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Geographic Information Systems: A Tutorial and Introduction

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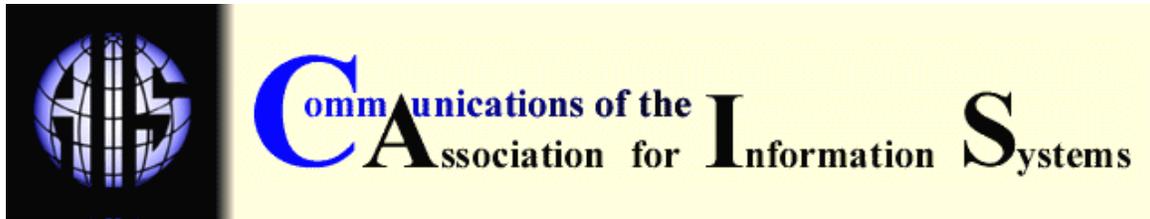
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GEOGRAPHIC INFORMATION SYSTEMS: A TUTORIAL AND INTRODUCTION

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ABSTRACT

This tutorial provides a foundation in GIS including its basic structure, concepts, and spatial analysis. GIS is a new field in business schools and presents opportunities for research. It is derived from about a dozen disciplines, some unfamiliar to most IS researchers.

Following an overview of vertical-sector uses of GIS, the paper introduces their costs and benefits. The links of GIS to related technologies such as GPS, wireless, location-based technologies, web services, and RFID are examined. Conceptual models and research methodologies are discussed, including Spatial Decision Support Systems (SDSS), and GIS in visualization, organizational studies, and end user computing. Suggestions for future research are presented.

Keywords: geographic information systems, spatial decision support systems, spatial analysis, conceptual models, methods

I. INTRODUCTION

A Geographic Information System (GIS)

- accesses spatial and attribute information,
- analyzes it, and
- produces outputs with mapping and visual displays.

GIS includes spatial boundary layers and uses attribute data that include spatial coordinates. It consists of both:

- a data-base, and
- tools and models to manipulate the data and boundary information.

To understand GIS, elements of geography and spatial science are necessary. GIS analysis includes (1) numerical algorithms, (2) statistics, and (3) optimization. In addition, spatial tools act on boundary layers, including union, overlay, buffering, nearest neighbor, and spatial attraction.

GIS may be regarded as a form of decision support system (DSS), often referred to as spatial decision support system (SDSS), that has a data-base, model base, and user interface to support decision makers. However, a SDSS differs from a DSS in its data-base in that it includes both attribute and spatial data; and in its model base, that includes tools for georeferencing, geocoding, and spatial analysis. These concepts are unfamiliar to most IT faculty. An example of the spatial analysis is algorithms to analyze the overlay of two or more spatial boundary layers. Several preliminary conceptual models are published for SDSS [Murphy, 1995; Jarupathirun and Zahedi, 2001; 2005; Huerta et al., 2005].

Other areas covered in this tutorial are:

- the design of enterprise GIS systems
- cost and benefits
- spatial knowledge discovery and data mining
- web-based GIS services
- the linkage between GIS and the associated technologies of global positioning systems (GPS), remote sensing, and location-based mobile services.

II. WHY GIS IS IMPORTANT

GIS was initially adopted by users in the government sector, but is now rapidly growing in business. Daratech estimates that the market for the core GIS software and services in 2003 was \$1.7 billion [Directions Magazine, 2003; Francica, 2005]. Longley et al. [2001] estimate total worldwide expenditure on GIS and related activities in 2000 was \$15-20 billion. Areas of business application are numerous, including marketing, sales, retail, logistics, fleet management, transportation, real estate, banking and finance, energy and power, natural resources, agriculture, building and architecture, and health care [Harder, 1997; Grimshaw, 2000; Boyles, 2002]. Many Fortune 1,000 firms use GIS, although most do not publicize it. Successful corporate examples are Sears Roebuck & Co (Sears) in optimizing delivery logistics nationwide, McDonalds for site location, and the Credit Union of Texas for direct marketing [Boyles, 2002]. GIS use is growing worldwide including in such developing nations as Mexico, Brazil, and India [Walsham and Sahay, 1999].

For IS researchers, GIS is significant because it can improve the efficiency of certain types of transaction systems, enhance many types of decision-making, and can influence corporate strategy. Its high growth rates in industry imply that applied researchers will need to recognize and become expert at it.

BUSINESS EXAMPLE

Only a single business example is given in some detail in this section, but many others are available [Harder, 1997; Grimshaw, 2000; Boyles, 2002; Pick, 2005a]. Sears Roebuck constitutes a case example of the benefits of GIS in a large-scale enterprise [Kelley, 1999; Pick, 2005b].

Sears delivers a vast amount of merchandise nationally every day. Yearly, its 1,000 delivery trucks perform over 4 million deliveries to homes [Kelley, 1999]. Its truck delivery system covers 70 percent of the U.S. territory. However, prior to implementing GIS, the manual process at Sears was time consuming and wasteful, with many hours each day spent by routing-center workers locating street addresses. The average time slippage rate of deliveries was 20 percent. In the early 1990s, an enterprise-wide GIS system was constructed by geocoding Sears' millions of customer addresses and setting up optimized delivery with the goal of 90 percent reliability in

the promised delivery window. The GIS calculates daily delivery routes, based on a model that includes “estimated travel times, in-home time, truck capacity, optimal stop sequence”. The system increased efficiency by reducing the time for routing and addressing from an average of 5 hours daily to 20 minutes. In all, equipment and facilities savings from the GIS-based networking enhancement is estimated as \$30 million per year [Kelley, 1999].

GIS IN ACADEMIA

From the standpoint of academia, GIS originated in the 1960s and 1970s in landscape architecture, geography, cartography, and remote sensing [Longley et al., 2000a]. During the last twenty years, it has branched into other academic disciplines notably computer science [Longley et al., 2000a], statistics (more particularly geostatistics) [Getis, 2000], land administration [Dale and McLaren, 2000], urban planning, public policy [Greene, 2000], energy studies [Harder, 1999], social sciences, medicine [Khan, 2003], and the humanities [Gregory et al., 2002]. In the 1990s, it began to spill over into the business disciplines including management [Huxhold, 1991, 1995], information systems [Grimshaw, 2000], logistics, organizational studies [Reeve and Petch, 1999], real estate [Castle III, 1998; Thrall, 2002], retail management [Longley et al., 2003], and telecommunications [Godin, 2001].

In the early 21st century, some business schools recognized the importance of GIS by including it as a required course or degree emphasis; for example, the elective GIS course offered at the University of California Berkeley’s Haas School of Business, and the University of Redlands’ MBA emphasis in GIS [UCGIS, 2003]. Several business schools established centers for GIS research, such as the Wharton Geographic Information Systems Laboratory. University College London established the interdisciplinary Centre for Advanced Spatial Analysis (CASA), an initiative to combine spatial technologies in several disciplines which deal with geography, location, business, and the built environment.

III. PRINCIPLES OF GIS

Geographical information systems (GISs) access spatial and attribute information, analyze it, and produce outputs with mapping and visual displays. An early definition stated GIS is:

“an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data” [Star and Estes, 1990].

A GIS consists of layers of geographic boundary files, shown in Figure 1, on the right side, which are tied to geo-referenced attributes in data tables (Figure 1, on the left side). It provides analysis and modeling tools based on both the attribute data-bases and spatial boundary files. Results are output in a variety of visual and tabular displays.

