Information Technology, Spatial Analysis, and Comparative Urban Research

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San Francisco State University

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New information technologies have made it possible for faculty and students in urban and regional planning to find and display spatial information on cities and regions around the world in map form. Often they can download original spatial and attribute data associated with map features for re-analysis or use in combination with other data. Increased availability of high quality urban data and advances in Geographic Information Systems (GIS) and related technologies have revolutionized the way in which urban spatial data—including comparative data—can be analyzed.

This paper summarizes recent advances in information technology that are most important for understanding cities and regions worldwide, suggests how theoretical approaches to pedagogy from the emerging fields of GIScience and spatially integrated social science are significant to planners, summarizes major themes appropriate for comparative urban research, and describes an approach to teaching urban planners how to integrate the new information technologies for spatial analysis and data visualization into their teaching and research.

The last five years has seen an exponential increase in the amount of high quality digital data on cities and regions, a revolutionary transformation in planners' ability to find and access digital spatial data, and dramatic advances in analytic software for understanding, managing, and planning urban space.

Understanding physical space is critical for land use, transportation, environmental, and regional planning as well as other planning specialties. To implement growth management plans, achieve more sustainable development, and make smart growth work, physical planners must understand current land uses and plan for how much land, where, is needed for different uses in the future. Transportation planning requires planners to understand transportation networks. Environmental planners must understand the physical environment in order to set aside sufficient land for parks and open space, design with nature, and make habitat conservation plans. Regional planners need to understand the spatial dynamics of entire metropolitan or natural regions.

Digital tools for comparative urban research

The use of spreadsheets, web resources, statistical packages, computer-assisted design (CAD) software, computerized econometric and transportation modeling, and other computer skills are now taught in city and regional planning programs everywhere in the world (LeGates, 2006a). However, the maturation and convergence of three information technologies in the last five years—GIS and related software, web-based resources, and software for creating and manipulating digital images—have created a new environment for comparative planning pedagogy.

GIS technology

Much of the revolution that GIS software has created in our capacity to do spatial analysis has occurred within the last five years. Planning faculty and students can now learn GIS concepts and operations using texts that use substantive urban planning material to teach GIS (Huxhold, Fowler, and Paar 2004; Mantay and Ziegler 2005; Greene and Pick, 2005, LeGates 2005c; Pamuk forthcoming).

During the last five years there have been four GIS trends with profound implications for comparative urban research: (a) the exponential growth in the use of GIS, (b) greater interoperability among GIS file formats and application software, (c) the convergence of GIS with CAD and remote sensing, and (d) the emergence of web-based GIS resources.

The first major trend in comparative spatial urban research is the exponential growth in the use of GIS. The number of professors, academic researchers, and professional planners using GIS worldwide has grown rapidly in the last five years. Professional associations and academic conferences related to GIS continue to grow worldwide. In the summer of 2005, the ninth major international conference on computers in urban planning and urban management (CUPUM), organized by the Centre for Advanced Spatial Analysis (CASA) at University College, London, took place in London and ESRI's 25th annual international users conference attracted more than 14,000 participants, with representatives from all over the world. This proliferation of organizations and conferences facilitates comparative urban research by allowing researchers with similar interests to meet and share information.

A second important trend for comparative spatial urban research is the increased standardization of GIS. More standardized spatial data infrastructure and greater interoperability are facilitating comparative spatial urban research. In 1994 President Clinton signed executive order 12906, which required the United States to create a national data infrastructure to rationalize the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data (Executive Order 12906 1994). Under the direction of OMB's Federal Geographic Data Committee (FGDC) a national spatial data framework for the United States has been developed as a result of executive order 12906. Many countries and regional groupings of countries have either completed or are working on spatial data infrastructures modeled on the U.S. example. GIS file formats are becoming standardized and software translation tools to convert file formats are improving. It is increasingly easy to re-project spatial data so that data in map projections from different countries can be combined.

