designed and deployed by the U.S. Department of Defense to support the navigation requirements of its land, air, and sea forces. In the last decade, civilian use has exploded. GPS allows engineers and land surveyors to produce location information that is accurate to within one centimeter. Backpackers use the GPS to find their way in the backcountry, and geocachers use the system to follow clues in a form of electronic treasure hunt. Cars equipped with GPS technology allow drivers to find their way through unfamiliar cities and neighborhoods and plot alternative routes to avoid congestion.

Automobile-based GPS systems particularly depend on the detailed street networks and address ranges developed over the previous two decades, beginning with the U.S. Census Bureau’s GBF-DIME and TIGER files. GPS technology is also available on cell phones. Initially, this technology was added to allow 911 operators to locate emergency calls made from mobile phones, but location-specific commercial marketing applications that link a cell phone location to a GIS database to provide the user with a list of nearby stores, restaurants, or tourist attractions are now beginning to appear as well.

Remote Sensing

Remote sensing is the interpretation and analysis of aerial photography or satellite imagery to provide data about the earth's surface. Aerial photos from balloons became available in the mid-1800s. World War II greatly expanded the use of aerial photography and extended it beyond the visible spectrum. Color-infrared (CIR) film was originally developed to detect camouflaged military equipment. It now provides useful information for crop and forestry surveys. High altitude aerial photography was refined for reconnaissance during the Cold War and sensors were developed for a wider set of spectra (e.g., thermal imaging).

In 1972 the National Aeronautics and Space Administration (NASA) launched its first Landsat satellite. Seven Landsat satellites now collect visible and infrared imagery for 30-meter pixels, thermal imagery for 60-meter pixels, and 15-meter panchromatic (black-and-white) photography. More than 1.5 million Landsat images are available from the Earth Resources Observation and Science (EROS) data center. Successive Landsat images can be compared to track the expansion of urbanized areas over time.

Over the past two decades, civilians have gained access to high resolution aerial photography. The USGS National Aerial Photography Program (NAPP) has produced aerial photography consisting of 1-meter pixels for the entire United States, except Alaska. These images are orthorectified (see Table 1) so they can be combined with other GIS data layers. More recently the Department of Homeland Security has supported the collection of high resolution imagery for major metropolitan areas. The private firm Space Imaging has been selling 1-meter panchromatic and color imagery collected by its IKONOS satellite since 1994. High resolution digital imagery is now generally available for most metropolitan areas in the United States. It can provide a realistic backdrop for GIS data, be used to create inventories of features, such as roads, streams and buildings, and provide basic land use and land cover information to support a wide range of environmental analysis. Light detection and ranging (LIDAR) is providing highly accurate elevation information for flood modeling, and side aperture radar (SAR) is used in post-disaster damage assessments. Remote sensing is now providing nearly continuous, low-cost data collection for large areas of the globe.

Wireless Communication

Wireless communication has grown tremendously in the past decade. It is hard to remember that mobile phones were fairly exotic devices as recently as the early 1990s. Today they can be found in the backpacks of most high school students and they come in designer colors for teens and animal shapes for younger children. High-speed cellular data networks are now available in many metropolitan areas, allowing data communication in addition to voice. Most wireless providers now offer PC cards that provide broadband access for laptops over the cellular network. Communication is no longer tethered to telephone land lines or building-specific local area networks. Any computer can now be connected and share data in real time in any location that is served by the cellular network.

The Internet

The internet, or world wide web, is relatively simple in concept. At its core it is a set of protocols that support peer-to-peer communication. This allows computer users to publish data over the network, so they can be accessed by others. The internet provides access to the vast stores of information that have been collected by firms, agencies, and individuals. It has been possible to publish interactive maps over the internet for more than a decade. It is now becoming practical to provide a wider array of web-based geospatial analysis functions.

Web-based GIS provides basic GIS functions to users with browsers. The ability to pan, zoom, turn data layers on and off and, more importantly, to query and view attribute data linked to mapped objects, is widely available. More sophisticated techniques such as routing and point-in-polygon analysis are becoming available. This type of online mapping technology has been used to support local comprehensive planning efforts and interactive mapping of neighborhood indicators (Craig, 1998; Sawicki & Craig, 1996). Internet sites with these capabilities allow users to interactively map demographic and other data at the neighborhood level.