GIS achieves data power by linking data-base with spatial features. Specifically, each geographic entity (point, line, or polygon) is linked to the row in an RDBMS table, as seen in Figure 2. That table contains any number of attributes – three are shown in the figure. The presence of relational tables implies that many relational functions may be brought into play in a GIS. An example is a relational join operator, which could be used to join this attribute table with a non-spatial relational table containing additional attributes. Depending on the software and its algorithms, other relational operators can be used.

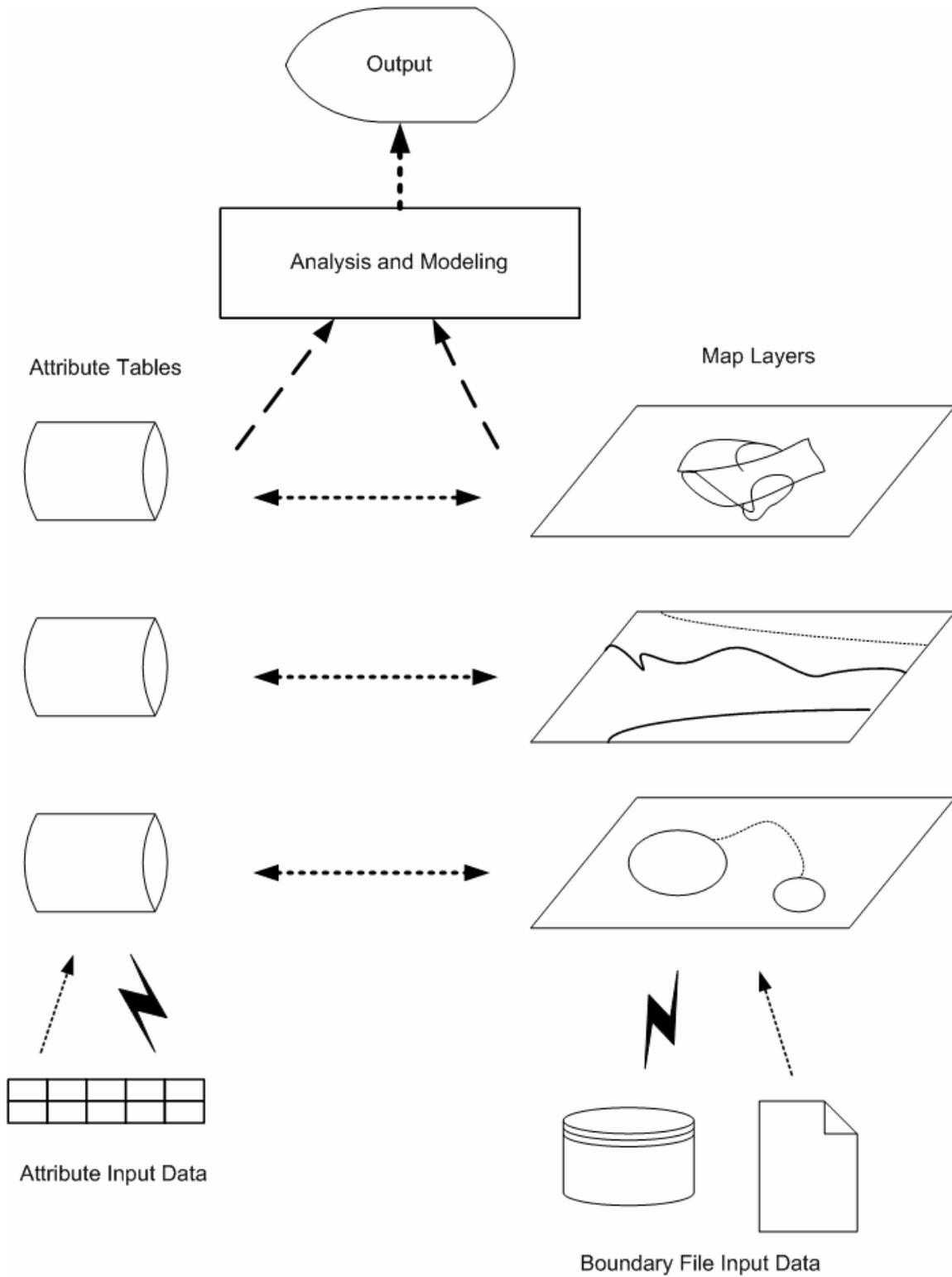
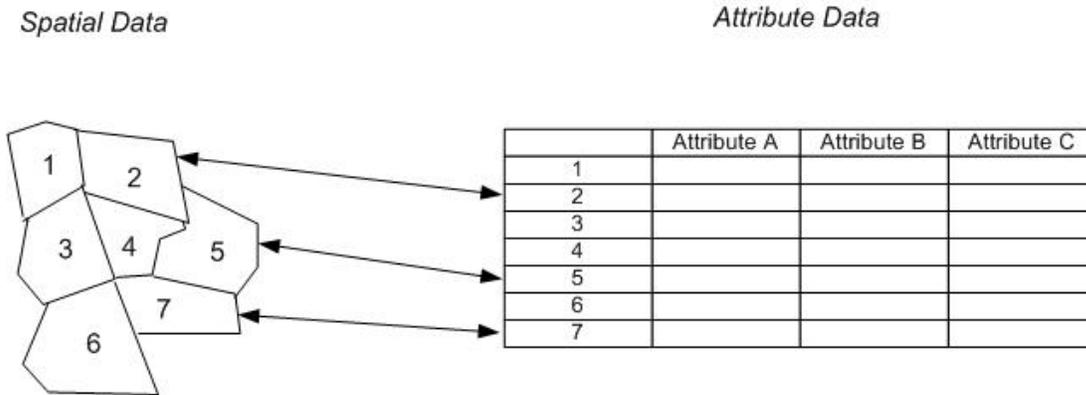


Figure 1. Design Elements of a GIS



(Source: Adapted from West, 2000)

Figure 2. Example of a GIS Layer Linked to an Attribute Table

If a GIS consists of several geographical layers, each layer contains an associated relational table. Figure 3 shows an overlay of three layers, which have different spatial entities, polygons for the top layer, points in the middle one, and lines for the bottom layer. The geographic entities for each layer are keyed to one row of a corresponding table. In each table, the number of attributes varies. In thinking of this overlay, the polygons might be marketing districts, the points might be megastores, and the lines might be major transport routes. This could be much more powerful, with even hundreds of layers overlaid, and an equivalent number of relational tables, for which attributes might number in the hundreds or more. As GIS storage may get large, there is increasing reason to use a commercial data-base product, such as Oracle or Informix. GIS software vendors are able to link the GIS software with most or all of the leading data-base packages. Another development is that large data-base vendors offer spatially-enabled data-bases, so the data-base may be considered enhanced by GIS features, rather than the other way around.

IV. COMMON GIS ANALYSIS METHODOLOGIES

GIS analysis techniques consist of methods that are used in the spatial analysis, modeling, and statistical analysis of a GIS. This section describes only a few important analysis techniques. A full treatment is available in specialized sources [Mitchell, 1999; Getis, 1999; Lo and Yeung, 2002; Longley and Batty, 2003].

Spatial analysis consists of analytical techniques that emphasize the map layers, portrayed on the right side of Figure 1. It relates and compares the features of the physical locations of objects in space [Getis, 1999; Longley and Batty, 2003]. Since it draws from geography, it is not familiar to most IS researchers. Modeling and statistical analysis methods include many methods and techniques well known in business disciplines, but often modified to take into account spatial relationships. These methods are based on attribute and spatial data, portrayed on both sides of Figure 1. Specialized statistical methods that include space are referred to as geostatistics [Getis, 1999]. Some desktop/laptop software packages include geostatistics modules, such as ArcGIS Geostatistical Analyst [Johnston, 2001].