A third major trend that is particularly important for comparative spatial urban research is the increasing convergence of GIS with two other technologies—computer-assisted design (CAD) and remote sensing. Most architects and many planners educated in the last decade use CAD software. Like GIS, CAD software digitally represents spatial features, but does not offer users the ability to manipulate and analyze the underlying data to the extent GIS does. CAD systems have been widely used by cities to digitally represent land parcels, streets, utility networks, and other urban spatial data. TransCAD, a software program that combines aspects of CAD and transportation modeling, is now widely used in transportation planning. GIS software can now read CAD files, making it possible for researchers to use existing CAD-format data without having to recreate it from scratch in a GIS.

Remote sensing involves technologies to take aerial photographs and satellite images. Today, digital aerial photos can be rectified to create digital orthophotos that can be aligned with GIS layers and used as a base layer in GIS analyses. Overlaying digital orthophotos of different cities and regions and analyzing differences among them is a particularly fruitful avenue for comparative urban research. Grid-based population estimation is improving. For example, it may be possible to estimate the population of a third-world city by analyzing lights in a high-resolution satellite image. Geographers and planners can create a grid of the earth's surface and assign night satellite imagery to cells on the grid. While it is not possible to precisely specify population based on this kind of indirect data, image analysis of the individual grid cells makes it possible to estimate population, perhaps more accurately than official censuses. The accuracy of estimates depends on the resolution of the satellite imagery and the size of grid cells. This type of research is particularly important in developing countries that have poor quality census data and in countries that do not make census data available.

A fourth major trend with profound implications for comparative urban research is the development of web-based GIS resources. Two aspects of this development are important for comparative urban research. The technology for placing maps on the web in a form where they can be manipulated by users without GIS software now permits users to perform simple GIS operations such as zooming in on an area of interest, panning, turning data layers on and off, and opening attribute tables associated with maps. Users who are not familiar with GIS—including beginning students in urban planning—can obtain comparative urban data directly from the web and tailor it to their own interests. Social Explorer, developed by City University of New York sociology professor Andrew Beveridge, allows users to access maps of New York City and display the demographic composition of census tracts over time (http://www.socialexplorer.com/home/home.asp). Users can specify ethnic groups for display and zoom in on neighborhoods of interest. The United States Environmental Protection Agency (EPA) Enviromapper program (maps.epa.gov/enviromapper) allows users to navigate to a state, county, city, or neighborhood and add layers showing any combination of superfund sites, sites where hazardous waste is handled, sites of toxic releases, and sites where pollutants have been discharged into the air or water. The David Rumsey historical map collection website (http://www.davidrumsey.com/) provides viewers access to thousands of historical maps and online tools to view them in different ways, such as simultaneously viewing the same area of a city at different historical periods. For the San Francisco Bay Area, Boston, and Washington D.C. viewers can watch a series of maps of cities or particular neighborhoods evolve over time by sliding a slider bar on the computer screen—a powerful feature for comparative urban research. It is probable that many more spatial data websites of interest to students of comparative urban research, like those pioneered by Rumsey, Beveridge, and the EPA, will soon be available with functionality approaching full-featured GIS software.

Of greater immediate importance for purposes of comparative urban research today is the online availability of free, public-domain, primary spatial data that can be re-analyzed or combined with other data. Cataloguing systems and search tools to access this data are improving quickly. Many organizations have developed spatial information libraries with front-end portals as one-stop sites for searching and retrieving spatial data (Tang 2005). For example, the U.S. Census Bureau's American Fact Finder website (http://factfinder.census.gov/) allows users to download demographic, housing, economic, and other census data. Users can specify variables of interest for any part of the United States for different census areas including blocks, block groups, census tracts, urban places, and counties. The U.S. Geological Survey website (http://www.usgs.gov/) provides access to digital raster graphics (scanned images of topographic maps), digital elevation data, digital orthophotos, and land cover data. California, New York, New Jersey and other states have excellent state spatial data archives and portals.