Commercial sites such as Google Maps and Microsoft's Live Search Maps (http://maps.live.com) provide detailed maps, aerial photos, business locations, and driving directions for the United States, Europe, and most major cities worldwide. These systems are possible because a rich set of imagery, street networks, and digital photos have been produced over the past decade. Several of these sites provide open application programming interfaces (APIs) that allow sophisticated users to add their own data and functions. This allows users to produce *mashups*, or applications that display user-generated content on top of the commercial site's data and take advantage of the site's display and query capabilities. Zillow.com combines Google Earth with tax assessor and real estate information to create a nationwide tool for real estate comparison shopping. Walkscore.com is a site that should be of particular interest to planners. It allows users to enter a street address, calculate a walkability score for that location, and view walkable destinations by type around that address. Wikimapia.com allows users to post location-specific notes and comments onto Google Earth, much as users provide the content for Wikipedia. This creates an opportunity for users to provide input about features or conditions at particular locations.

Several of these commercial sites are currently experimenting with replacing traditional two-dimensional maps with more realistic views of locations. Several sites have recently added bird's-eye views that provide perspective using oblique photography. Google Maps has added a feature that uses video shot from street centerlines. It is currently available for San Francisco, Los Angeles, Seattle, Denver, Chicago, Boston, and New York, but additional cities are continually being added. Figure 3 shows what looks like a simple photograph, but allows a person accessing http://maps.google.com and choosing the "street view" button to move through the block faces shown in the photo by pointing at the directional arrows on the street centerlines.

Google Earth and Microsoft's Live Search Maps allow users to navigate through realistic three dimensional buildings for selected areas, providing the user the perspective he or she would actually have in the urban environment. The buildings in Google Earth are based on digital photographs, while Microsoft's Live Search Maps uses three-dimensional CAD models (see Figure 4). While not all areas are covered, many major urban areas are currently available. These applications are moving GIS from traditional two-dimensional maps that can be difficult for non-technical users to inter-