SPATIAL ANALYSIS

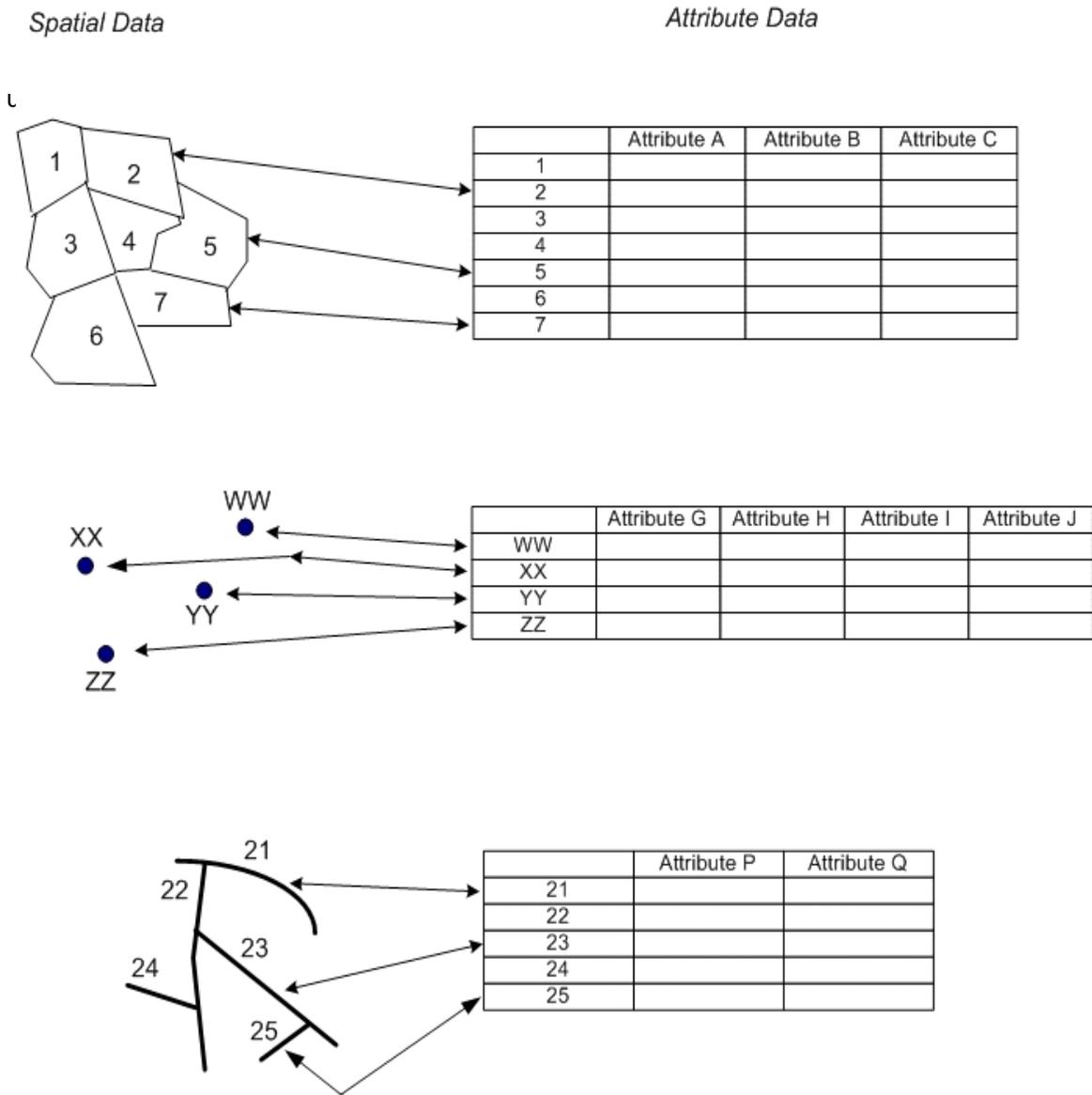
Since spatial analysis techniques compare spatial features, they can, for example, determine how many points are inside a polygon, how many line segments cross a polygon boundary, or how much polygons overlap each other. A practical example would be to ask how many highways and streets (lines) cross a zone of retail businesses.

Buffer Analysis

In buffering, GIS software forms bands on all sides of a point, line, or polygon, in order to perform analysis within the bands. A simple example would be to assign half-mile buffers on both sides of a highway to query how many service stations are within the buffer.

Map Overlay Functions

Overlay consists of superimposing two or more map layers. Quite a few operations for map overlays are typically supported. One example is the union procedure, in which two boundary file layers are combined to result in a third output layer. The resultant layer has the identical geographic extent as the two layers that form it, and it concatenates the attributes from those two layers in its associated data-base. Greene and Stager [2005] demonstrate the overlay union procedure (Figure 4).



Source: Adapted from West, 2000

Figure 3. Three GIS Layers with Corresponding Attribute Tables

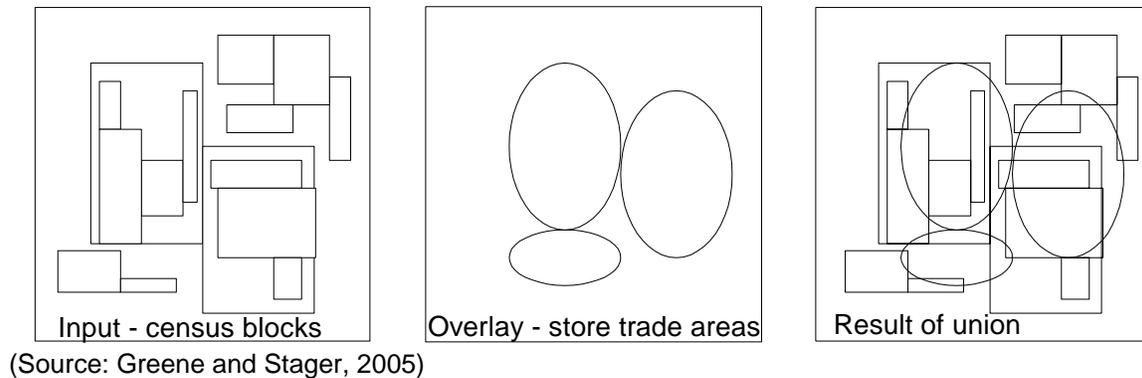


Figure 4. A GIS Union Procedure

This diagram shows one layer consisting of census blocks and a second layer with three store trade areas. The resultant map combines all these features. The attributes of each layer are combined into a resultant table (not shown). The advantages of overlay procedures include the ability to combine component maps in many different ways and turn on or off layers for particular purposes. The business purpose in the example is to make available the census block attribute characteristics for the sales areas [Greene and Stager, 2005].

An example of a spatial analyses is trade area analysis, based on a gravity model, which can examine customers' attractions to competing consumer destinations. Greene and Stager [2005] applied the gravity model to attraction of opera buffs to major opera houses in Chicago, Milwaukee, and Madison.

Proximity Analysis

Proximity analysis assesses how close certain map objects are to other map objects. For example, proximity analysis can determine how close the population residing in a census tract is to grocery stores.

LONGITUDINAL CHANGE DETECTION

This type of analysis compares maps over time, and assesses what significant spatial changes took place. For example, real estate maps produced for a suburb on an annual basis can show from year to year in the spatial patterns of housing prices and their changes.

MODELING AND FORECASTING

Forecasting and simulation models can be built with spatial data, and the results displayed in map form. An example is a model that projects the population distribution of retail consumers within a county, based on starting year data. The future population distributions of retail consumers can be mapped to inform businesses and the public.