New three-dimensional, web-accessible repositories of digital data that appear as "digital earths" and software tools called geobrowsers or geoexplorers such as Google Earth and ESRI's ArcExplorer promise to further revolutionize data searching and sharing. These technologies are just emerging and the underlying computer languages in which they are written, the distribution of functionality between servers and clients, and levels of licensing to access or share data and other fundamentals remain in flux. Their capabilities will surely evolve rapidly. It is not certain whether Google Earth or some other version of a digital earth created by ESRI, Microsoft, or another company will be universally embraced or multiple "digital earths" with different standards and content will continue to co-exist. But it is certain that more spatial data will be shared in this format in the future.

Other technology to digitally represent urban space.

In addition to GIS, related information technologies for visually representing spatial relationships have evolved rapidly with profound implications for comparative urban research.

The ability to take and edit digital photographs is evolving rapidly. The power and sophistication of digital cameras is increasing each year as prices drop. Software like Adobe Photoshop allows relative amateurs to edit digital images on personal computers. Illustration software like Macromedia Freehand and Adobe Illustrator make it possible to create and manipulate line drawings and other images. Faculty and students can assemble multi-media visual images or conference posters combining text, maps, photographs, data graphics, tables, and the output of statistical packages in illustration and desktop publishing software, or even PowerPoint.

Planners familiar with statistical packages like the Statistical Package for the Social Sciences (SPSS), SAS, or STATA and who know how to create data graphics using a spreadsheet like Excel, a statistical package, or a GIS can visually represent aspects of spatial data underlying maps as data graphics. Important pedagogical objectives in teaching planning students data analysis and communication skills are to make sure that they understand how to exploit the visualization capabilities of statistical package, GIS, and data graphics software to illuminate different facets of the same data and communicate the results visually. Some planning programs now teach students how to work with data graphics, maps, and other visual material. For example the University of Illinois at Chicago's Great Cities Urban Data Visualization Lab offers a series of seminars that provides students and professionals with little or no prior experience with practical graphic design instruction on how to produce professional maps and data graphics from GIS, CAD, Excel, and other sources. Further information on this program is available at http://www.uic.edu/cuppa/udv/people.htm

New conceptual frameworks for understanding the digital revolution

Given the complexity and rapid change in information technologies related to analysis of urban space, urban planning professors and students must grapple with the issue of how to understand the technologies and define the appropriate extent of technical knowledge to master.

Some scholars teaching geography and technical aspects of GIS have developed frameworks for understanding the relationship between technology and GIS applications particularly helpful for urban planners. Two approaches are GIScience and spatially integrated social science.

GIScience

U.C. Santa Barbara geography professor Michael Goodchild coined the term GIScience to refer to all the scientific knowledge related to GIS. He and scholars at ESRI, City University London, and University College London have written the standard text on GIScience (Longley, Goodchild, Maguire, and Rhind 2005). Goodchild defines GIScience as a multi-disciplinary field consisting of the science behind GIS technology

(Goodchild 1997). Many scholars have accepted Goodchild's formulation and subscribe to the GIScience perspective. In the United States a national consortium of academic institutions involved in GIScience—The University Consortium for GIScience (UCGIS)—holds national meetings and is working on a summary of the base of knowledge in GIScience (UCGIS, 2006).

Urban planning education cannot and should not attempt to incorporate all of the material included within the field of GIScience or included in the UCGIS base of knowledge any more than it should incorporate an entire economics or design curriculum. But it is important for planning educators to be aware of the emergence of GIScience as a field and the content of the evolving core GIScience curriculum in order to make intelligent choices of material to include in urban planning courses related to spatial analysis.

Spatially integrated social science.

A second movement of particular interest is a national effort to integrate spatial analysis into social science research and education at the University of California, Santa Barbara's Center for Spatially Integrated Social Science (CSISS). CSISS is completing a major six-year grant from the National Science Foundation designed to build the national scientific infrastructure by disseminating spatial thinking in the social sciences. As members of an interdisciplinary applied field that draws heavily on the social sciences, urban planners have much to learn from CSISS. During the last six years, CSISS has conducted a variety of conferences and workshops and supported Ph.D. students learning to incorporate spatial analysis into their dissertation research. The CSISS website (http://www.csiss.org/) provides resources including classic articles on spatial thinking, video clips of lectures at CSISS workshops, e-journals, bibliographies, search engines for finding spatial data and information about spatial analysis, and course syllabi.