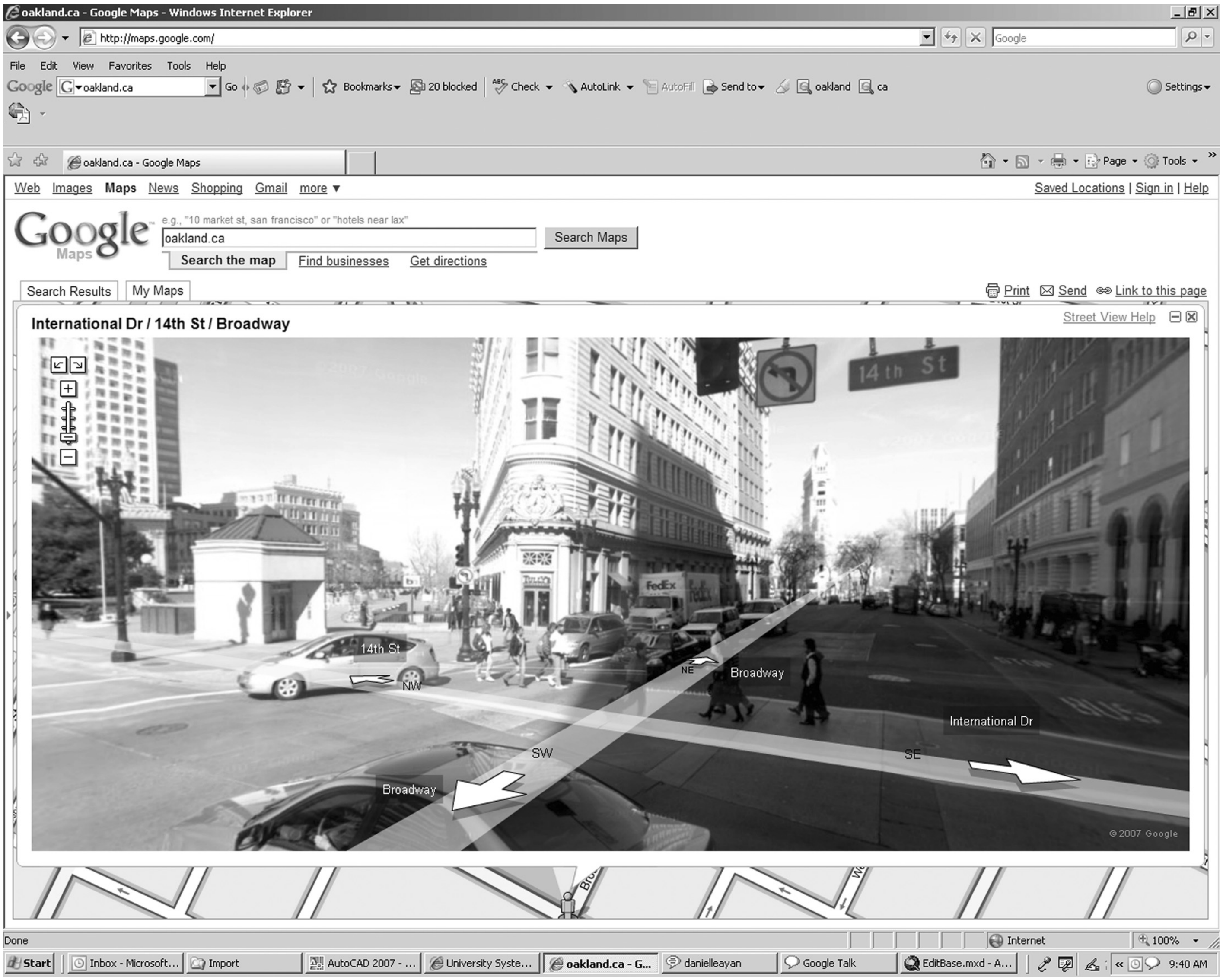

Figure 3. Google StreetView: Downtown Oakland, California.

Source: Google StreetView.