STATISTICAL ANALYSIS

Statistical models are often applied to study the relationships of certain spatially-referenced attributes to other attributes [Getis, 1999]. They include correlation, regression, analysis of variance (ANOVA), cluster analysis, principal components, and t tests. Often the methods are corrected or refined for geostatistics [Getis, 1999]. Both the input data and the results of many of these models can be represented as spatial displays. This visualization enhances understanding of the geographical effects and influences. Although beyond the scope of this paper, a specialized part of statistics, called geostatistics, takes into account spatial effects and interactions, such as spatial autocorrelation [Getis, 2000]. An example is predicting the future spatial patterns of demand for advertising services in an urbanized area.

EXAMPLE: LOCATION QUOTIENT ANALYSIS FOR SITING

A common problem facing businesses is the decision on where to site new facilities that include retail outlets, distribution sites, factories, service offices, and administrative offices. The decisions are often influenced by concentrations of business facilities for the industry as a whole. For example, professional services firms often group together in the same urban zones to share workforce pools, services, and customers. Similar agglomeration is present for locational groupings of hotels and restaurants. The location quotient (LQ) indicates the ratio of proportion of workforce in a particular industrial sector for an urban zone to the proportion of workforce in that industrial sector for the entire urban area. An LQ of 100 indicates the proportion of workforce in the zone is the same as that for the urban area, while an LQ of 400 indicates the zone's proportion is 4 times the urban area's [Greene and Stager, 2005; Greene and Pick, 2005].

LQ spatial analysis maps the levels of LQs for an urban area. For example, LQs for manufacturing employment and professional employment are shown for the Los Angeles urban area in Figure 5. A high-tech business that manufactures and provides professional services can use maps such as these to make decisions on siting of its plants, R&D facilities, and office locations. For a large corporation with locations in hundreds of cities worldwide, LQ spatial analysis can lead to competitive advantage on a national or global scale.

V. COSTS AND BENEFITS OF GIS IN BUSINESS

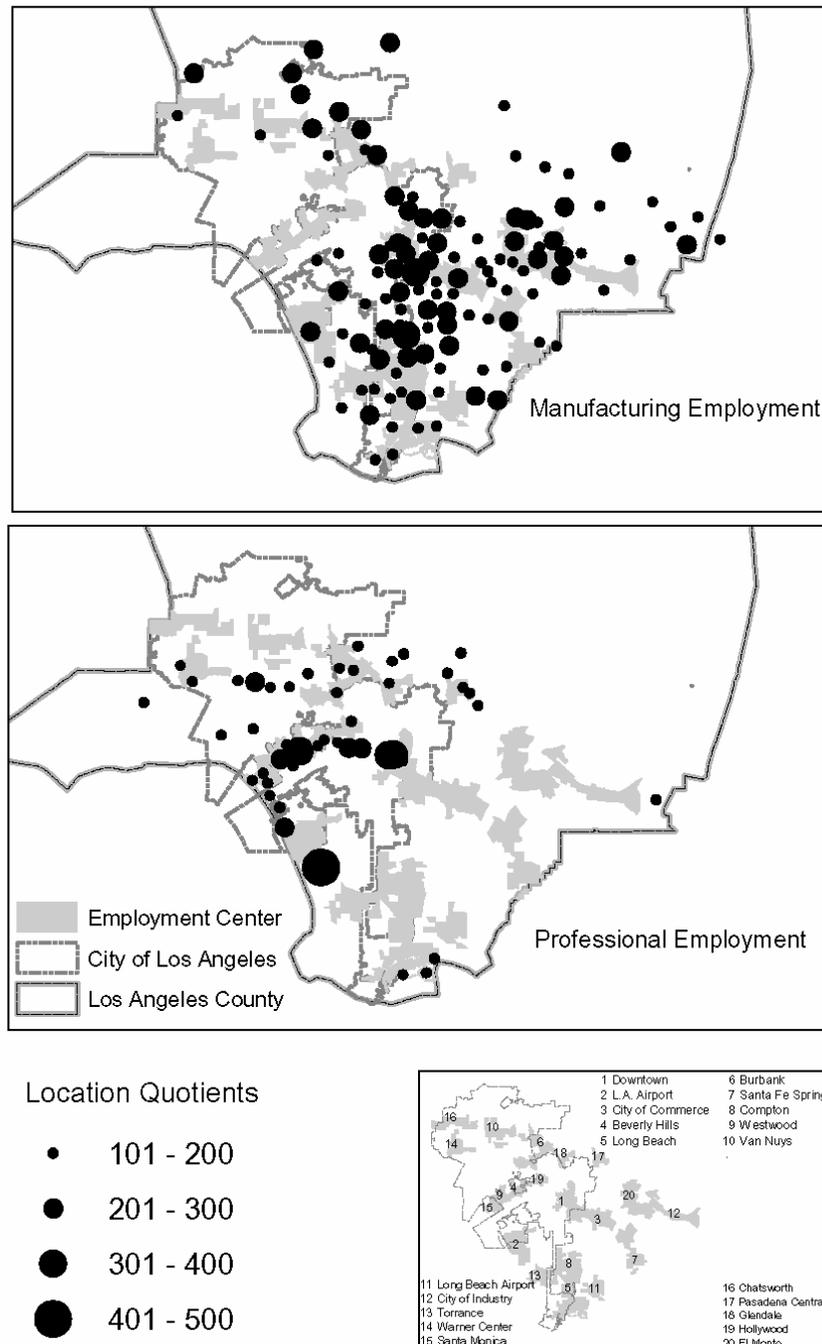
An area of both practical and research interest is the study of costs and benefits of GIS. In anticipating applying GIS in an organization, a crucial aspect is to examine the key factors and methods for assessing costs and benefits [King and Schrems, 1978; Obermeyer, 1999; Pick, 2005b]. Cost-benefit (C/B) analysis for GIS differs from C/B analysis in non-spatial IS in three ways.

- GIS software tends to be linked with other technologies and software, such as GPS, wireless technologies, RFID, statistical software, and modeling packages. This need to link up may result in added costs as well as benefits.
- GIS data and data management must deal with both attribute and spatial data, which influence C/B differently.
- The visualization aspect of GIS is hard to quantify and therefore adds to intangible costs and benefits.

The costs and benefits are related to the organizational hierarchy. A long-term trend for GIS business applications is that they move up this hierarchy, i.e., from the operational to managerial to strategic levels. At the higher levels, benefits become more difficult to assess. A related topic considered with respect to GIS is the IT productivity paradox. The productivity paradox and value of IT investment literature can be helpful in assessing the payoff of GIS [Ahituv, 1989; Brynjolfsson, 1993; Brynjolfsson and Hitt, 1993; Lucas, 1999; Strassmann, 1999a, 1999b; Devaraj and Kohli, 2002].

Among the challenges in GIS cost-benefit analysis is that GIS usually involves higher costs than conventional information systems because it requires considerable data acquisition and data management to obtain the needed attribute and spatial data [Huxhold, 1991; Huxhold, 1995; Clarke, 2001; Tomlinson, 2003].

Data collection for GIS is estimated to constitute 65 to 80 percent of the total cost for conventional systems development and implementation [Huxhold and Levinson, 1995; Obermeyer, 1999; Tomlinson, 2003]. Further, the attribute and digital boundary data need to be linked together. These linkage tasks add to costs, relative to non-spatial IS. Another difference results from GIS's visualization feature [Jarupathirun and Zahedi, 2005]. In this respect, GIS is comparable to a multimedia business application, which may have higher costs, due to its visual aspects.