Topics for comparative urban spatial research

There are many possible topics in comparative urban research that urban planning professors and students can explore using the new information technologies and conceptual frameworks described above. Following is a framework suggesting key areas for comparative urban analysis and providing examples of how the new technologies might be used in urban planning education and research.

Comparative urban growth management

Population growth and urbanization require city planners throughout the world to understand, plan for, and manage urban growth. The population of most countries is growing, often extremely rapidly (UN 2004). With the exception of recent deurbanization in Eastern Europe, most countries continue to urbanize—with especially rapid rates of urbanization in developing countries (World Bank 2004). Accordingly, the absolute population of many urban agglomerations is growing rapidly. Rates of growth are outstripping the capacity of many cities to provide adequate infrastructure. The sheer size of many world cities poses challenges for sustainability and livability.

One cluster of issues that is prime for comparative urban research and education involves studying urbanization and the way in which different cities are managing growth. There is a large body of theory about urban growth management (Porter et al. 1996, Weitz 2000), sustainable urban development (World Commission on Environment and Development 1987, Wheeler 2005, Wheeler and Beatley 2005), and planning for cities in developing countries (Jenks and Burgess 2001, Drakakis-Smith and Smith 2000). Empirical spatial analysis can test theory on growth management and provide insights on planning practice.

Good data for analyzing urbanization and growth management are now available from sources such as the World Bank (World Bank, 2004) and the population division of the United Nations (United Nations, 2004). It is possible to link this aspatial data to GIS files representing country boundaries and the location of cities so that spatial aspects of urbanization and city population size can be analyzed together (LeGates, 2006b). Standard GIS operations such as classifying data and symbolizing it with color ramps, in dot density maps, or with graduated or proportional symbols visually reveals patterns that are difficult to communicate with words, tables, or statistical output alone. Once patterns are identified, more fine-grained comparative analysis is possible. For example, as statistical analysis identifies a group of cities with similar growth characteristics (size, growth rates, per capita income) mapping different aspects of their urban patterns (transportation infrastructure, housing density, parks) will provide a comparative perspective.

Balancing the natural and built environment

A second major theme that is ripe for comparative urban research using the new information technologies described above involves the relationship between the built and natural environment. Urbanization often consumes prime farmland, threatens some plant and animal communities, creates air and water pollution, and causes toxic contamination. Protecting the environment in the face of urbanization is a worldwide problem.

Analysis of the impacts of urbanization on habitat for threatened and endangered species is one example of how the new information technologies can be used for comparative research on the relationship between urbanization and the natural environment. The Cambridge, England-based International Union for the Conservation of Nature and Natural Resources constantly updates a web-based version of their widely used global “red list” of endangered and threatened species. Of more than a million and a half plant and animal species in the world, the IUCN classified 38,046 as endangered as of December 2, 2004. The International Conservation Monitoring Centre website (http://www.wcmc.org.uk/species/data/index.html) contains links to similar inventories. This large body of data on endangered and threatened species worldwide is prime for comparative spatial analysis of the impact of urbanization on species.

Working in conjunction with biologists and other natural scientists, planners often identify and inventory habitat appropriate for species—including threatened and endangered species. Habitat conservation planning is premised on the assumption that if enough appropriate habitat can be maintained for a threatened or endangered species, the species is likely to survive (Beatley 1994). An important method of analyzing habitat is the gap analysis approach, which involves classifying land into polygons, assigning habitat attributes to each polygon, and then linking the polygons to data on habitat suitability for different species (LeGates, 2005). In the United States the U.S. Geological Survey's Gap Analysis program is classifying habitat throughout the country this way. Comparative urban research extending the gap analysis methodology is in order.