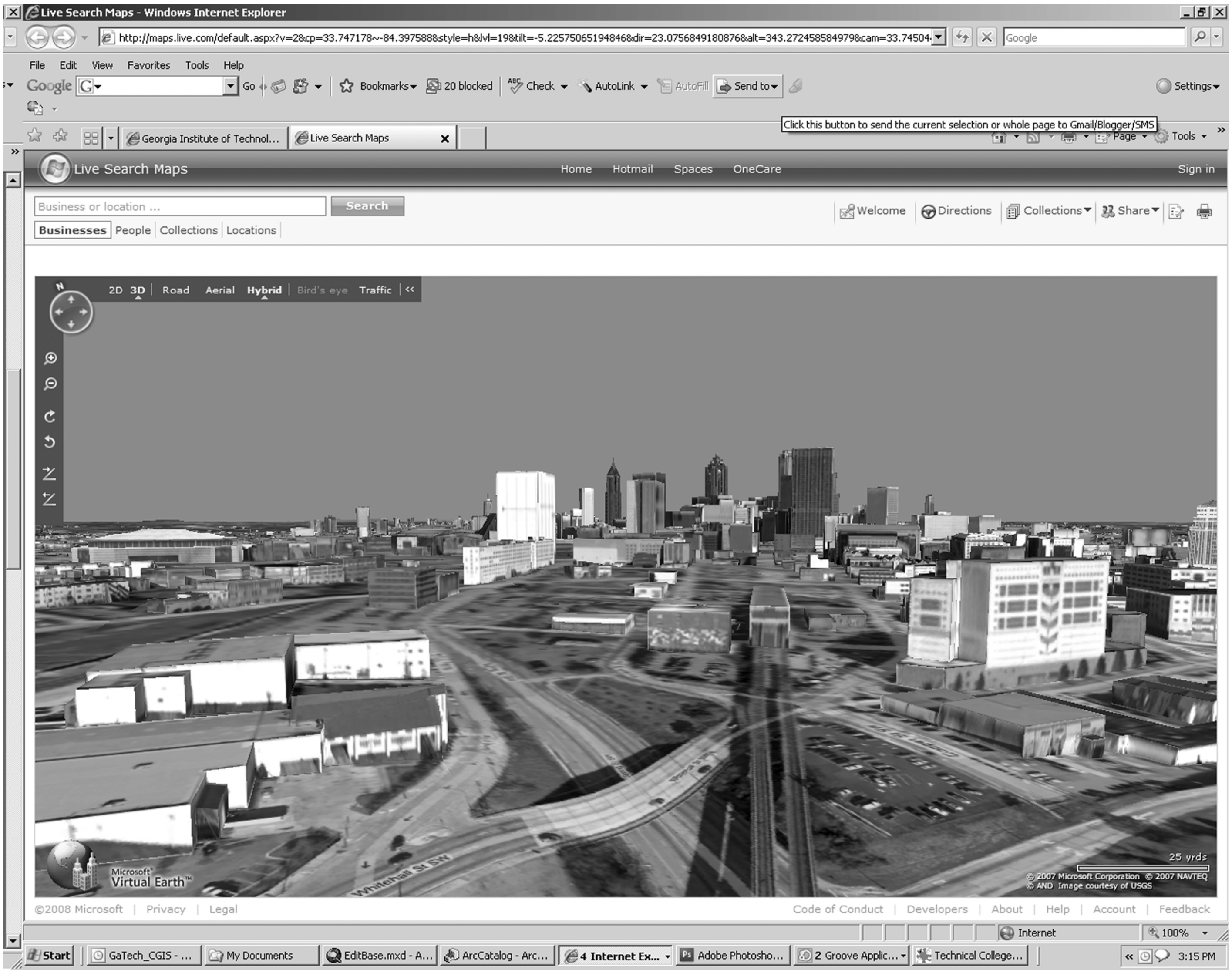

Figure 4. Microsoft Live Search Maps 3D View: Downtown Atlanta.

Source: Microsoft Live Search Maps. Reprinted with permission.

pret, to a three-dimensional, virtual-reality perspective. Whether these applications will be a more effective wayfinding tools than digital representations of traditional paper maps is still an open question, but they highlight how the interactive nature of the web is reshaping the ways we view and represent space, and they are stretching the definition of GIS.

The most exciting development is the emerging availability of web-based geospatial analysis functionality. On the commercial side, ArcGIS Server unbundles the functions of the widely used ArcGIS software package so they can be called and executed as web services by remote users. The Open Geospatial Consortium (OGC) has developed a number of protocols (GML, WFS, WMS; see Table 1) that support interoperable geospatial services. Online providers of mapping services such as Yahoo! and Google have published application interfaces that allow programmers to access certain GIS functions directly. One programmer has developed a web site (http://www.batchgeocode.com) that allows users to input a list of street addresses, submit them and retrieve latitude and longitude for each address. Once they are fully developed these web services will allow users assemble their own complex applications from spatial analysis functions distributed across the web.

Converging Technologies

GIS, GPS, remote sensing, wireless communication, and the internet are converging to create a highly connected world of ubiquitous data available to anyone, anywhere, anytime. This is not your father's GIS. Spatial location has become a commodity that can be packaged and sold in a variety of forms to support a wide array of new applications. GIS is evolving to meet the needs of this new world and the needs of the planning community are no longer vital to the evolution of this technology. The planning profession should become familiar with these new geospatial technologies and systematically explore how they can be used to support an array of planning activities.

GIS and the Planning Profession

As mainframe computers became available in the 1960s, planners, geographers, and regional scientists developed a number of large-scale models to simulate the growth of metropolitan areas. (For an excellent review of these models, see Klosterman, 1994.) These models proved difficult to build and calibrate and were not widely adopted for use in practice (Lee, 1973). Doug Lee's requiem notwithstanding, this urban modeling work continued in the academic world and eventually merged with GIS technology. (See, for example, Batty & Xie, 1994; Landis, 1994, 1995; Waddell, 2002; Wegener, 1994.) With the exception of metropolitan transportation planning applications, these models have largely stayed in university research labs because of their complexity and voracious appetites for input data.

A number of authors have argued for the development of planning support systems that would integrate GIS, urban, and environmental models and visualization (Brail & Klosterman, 2001). Harris and others (1989; Harris & Batty 1993) said there was a basic mismatch between the functions in a GIS and what planners really do. They saw GIS as more useful in management than in plan making, and called for the development of planning support systems that would extend the functions of GIS to meet planners' need for forecasting and scenario testing. French and Wiggins (1989) initially found that fewer than half of California planning agencies were using either GIS or thematic mapping software before 1987, though adoptions of GIS, CAD and thematic mapping systems surged between 1987 and 1989 (French & Wiggins, 1990). They also found that about half of the agencies that had some type of mapping system were using it in administrative and management activities, such as land parcel mapping, permit tracking, or zoning. And though such software fell far short of planning support systems, 60% of these agencies reported using their mapping systems in general plan preparation.

Klosterman (1997) suggested planning support systems be based on GIS, but also include additional tools to support economic, demographic and land use forecasting, environmental modeling and transportation planning. Klosterman's *What If?* planning support system incorporates the demographic and land allocation functions without the complexity inherent in most land use and transportation models (Klosterman, 2001). Vonk, Geertman, and Schot (2005) identified a number of impediments to the widespread adoption of planning support systems, including lack of awareness of such systems, lack of experience with them, and lack of recognition of their value.