(Source: Greene and Stager, 2005)

Figure 5. Location Quotient Spatial Analysis for Los Angeles

Because the benefits of visualization are predominantly intangible, the proportion of intangible costs and benefits tends to be greater than for a non-spatial information system. Another distinctive aspect of GIS is that it tends to be more linked, coupled, or integrated with other software systems and technologies than is normally present in IS applications. Among the systems and technologies with which GIS is often interfaced are global positioning systems

(GPS), remote sensing [Meeks and Dasgupta, 2003, 2005], marketing information systems [Allaway, Murphy, and Berkowitz, 2003], and global positioning systems [Clarke, 2003]. Because of this coupling, the cost and benefit calculation for any one of them can be more difficult.

VI. GIS'S LINKS TO OTHER TECHNOLOGIES

At the level of large-sized systems and applications, expanded computing power, combined with the Internet and modern telecommunications infrastructure, allows GIS to be deployed across organizations as a worldwide enterprise system. In an enterprise application, GIS processing is centered in specialized groups of servers that are interconnected through middleware to the client-based end users [Ray, 2005]. The development of enterprise GIS resembles the trend towards enterprise resource planning systems (ERP). Sometimes they are merged. Some ERP systems, such as SAS, allow for interconnections to GIS software [ESRI, 2004].

A number of other technology trends led to the expanding use of GIS. They include more sophisticated and robust GIS software, evolving data-base design, improved visualization display both hardware and software, and the growth of the commercial Internet [Longley, 2000a,b].

Like other information systems applications, GIS benefited notably from the Internet [Francica, 2005]. As a consequence, GIS applications are available as web services, and, in some cases, a single map server responds to millions of requests per week. This area of GIS is rapidly expanding. GIS is used in location-based applications, which refers to applications where small portable devices are connected by the Internet to send and receive data to and from centralized computing resources. Hand-held GIS devices such as ArcPad [ESRI, 2003], coupled with other mobile devices, support these applications.

Some of the more important technologies specifically advantageous to GIS in business are given in Table 1. These associated technologies add to the momentum of GIS use in business.

VII. WHERE GIS TECHNOLOGIES ARE HEADING

This section briefly examines where GIS and its associated technologies are heading, and what the implications are for IT researchers. It is based on recent industry and technological analyses [Chen, 2004; Francica, 2005; Geoplace.com, 2004; Keating, 2003; Levy, 2004; Ray, 2005; Richardson, 2003]. The discussion focuses on trends for enterprise computing, mobile technology, "virtual globe," web services, grid computing, and RFID.

ENTERPRISE COMPUTING

For enterprise computing, the trend is that GIS is linking up with existing enterprise IT systems to serve users consistently across the organization [Geoplace.com, 2004; Keating, 2003]. GIS use in larger enterprises is predicted to move from "geocentric specialization" to an "integration-centric" IS [David Sonnen, cited in Geoplace.com, 2004]. This growth is stimulated by large-scale data-base vendors such as Oracle and IBM incorporating spatial features in their products and by the specialized GIS vendors such as ESRI establishing enterprise products that are integrated with large-scale data-bases.

These associated technologies add to the momentum of GIS use in business.

Table 1. Examples of Technologies Closely Associated with GIS for Business

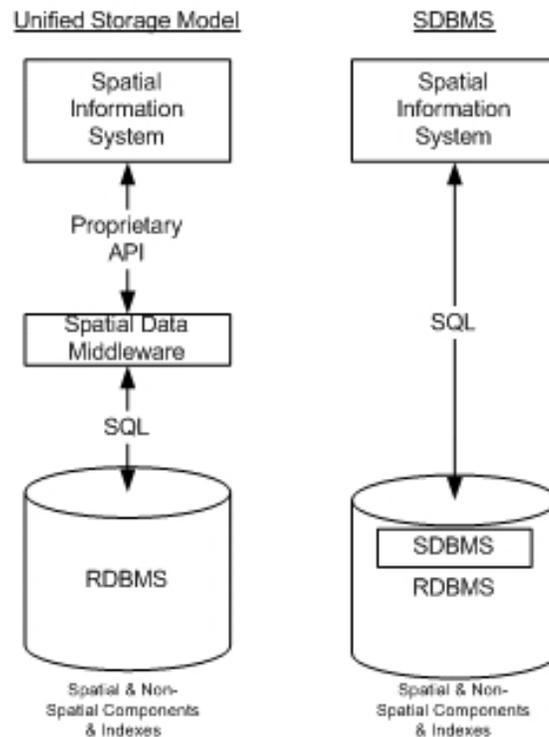
<i>Technology</i>	<i>Importance for GIS in Business</i>
Global positioning systems	GPS combined with GIS allows real-time locational information to be applied for business purposes.
RFID	Allows portable products of any type to be spatially registered and to carry a tag with data that can be accessed and updated remotely. This data far exceeds that in barcodes. Useful in business because its supply chains and inventories consist of goods that are moved around and can benefit by being tracked [Richardson, 2003]. The new information can allow precise planning and management, and automated replenishment of inventory. It is also useful for security.
Spatial features built into leading relational data-bases such as Oracle Spatial and IBM-Infomix's Spatial Datablade Module	Makes large-scale GIS applications easier and more efficient to realize. GIS software packages contain specific add-ons to link to the data-base spatial features. Applies to business because enterprise applications are mostly adopted by businesses
Mobile wireless communications	Allows field deployment of GIS technologies in mobile commerce. Useful in supporting the real-time field operations of businesses [Mennecke and Strader, 2003]. Combines GIS, GPS, and wireless technologies.
Hand-held GIS, such as ArcPad	A new type of product that is equivalent to PDAs, cell phones, and other mobile devices. It contains GPS and scaled-down versions of standard GIS software. Gives businesses field flexibility in inputting, modifying, and utilizing data. Important in business sectors such as retail that have substantial field force [ESRI, 2003].
Map servers	Specialized map server software to support map servers that deliver GIS over the internet. The software converts maps from conventional GIS storage form into versions that are coded and optimized for web delivery

As seen in Figure 6, a “unified storage model” employs a relational data-base for spatial and non-spatial components [Ray, 2005]. Spatial middleware translates to and from spatial objects inside the data-base so that outside analytical software can use it. A somewhat different model, the “spatial database management system,” does away with middleware. The data-base performs all functions spatial and non-spatial, storage and analysis, within the data-base [Ray, 2005]. The contrast of these two approaches is seen in Figure 6 [Ray, 2005].

Both these models offer advantages over a traditional GIS software package:

- efficient management of numerous clients concurrently using the system,
- efficient management of very large volumes of data since tables can span multiple devices,
- improved performance of relational operations, and
- enhancement in security provided by advanced relational data-base security features [Ray, 2005].

On the other hand, the analytical features are currently stronger in proprietary packages, although data-base vendor firms are putting increasing emphasis on incorporating analytical capabilities [Francica, 2005; GeoScience.com, 2004].



(Source: Ray, 2005)

Figure 6. Unified Storage Model and Spatial Data-base Model

Another approach to enterprise GIS is through linkages of ERP and GIS packages [ESRI, 2004]. For example, SAP GBC is a middleware product from SAP that conveys information back and forth between SAP and a GIS software package. SAP and GIS are linked together in such diverse communities and enterprises as Hamburg, Germany's Department of Sanitation, City of Richmond, California, and Lyse Nett AS, a Norwegian utility firm [ESRI, 2004]. Another approach is for an outside integrator to build the transfer capability between and ERP and GIS packages. This integration was done, for example, for SAP and ArcInfo/ArcView at the Metropolitan District of Hartford, Connecticut [ESRI, 2004].