Regional equity and spatial integration

Cities pose problems of poverty and inequality. Some urban planners are principally concerned with advocacy planning on behalf of the poor and disenfranchised (Davidoff 1965), equity planning to improve social equity for low-income and minority groups (Krumholz and Forester 1990, Krumholz and Clavel, 1994), and restructuring municipal tax regimes to more fairly distribute tax revenues (Orfield 2002).

In the United States, urban planners routinely use census data to analyze the income of residents at the census tract level and the racial and ethnic breakdown of residents down to the block level. Within cities, these maps often reveal spatial inequality—with concentrations of low-income and minority residents in some areas and more affluent residents elsewhere. At the metropolitan scale it is possible to identify similar patterns of racial and income inequality among jurisdictions. These variations lend themselves to mapping. Choropleth or dot density maps show patterns and clusters clearly (Pamuk 2004). Spatial analysis can show spatial coincidence between demographic patterns and other geographical features such as the presence of contaminated sites, schools with high or low test scores, high crime, and teen pregnancy. Data like this is widely used to target government financial assistance, establish school district boundaries, distribute state education equalization aid, deploy policemen, and for other targeting purposes. University of Minnesota law professor Myron Orfield has analyzed what he calls metropatterns (Orfield 2002) and articulated a metropolitics agenda (Orfield 2002) for poor inner cities and their potential allies.

Other countries also collect census data—though not all countries make it as accessible as the United States. San Francisco State University Urban Studies Professor Ayse Pamuk has assembled comparative mapped census data from Brazil, the Netherlands, and France (Pamuk, 2006).

Comparative research on poverty and inequality, racial segregation, inequality in municipal taxation and service delivery, and other areas can be greatly facilitated by the new technology.

An approach to spatial analysis and data visualization

An approach to teaching spatial analysis and data visualization developed by the author (LeGates 2005a, LeGates 2005b) and incorporated in a new instructional module titled *Think Globally, Act Regionally* (LeGates 2005c) provides materials that introduce urban planning students to GIS and data visualization and equip them to do modern comparative urban analysis. The instructional module consists of a book, exercises, a CD-Rom with exercise data, and additional material on a website (http://www.nsfgis.sfsu.edu). It contains examples of GIS analyses and data graphics using material at the world scale from the United Nations (UN 2004), the World Bank (World Bank 2004), and Tertius Chandler and Gerald Fox (Chandler 1987, Chandler and Fox 1974); at the metropolitan and local level it uses a variety of data sources for the San Francisco Bay Area, Southern New Jersey, and the Portland Metropolitan regions. *Think Globally, Act Regionally* focuses on teaching students GIS concepts and operations that will empower them to do urban spatial analysis and create professional data graphics. Subsets of the UN and Chandler and Fox data and data from a variety of sources for the metropolitan areas discussed are used in exercises to teach GIS concepts and operations and are included on a CD-Rom that comes with the module.

Think Globally, Act Regionally is divided into four parts. The first three parts focus on each of the three issue areas described above: (a) planning for and managing the consequences of urbanization, (b) balancing conflicts between the built and natural environment, and (c) regional equity and spatial integration.

Each of the first three parts contains: a chapter describing aspects of the issue and explaining how spatial analysis and data visualization can help researchers better understand the issue and devise policies to address it; one or more chapters on GIS concepts using examples from the material; and a chapter on data visualization that also uses examples from the material. The fourth and final part of *Think Globally, Act Regionally* describes metropolitan Portland's regional land information system (RLIS) and how it is used in regional planning for the Portland region.

In addition to the substantive text, *Think Globally, Act Regionally* contains step-by-step exercises to teach students to produce analyses and maps similar to those described in the book. A CD-Rom contains data for the exercises, including a subset of Metro's RLIS data.

Conclusion

The digital information revolution is transforming our ability to do comparative urban research. Developments in the last five years have transformed our ability to do quantitative, comparative, urban spatial analysis. Insights from GIScience and spatially integrated social science can enrich planning education. Many topics related to urban growth management, conflicts between the natural and built environment, spatial equity, and other areas are now ripe for comparative urban research using the new technologies. The framework in *Think Globally, Act Regionally* will help equip planning professors and students to undertake this kind of research.

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