A more recent development is the emergence of public participation GIS (PPGIS). Taking advantage of ubiquitous data, neighborhood and environmental groups have adopted GIS to support their advocacy activities (Carver, Evans, Kingston, & Thurston, 2001; Sawicki & Craig, 1996; Sieber, 2006). At their simplest, such systems make data available to neighborhood groups. More sophisticated systems can solicit input from participants about conditions, plans, and proposals (Talen, 2000), and link these comments to map locations when appropriate. Such systems begin to provide a framework for collaborative decision making (Shiffer, 1992). For example, the National Neighborhood Indicators Partnership (NNIP) aims to capture grassroots information on neighborhood conditions and make it available to neighborhood groups for use in community development activities. This democratization of information has empowered a number of nontraditional groups by providing them with GIS data and analysis capabilities. It offers an interesting avenue for the future evolution of GIS within planning.

Whither the Low End?

In the early days, a self-taught, computer-savvy planner could get some census data, do a few calculations, and amaze colleagues by producing a set of thematic maps. Though the learning curve was initially steep, it flattened rapidly, and the overhead for setting up a system was fairly low. Practicing planners could and did build and maintain fairly complex systems that met the needs of their jurisdictions. Those days are gone. The new systems require too much technical support and staff training to be cost effective for simple thematic mapping exercises. High-end users will always want the power of a full-fledged GIS on their desks, but much of the demand for low-end applications will be met by web-based services. For example, Fannie Mae's Dataplace (http://www.dataplace.com) allows users to make a wide range of thematic maps using census and housing data. So, just as it is becoming more expensive to support robust GIS locally, many basic GIS functions are becoming available over the web. This broadens access to GIS, but only to those capabilities that can be supported by a third-party web site.

As the GIS community divides into technology experts and mass-market users, planners must develop a new relationship to GIS technology. If planners are users only, GIS systems will probably not evolve to support planning analysis. Yet only a small proportion of planners are likely to develop the skills to become GIS technology experts. Should we continue to train planners to make thematic maps with stand-alone GIS software, leaving system design and management to specialized GIS professionals who possess only limited knowledge of planning? Or should planning programs teach the advanced database-management and application-programming skills that will allow planners to be full participants in the design, development, and operation of advanced GIS? We believe there is a middle path that will require new skills, but will allow planners to tailor the evolving web-based systems to meet their needs.

Users desiring more direct control of their computing resources created the personal computer revolution. Few would argue that we should return to the miserable level of service planning departments received from their central data processing departments before the advent of the personal computer. If all planners in the future were users only, it is unlikely that the GIS experts would understand or adequately serve our professional needs.

Few, if any, academic planning programs are currently staffed to meet this challenge, and relatively few planning students have the inclination to become database management and application programming experts. If planning programs continue to train their students to be GIS users only, developments in GIS and the planning profession will likely diverge and the two will evolve independently. Each may remember their early affinity fondly, but they will move on with their separate lives. This could pose a problem for planning. To know whether that is likely, we should define what planners might want from GIS in the future.

What Might Planners Want From GIS in the Future?

To think broadly about what is possible, we return to Michael Teitz's 1974 article on planning methods. Teitz argued that planners commonly use at least three fundamental conceptual perspectives: *analysis*, *design,* and *process*. *Analysis* includes observation, data collection, and data manipulation. *Design* involves creativity, the invention of new forms, and the generation of new ideas. *Process* focuses on the procedures used to achieve a specified set of ends. One way to determine what planners might want from GIS would be to adopt Teitz's three conceptual modes as a framework for assessing the past and potential future contributions of GIS to planning.

Traditionally, GIS's greatest contribution to planning has been in the area of analytic thinking. It has greatly eased the task of collecting and manipulating mountains of geospatial data. GIS analysis techniques, such as overlays, buffers, routing, and gravity models, are now a routine part of the planner's toolkit. In today's world it is almost unthinkable to develop any type of plan without using GIS. Yet, we can think of even more ways in which GIS might support planners' analytic capabilities.