Few academic research papers elaborate on enterprise GIS. Ray [2005] discusses the enterprise architecture choices, while Keating et al. [2003] present a case study of implementing enterprise GIS at the Los Alamos National Laboratory [LANL].

The stimulus for the LANL enterprise approach came from poor GIS response during the disastrous Cerro Grande wildfire at LANL in May of 2000. At Los Alamos, many barriers prevented changing from local to enterprise-wide, including organizational divides (siloeing), traditions of separate budgets that excluded enterprise-wide support, and the need to adopt data standards across the Lab. At LANL, "strong competition for perceived limited resources leads to many isolated, independent, project-centric GIS groups with limited motivation for data sharing and collaboration" [Keating et al., 2003]. Establishing an enterprise-wide data repository and sharing data that particular groups regarded as proprietary ran into resistance. Keating suggests that the Lab may not be able to implement totally centralized GIS, but rather would select a solution between localized and centralized. Nevertheless, the metadata, i.e. data that serves to

define the characteristics of data, would need to be enterprise-wide [Keating et al., 2003]. Although LANL is a high-security government organization, many of the same problems and issues confront businesses anticipating enterprise-wide GIS.

WEB SERVICES

Web services for GIS, in particular map services, constitute another technology trend. Map services are exemplified by MapQuest, for finding locations, and REALTOR.com, that provides market information including map locations for millions of real estate properties. The maps can be scaled up and down, to view locations, pricing, and proximities. Spatial information is commonly transferred by XML, between the map server and the client. The client-server exchange is driven by spatial data middleware [Ray, 2005]. An example of specialized map server software is ArcIMS from ESRI.

GIS web clients are not limited to desktops/laptops, but also can be provided on a variety of mobile wireless devices, although those devices currently have display, ergonomic, and bandwidth limitations. A mobile workforce can interact with web services through mobile devices and make use of GIS regardless of their location [Francica, 2005]. Specialized GIS web services may offer particular mobile customers a wealth of information suitable to certain activities. A simple example is a tourist in a city, who could have a changing array of location-specific maps and associated information provided, as he/she moves around. This phenomenon has been referred to as "virtual globe" [J. Dangermond, quoted in Levy, 2004]. It implies that a wealth of location-based information will be available to the user on the spot.

It is likely that much larger architectures for map serving will make map services more powerful to the user. This assumes that the servers have sufficient speed and bandwidth. Among the arrangements being discussed is GRID computing, a software architecture that transparently combines many different servers, networks, and storage units [X. Lopez, in Geoplace.com, 2004].

MOBILE TECHNOLOGY

Cell phones and Wi-Fi devices are increasingly spatially-enabled and often can be connected to GIS. The U.S. Federal Communications Commission (FCC) has mandated and is in process of requiring cellular carriers to identify two thirds of cell calls within 50 meters and 95 percent within 150 meters [Francica, 2005]. That implies that nearly all cell phones will eventually offer GPS capabilities, although GPS may also be available in several types of mobile devices.. Wi-Fi is another location-aware technology commonly present in laptops [Francica, 2005]. The location-enablement of these prevalent classes of devices encourages dispersed spatial business intelligence.

RFID

RFID is likely to grow significantly [Chan, 2004; Richardson, 2004]. An RFID tag offers non-volatile memory, which can be read by an RFID reader located nearby. RFID is required by the U.S. Dept. of Defense, by Germany's Metro Group (fifth largest retailer worldwide), and by Wal-Mart for 100 of its key suppliers by 2005 [Chen, 2004; Richardson, 2004]. A key parameter for GIS is the maximum distance a RFID tag can be away from an RFID reader to be read, since once an item passes an RFID reader, its point location is immediately recorded at the reader location [Francica, 2004]. There can be very accurate spatial mapping and analysis of items for parcel shipping, medical device tracking, document management, and point-of-sale auditing [Francica, 2005]. From a GIS standpoint, RFID is analogous to GPS, which allows objects having GPS to recognize their exact location and transmit it. RFID applies to smaller and more numerous land-based objects. The restriction is that a reader needs to be present within a certain distance, whereas GPS applies globally. Privacy is a controversial issue with RFID. Since information is being sent by radio transmission, it can be detected analogously to cell phones. This problem will only be solved when the communication between the readers and tags is made safe by encryption [Chen, 2004].

VIII. PRIOR RESEARCH ON GIS IN THE IS FIELD

Although books and some journals are devoted to GIS in general [Longley et al., 2000b; 2001; Clarke, 2003] and to its practical applications in business [Harder, 1997, 1999; Grimshaw, 2000; Boyles, 2002], the amount of peer-reviewed research on GIS in business is small [Huerta, Navarrete, and Ryan, 2005].

GIS in business as a scholarly field developed over the past four decades, drawing from and relating to information systems and other business disciplines, as well as to the real world. Keenan [2005] delineated the growth of this field's body of knowledge, referencing and linking together key studies in the literature. The literature and key concepts for important areas of business application of GIS include logistical support, operational support, marketing, service, spatial decision support systems (SDSS), electronic commerce, and mobile commerce [Keenan, 2005]. In service for instance, the movement towards customer relationship management (CRM) systems is reinforced by GIS. Customers' spatial relationships to one another can be used to provide better service. For consumer electronic commerce, GIS supports the delivery logistics. In mobile services, GIS, combined with wireless and GPS, customizes service at the customer location. Referring to the classic Nolan stage theories of IS growth [Nolan, 1973], Keenan [2005] suggests that GIS in today's business world is entering the expansion/contagion stage. GIS will likely do well in the subsequent stage of data integration. However, because of its complexity, the data administration stage may pose problems for GIS.

To study of the extent of business GIS research for decision support during the past twelve years, Huerta, Navarrete, and Ryan [2005] examined 20 leading information systems journals and conference proceedings predominantly in information systems but with some from the GIS field. They found only 9 articles on GIS and decision support. Using a well-known model of decision support by Todd and Benbasat [2000] they classified the articles by area. They found a deficit of studies on "desired effect" and "decision strategy". The paucity of peer-reviewed research in the GIS-DSS area suggests an overall lack of research on GIS in business.

IX. CONCEPTS, METHODOLOGIES, AND THEORIES OF GIS IN BUSINESS

REFERENT DISCIPLINES, CONCEPTS, AND THEORIES FOR GIS IN BUSINESS

Geographic information systems use methods and techniques drawn from many disciplines, including geography, cartography, computer science, spatial information science, information systems, operations research, statistics, economics, and business. It is typical of new fields to draw on referent disciplines, eventually combining concepts to form a core for the field. Some of the concepts and theories for GIS in business and their referent disciplines are shown in Table 2.

For example, spatial analysis stemmed originally from developments in geography and regional science in the early 1960s [Fischer, 2000]. It includes "*methods and techniques to analyze the pattern and form of geographical objects, ... the inherent properties of geographical space, spatial choice processes, and the spatial-temporal evolution of complex spatial systems*" [Fischer, 2000].

This area is less familiar to scholars in the business disciplines. Although GIS research in the IS field is sparse, it is beginning to build and be included in IS body of concepts, knowledge, and theories. This section discusses several instances of research in four areas: SDSS, GIS and visualization, GIS and organizations, and GIS and end user computing. It is not meant to be an inclusive literature review, but rather to demonstrate several emergent and promising lines of research.

SPATIAL DECISION SUPPORT SYSTEMS (SDSS)

Over the past 30 years, GIS moved upward in organizational level just as conventional Information Systems moved from transaction processing to MIS to decision support systems. GIS can be applied for decision support. It combines traditional DSS concepts with spatially-referenced data and spatial analysis. SDSS analytical tools go beyond ordinary DSSs and include spatial tools. Examples are 3-D visualization, statistical modeling, and network analysis

Table 2. Referent Disciplines for Concepts and Theories of GIS

<i>Concept or Theory in GIS in Business</i>	<i>Referent Discipline(s)</i>	<i>Concept or Theory in GIS in Business</i>	<i>Referent Discipline(s)</i>
Spatial Analysis	Geography, Regional Science	Networking Configuration	Telecommunications
Location Theory	Geography, Operations Research	Visualization	Psychology, Computer Science, Media Studies, Geography, Earth Sciences
Gravity Model	Geography	Geostatistics	Statistics
Remote Sensing	Geography, Earth Sciences	Customer Relationship Management	Marketing, Information Systems
Decision Support Systems	Information Systems	Adoption/Diffusion Theory	Marketing
Knowledge-Based Discovery	Information Systems	Market Segmentation	Marketing
Data Mining	Information Systems	CAMA and AVM Models	Real Estate
Location Based Services	Information Systems	Cost-Benefit Analysis	Economics, Business
Value of IT Investment	Information Systems, Economics	Organizational Theory	Management, Sociology
Electronic Business	Information Systems, Economics	End User Computing	Information Systems

[Jarupathirun and Zahedi, 2005]. The unique visualization features of SDSS include the dynamic nature of map visualization, visual thinking, and the behavioral impact on decision makers [Jarupathirun and Zahedi, 2001; 2005]. Given all this capability, how can the effectiveness of an SDSS be evaluated and tested?

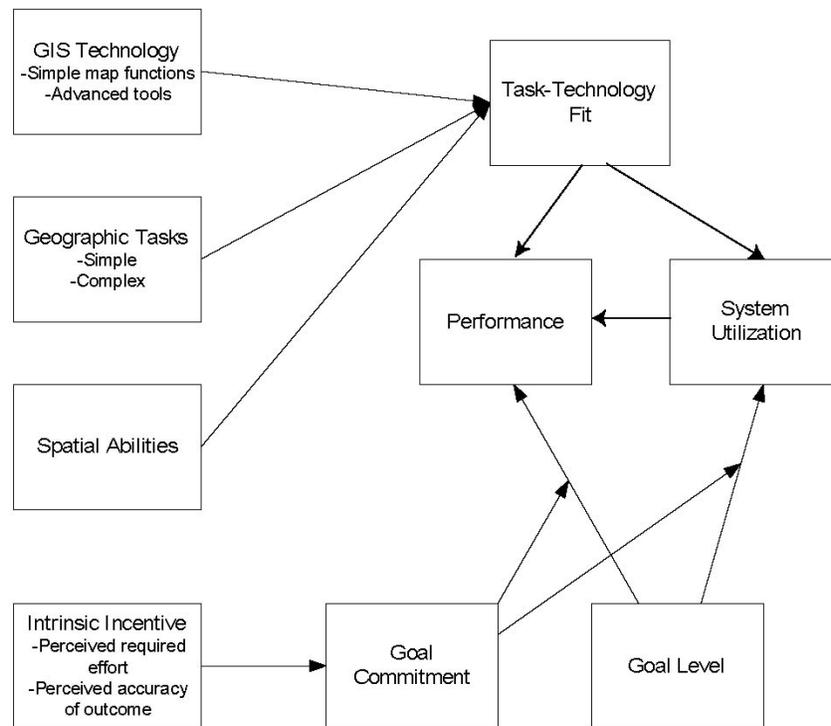
This line of research began in earnest with a series of studies that compared problem solving and decision-making for maps versus tables, or for paper maps versus GIS. The studies were experimental, drew on psychology methods, often used students as subjects, and sometimes referred to cognitive fit theory [Vessey, 1991]. One study [Smelcer and Carmel, 1997] experimented with student subjects to study differences between two spatial concepts (map and table), three geographic analysis concepts (proximity, adjacency, and containment), and three levels of difficulty of tasks (low, medium, high). The findings indicated that for low-difficulty tasks, maps versus tables didn't matter, but maps shortened problem-solving time for high-difficulty tasks. Respondents' spatial visualization ability had no effect. This experiment was carried further in a study by Dennis and Carte [1998] in which respondents made faster and more accurate decisions for tasks involving the geographic concept of adjacency. However, for tasks not providing adjacency or other spatial relationships, the decision-making was faster but less accurate.

The next step in this series of studies was to examine the decision-making value of GIS. In an experimental study not based on a theory [Swink and Speier, 1999] subjects performed tasks with a GIS in which problem size, data aggregation, and data dispersion varied. The spatial orientation skill of the subjects differed. The findings demonstrate that more complex problems resulted in longer decision times and lower decision quality. For tasks with data disaggregation, decision times were longer and decision quality was approximately the same. For data dispersed across many geographic units, GIS led to better decision quality but more decision

time, while higher spatial orientation skill led to better decision quality. Overall, the study demonstrated a number of decision-making benefits from GIS.

In a more elaborate study [Mennecke et al., 2000], involving 240 subjects, experiments were performed based on the concepts of cognitive fit, map reading and interpretation, and literature on the expertise and experience of subjects. The subjects were both students and professionals in planning. The three input variables were subject experience/expertise (students vs. professionals), technology (maps vs SDSS) and problem complexity (low, medium, high). An intermediate variable was cognition, defined as the amount of cognitive effort by the subject [Mennecke et al., 2000]. Findings showed that students and professionals were more efficient with SDSS versus maps, when working on more complex problems. The professionals were more accurate, but less efficient than the students. The study was consistent with the framework of cognitive fit, i.e., that the subjects mental representation served as an intermediate leading to the benefits. Generally, this study also found decision-making gains from SDSS, especially for more complex problems and surprisingly somewhat more for the less-experienced user.

A recent and enlarged, but yet untested, SDSS conceptual model [Jarupathirun and Zahedi [2005], shown in Figure 7, includes technology, problem tasks, behavioral abilities, and the resultant task-technology fit, as well as incentives, goals, performance, and utilization. The investigators suggest future enhancements of SDSS to include use of 3-D, animation, and intelligent agents.



(Source: Jarupathirun and Zahedi, 2005)

Figure 7. Jarupathirun/Zahedi Conceptual Model to Test and Evaluate SDSS

This brief discussion of SDSS research shows it to be a promising field with methods aligned to those used in DSS and GDSS studies. It challenges the IT community to reach more deeply into

the areas of visualization and spatial cognition to comprehend further when and how GIS can be advantageous for decisions.

GIS AND VISUALIZATION

The research on GIS and visualization comes from diverse sources that include psychology, educational media, computer science, geography, earth sciences, and visualization [Crampton, 2001; Jariputhirun and Zahedi, 2005; Blaser et al., 2000; Keenan, 2005]. In the IS literature, some studies examining the decision-making benefits of maps and GIS are the same as described in the previous section [Crossland et al., 1995; Smelcer and Carmel, 1997; Dennis and Carte, 1998, Swink and Speier, 1999, and Mennecke et al., 2000]. Those studies focused on concepts and theories of decision-making, rather than visualization. Since geographers recognized and studied the visual aspects of maps for generations, their studies are often relevant [Montello et al., 1999; Crampton, 2001]. For instance, “geographical visualization” is explored as a concept of the user taking the map’s contents and applying it to “explore, analyze, and visualize spatial datasets to understand patterns better” [Crampton, 2001]. GIS software can contribute to visualization by its abilities to query, explore, analyze, change overlays, work in 3 dimensions, and even work in 4 dimensions if there is a temporal activity. Finished map presentation is regarded as the result of stages that include exploration, confirmation, synthesis, and presentation [Crampton, 2001, based on DBiase, 1990]. The framework of stages of visualization may be helpful in future studies of visualization and GIS.