For example, there is still significant room for improvement in modeling in planning. Most urban models have focused on forecasting the amount and location of urban growth, but another class of models is evolving to estimate the consequences of such growth. Index and CommunityViz are two GIS-based software tools that provide users with the ability to estimate the land consumption, traffic, and environmental impacts of plans and proposed development projects. HAZUS-MH, developed by the Federal Emergency Management Agency, is a GIS-based model that estimates the physical damage and the resulting social and economic impacts of floods, hurricanes and earthquakes (For a full description, see http://www.fema.gov/plan/prevent/hazus/index.shtm). Although it was initially developed by the structural engineering community, this model produces impact measures that can be useful to planners.

Guhathakurta (1999) has made significant progress toward linking urban simulation and environmental systems models, including traffic impact models, stormwater models, fiscal impact models, social impact models, and various kinds of economic models. If these can be seamlessly integrated with GIS they will permit planners to evaluate alternative development proposals rapidly, perhaps in real time. This will move us toward robust planning support systems that allow planners and stakeholders to better understand the consequences of alternative courses of action. There are a number of efforts underway to produce such systems, but to date the vision remains elusive.

Planners might also want GIS to provide more sophisticated three-dimensional display tools, to better help citizens, developers, and elected officials visualize different development scenarios. For example, it should be possible to portray how a jurisdiction's current zoning map and zoning regulations would look in three dimensions if fully built out. Comparing this with alternatives showing planning scenarios with different levels of growth might surprise even planners who know the area well.

In contrast to its uses for analysis, GIS has in the past been much less successful in supporting design. In fact, designing with GIS may be more difficult than using traditional paper-and-pencil methods. Within the rigid bounds of traditional GIS data structures it is virtually impossible to sketch, experiment, or doodle. Yet there are promising developments. Tablet personal computers provide a much friendlier hardware platform for design, and the recent ArcSketch extension for ArcGIS may help integrate informal drawing into the GIS world. It would be wonderful, for example, if a sketch-friendly GIS design interface allowed planners to explore alternative designs, then quickly model the fiscal, traffic, and environmental impacts of each alternative. Or if at the metropolitan level planners could sketch broad alternative patterns of future development, then run a large-scale urban model to estimate the air pollution or traffic congestion effects of each alternative.

In the area of process thinking, traditional GIS has not yet made a significant contribution. PPGIS has focused primarily on soliciting input in the plan making process. If the ethos of PPGIS could be married to the distributed platform provided by internet GIS, the combination could potentially support unprecedented levels of citizen participation. There are now multiple software environments that allow plans and other geographic datasets to be published on the internet with basic pan, zoom, and query capabilities. If such systems supported two-way communication between citizens and planners, planners could conduct virtual charrettes. Several alternate plans would be published on the internet. Citizens could submit spatially referenced comments, and planners could respond to those comments, perhaps interactively during a certain designated time period. The comments could then be vetted and published as a new GIS layer, so that residents could review both the plan and the comments for their neighborhood. Imagine how a tool like Wikimapia could be extended to support a dialog about a community and its future.

Initially, planners could use available resources like Google Earth to create mashups that could support such a vision of the planning process. Citizens could provide textual input about alternative scenarios and even tie their comments to specific locations. At a more sophisticated level, users could create their own maps and plans and post them for consideration and discussion. Such systems could significantly enhance the current state of the art for public participation and improve the quality of civic dialog during the planning process.

GIS-based systems could also be used to support negotiations between neighborhood groups and developers over large projects, especially on infill sites. Three-dimensional visualization tools could help neighborhood groups understand exactly what is being proposed. Such a tool should allow users to navigate freely through a three-dimensional model of the project in real time at a public meeting, as well as allowing users to change the footprint, height, and material of proposed buildings in real time to allow them to visualize potential modifications to the proposed project. But such a system should also link to a set of integrated impact assessment models so that as the model of the project is modified, the system calculates changes in traffic, stormwater runoff, school children, and fiscal impact. Such project-level GIS tools would be invaluable as planners, developers, and neighborhoods wrestle over proposals for infill development.

Strategic Recommendations

Given GIS's recent move to a client-server model and the likelihood that mass-market GIS will become less responsive to the needs of planning, how might planners engender ambitious extensions of current GIS capabilities? We make four suggestions, one for the short term and three for the long term.

In the short term, planners should focus immediately on the extraordinary promise of marrying PPGIS with internet GIS. This will require GIS-savvy planners to move beyond commercial GIS software into the unfamiliar and rapidly changing world of XML, web-based services, and direct application programming. It will also require participation-savvy planners to experiment with new technologies and radically different modes of participation. This transformation has already begun, as forward-looking planning entities publish GIS input data, analysis results, and proposed plans on their web pages, using online versions of traditional GIS software. Unfortunately, using traditional GIS for this purpose is slow, difficult to implement, and much more difficult to use than the online mapping services provided by Yahoo! and Google.

Thus, planning entities should move toward soliciting relatively simple citizen input, using web-based GIS to link locations to citizen-generated text, photographs, and graphics. These inputs should probably be moderated, but once screened they could be published, perhaps with planners' comments attached, to cultivate an ongoing, two-way, spatially referenced conversation between citizens and planners. Eventually, we envision citizens sketching their own plans with associated data, perhaps conducting their own GIS analysis with buffering, polygon overlay, and land suitability analysis.

The next three suggestions address the longer term. First, since all professional planners have access to personal computers, spreadsheets, and relational databases, very few learn any computer programming. By and large this has been a positive development, but virtually any user-initiated extension of GIS currently requires a working capability in a programming language such as Python, Visual Basic, or C++. Moreover, successful extension of internet-based GIS depends on understanding standards such as XML. Certainly not all planners, and not even the majority of planners, need programming skills. But if the commercial GIS industry does not continue to respond to planners' needs, it will be necessary for planning students specializing in GIS to develop some level of programming or scripting skills. Fortunately, it is now easier to develop basic scripting and web service skills than it was to master the traditional programming required by earlier forms of GIS. Whether academic planning departments teach these skills or obtain them from allied fields will vary by institution. In the long run we hope that the new planning domain experts will be able to upgrade their experimental one-off GIS tools into polished, distributable applications that jurisdictions with less in-house computer expertise can deploy successfully.

Second, the GIS wing of the open-source software movement (http://www.opensourcegis.org) provides a broad range of fascinating, but chaotic, and somewhat bewildering alternatives to the world of commercial GIS. We recommend that public-sector planning agencies allow their GIS specialists to use and develop open-source tools on projects in order to encourage the creation of open-source GIS alternatives to commercial GIS products.

Third, there is the issue of money. For two decades our profession has received major benefits from investing time, effort, and money into GIS hardware and software. However, such investment becomes less appealing if future commercial GIS providers will be less responsive to our needs. Thus we suggest two possible means of funding the future development of planning-related GIS. First, academic planners should form alliances with colleagues in civil engineering, environmental engineering, and computer science. Visualization is a vibrant branch of computing, and civil and environmental engineers receive external support for the development of elaborate GIS-based models. Planners participating on interdisciplinary visualization and GIS teams could provide interesting problems, extensive data, dedicated students, and a supportive professional community. Second, many historic large-scale urban models resulted from cooperation between planning agencies and university-based planning programs. Planning agencies could redirect funds they now spend on commercial GIS and commercial land use and transportation models to support a new generation of such professional-academic alliances. Academic planning programs willing to build the necessary expertise for this effort could develop new GIS analysis, design, and participation tools if local and regional planning agencies provided funding and a real world application environment. If universities and governments committed to such a program they would be investing in the futures of cities and of the planning profession.

Only recently has GIS become a major battleground for software firms with billions of dollars of available cash and the intent to dominate the next generation of software development. This monumental change in the GIS landscape has just begun to transform the cozy, longstanding, mutually beneficial relationship between planning and GIS. The danger is that planners could become as irrelevant to the future of GIS as we now are to operating systems, word processors, and spreadsheets. However, if we are nimble enough to seize these new opportunities we should be able to shape our own future with GIS rather than being swept along, or in the worst case, swept aside.

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Comment on Drummond and French: Another View of the Future of GIS

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There is no question that geographic information systems (GIS) have become extremely important tools for professional and academic planners over the last 20 years. However, it is less clear how they will and should be used by planners in the future. Drummond and French have some interesting things to say about this. I'd like to provide a more optimistic view of the role that GIS will play in the future of planning, and propose other strategies for taking advantage of the potential it offers planning research and practice.

To begin, it is important to recognize that we are witnessing a second revolution of computer use in planning. Computers first entered planning 40 years ago along with a widespread belief that scientific and computer-assisted methods could solve society's most pressing problems. This optimism was reflected in two influential issues *JAPA* (see Voorhees, 1959, and Harris, 1965), and a number of ambitious, expensive, and unsuccessful attempts to build