A different example of geography’s contribution to the GIS and visualization literature is a study by Montello et al., [1999] of gender differences in spatial ability. The method was an experiment with 79 subjects who received a large group of geographic and spatial tests, including psychometric, map-learning, spatial memory, and survey tests. The findings of this comprehensive testing are mostly in agreement that women subjects were better on static object-location memory tasks, while males were better in new acquisition of spatial knowledge from places recently visited. No gender differences were found on map-derived knowledge. Although GIS displays were not included (hardcopy maps were used), many of the results are likely to carry over to GIS. This type of study is important, since it underscores that SDSS models should include a spatial ability construct, as was evident in the model in Figure 7. In sum, visualization and visual abilities moderate whether the outputs of an SDSS or other type of GIS will register in a user’s thought and behavior.

GIS AND ORGANIZATIONS

Because GIS grew up in the public sector, more research attention is paid to GIS and organizations by investigators concerned with the public sector, such as planners and urban geographers, rather than by business. For example, books on GIS and organizations or communities tend to be based in planning, and urban and regional geography [Campbell and Masser, 1995; Reeve and Petch, 1999; Craig et al., 2002]. However, since the mid-1990’s, as IS and IT in industry used more GIS and location-based technologies, opportunities for studies draw on the organizational theories and concepts in information systems.

One example study of GIS and organizations by IT researchers focused on district-level agencies in India [Walsham and Sahay, 1999]. It is included to demonstrate how an IT-related theory can be applied to GIS. The study was of an attempt by the Indian federal government during 1993-1995 to develop and implement GIS for wasteland management at the district level. Actor-network theory was principally used, and some the research draws on grounded theory. Actor-network theory “examines the motivations and actions of actors who form elements, linked by associations, of heterogeneous networks of aligned interests” [Walsham and Sahay, 1999]. Particularly, the study involved field investigation over three years with ten GIS projects applied to wastelands, sponsored by the Ministry of Environment and Forest (MOEF). The main actors were GIS technology (the theory allows for non-human actors), U.S.-based actors (an Ohio-based GIS organization, USAID, and U.S. GIS vendors), Indian federal government officials, and regional scientific institutions involved in implementing GIS in the districts [Walsham and Sahay,

1999]. The actors built a network of relationships, values, and beliefs that held through the three years, although some actors came and went.

The research follows the building of this network from initiation through Phase I (use by regional scientific institutions), Phase II (attempts to apply the GISs in districts for practical problem-solving), and the role of the researchers in the network, since they became actively involved as the three years progressed. The overall outcome was that GIS was not successful in these projects, although GIS was available for a quarter of the districts at the end of the study period [Walsham and Sahay, 1999]. The organizational reasons for the poor adoption are explained by cultural differences, over-emphasis on remote sensing data, and political factors. The study was fruitful in bringing forward ideas to improve implementing GIS in developing nations.

This study illustrates the power that IS concepts and theories can have in studying GIS in organizations. Although the organizational-GIS literature heretofore mostly originated from geography and planning, IS theory offers a lot as spatial technologies and applications proliferate.

GIS AND END-USER COMPUTING

GIS has been studied in the context of end-user computing. One study [West, 2000] examined how GIS can be provided more successfully to end users, who are often non-geographers. Since GIS for business end users only became available since the early 1990s [West, 2000], a learning and training gap exists. Among the business end-user's weaknesses relative to succeeding with GIS are how to choose GIS boundary layers; how to order the layers (i.e., what layer goes on top of others); when to suppress geographic features as the scale changes; how to place scale, labels, and legends for hardcopy map printing; and how to decide the extent of user authorizations to add and change data. Although some of these problems are reduced today with newer software, West's general point about the business user's unfamiliarity with geography and cartography remains. He suggests remedies such as more training, adding automated features, and asking a knowledgeable user to plan and complete metadata ahead of time .

This paper in some ways emphasizes a technology that grew up in a public-sector culture, starting in the U.S. and Canada. Its users were assumed to be well versed in geography. Since the growing business user base is different, GIS technology and training may need to be shifted. Since the private-sector market for GIS is presently growing more rapidly than the public sector, this issue will only become more acute, and suggests the need for end-user research.

X. CONCLUSION

GIS grew up in the government sector, and today is expanding in businesses. Its business uses are at different maturity levels in stages of growth [Nolan, 1973]. For instance, GIS use in logistics, transportation, natural resources, utilities, and health care is well developed; GIS in marketing, agriculture, real estate, and banking is moderately developed; while GIS use is in the early growth stages in business law, human resources, and insurance [Harder, 1997; Boyles, 2002, Viswanathan, 2005; Adrian et al., 2005; Hilton et al., 2005; Wachter et al., 2005]. Adoption and applications are expanding in all these areas. Since an estimated 90 percent of all data can be spatially referenced, many business applications remain yet to be discovered.

The GIS academic research literature is stronger in the base discipline of geography and its neighboring fields, but weaker in business disciplines. An important example of emerging research in GIS is cost-benefit analysis. The methods used draw on studies of information systems C-B analysis, and on the IT productivity paradox literature. Many referent disciplines contribute conceptual theories and concepts to the study of GIS in business, including information sciences, geography, earth sciences, computer science, economics, psychology, and business disciplines.

As GIS and its related technologies continue to become more prevalent and strategic for enterprises, a growing academic base of knowledge can provide useful ideas to the wider group

of real-world practitioners, and vice versa. Promising research areas are at the boundaries between GIS and IT, such as SDSS, organizational, and end user studies, and somewhat less familiar areas for IT researchers, such as visualization. Because the academic field of GIS for business school investigators is still new, it offers exceptional potential for research and publication.

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1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
 2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
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 4. the author of this article, not CAIS, is responsible for the accuracy of the URL and version information.
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APPENDIX: USEFUL WEBSITES FOR GIS FOR IS ACADEMICS

<i>Name</i>	<i>URL</i>
GENERAL	
About GIS	http://www.gis.com/site/index.html
Geography Network	http://www.geographynetwork.com/
ORGANIZATIONS	
Am. Society for Photogrammetry and Remote Sensing	http://www.asprs.org/
Geospatial Information and Technology Assn	https://www.gita.org/about_gita/about_gita2.html
ISO-GIS (standards)	http://www.isotc211.org/
Nat'l Center for Geographic Information and Analysis	http://www.ncgia.ucsb.edu
Open GIS Consortium (OGIS)	http://www.isotc211.org/
University Consortium for Geog. Information Science	http://www.ucgis.org/
U.S. Federal Geographic Data Committee	http://www.fgdc.gov/
GIS SOFTWARE COMPANIES	
ESRI Inc.	http://www.esri.com
Intergraph	http://www.intergraph.com
MapInfo	http://www.mapinfo.com
SPATIAL DATA SOURCES OR PORTALS	
CGRER Maps and References	http://www.cgrer.uiowa.edu/servers/servers_references.html
SEDAC-CIESIN Data Cartogram Service	http://sedac.ciesin.org/
Stephan Pollard's Guide to Free U.S. Geospatial Data	http://www.cast.uark.edu/local/hunt/index.html
U.S. Census Bureau – TIGER – Geography Products	http://www.census.gov/geo/www/tiger/
JOURNALS – ONLINE	
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