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GIS Applications in Real Estate and Related Industries

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Abstract

Geographic Information Systems (GIS) have many applications in the real estate industry—an industry inherently spatial in nature—enabling real estate professionals to measure the true impact of location and thus make appropriate judgments in many areas, including residential brokerage, appraisal, and market analysis. This article assesses how GIS will affect real estate and closely related industries and provides a critical review of GIS business applications serving to effect that change.

GIS technology will lead to increased productivity in many industry operations and to greater accuracy and timeliness of information for both professionals and the general public. As its full potential is realized, the market will move to higher levels of efficiency, which may ultimately drive down the cost of real estate transactions. There should also be a reduction in traditional information arbitrage of real estate, where inside information or market knowledge historically has allowed for unusually large real estate returns.

Keywords: Geographic Information Systems; Real estate; Community Reinvestment Act; Home Mortgage Disclosure Act

Introduction

Recent innovations in Geographic Information Systems (GIS) technology will have a profound effect on real estate and related industries. The transfer of academic work to practitioner needs is mostly spurring these innovations. Real estate practitioners have long valued the importance of "location, location, location" in their industry. Yet few practitioners have considered academic geography as the disciplinary home for locational analysis. Academics affiliated with the discipline of geography have for several decades been analyzing phenomena central to the real estate industry using technology that today falls under the umbrella of contemporary GIS. But until now, that academic work has seldom filtered down to practitioners. Practitioners are interested in methodology that they can themselves apply or benefit from today—not basic research that will offer benefits far in the future. The body of basic academic knowledge accumulated over the decades is now ready to change how the

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This article makes reference to specific commercial products. Such reference is not intended to be an endorsement of these products nor does it claim to be an exhaustive listing of all similar products.

practitioner goes about his or her profession. Why now? The answer is productivity: old concepts can be combined with new technology to result in higher productivity (see, for example, Thrall 1979, 1993).

The heightened productivity in the GIS industry is tied to the overall technological transformation of the personal computer industry: faster computational processing; inexpensive mass data storage, especially on CD-ROM; the emergence of a highly competitive industry for geographic and demographic data; falling prices for mass-market user-friendly software (Thrall 1995); and the availability of rapid development programming languages such as Microsoft's Visual Basic. Because of these technological advances, a moderately skilled practitioner can today perform geographic analysis—often in minutes—that in the 1970s required several years and highly specialized technical skills.

Recent innovations in GIS technology will not only increase the productivity of existing industry operations but will also lead to greater accuracy of information and access to information that previously was cost prohibitive or simply unavailable. These advances will provide a greater range of information with which a real estate decision can be made, which will benefit consumers by leading to decisions that more closely address their needs and preferences. From the perspective of the industry, as GIS and related computer technology are integrated into market operations, fewer people may be needed to perform some of the traditional tasks such as residential brokerage and mortgage origination. Somewhat as a counterbalance, however, the need for professionals with advanced technology skills, including GIS, will grow.

This article assesses the current and potential contribution of GIS to the residential and commercial real estate industry. Existing GIS business applications by major industry function are examined, including residential brokerage, appraisal, mortgage default tracking, insurance underwriting, regulatory compliance, and market analysis. The article concludes with an overview of GIS commercial products that support these functions.

Residential Brokerage

Residential brokerage provides an interface between people who want to sell their homes and prospective home purchasers. Key to any successful real estate transaction is timely information—in a structured and repeatable standardized framework—about the property, market conditions, and transaction terms. The industry standard medium for providing such information has been the well-known Multiple Listing Service (MLS) system.

While the availability of online MLS since the mid-1970s quickened the flow of information to the market, a traditional MLS has several limitations. First, the MLS data provide limited information about the housing market because the MLS database does not include the entire stock of all property for sale, but typically includes only current listings from MLS members. Properties for sale by owners are not included, and many MLSs also lack listings of newly built housing because MLS member real estate professionals largely focus on resale housing. Second, MLS systems are geographically constrained. The geographic boundary of an MLS usually coincides with jurisdictional boundaries, which may lead to confusion and, most important, inefficiencies in market transactions for large and robust metropolitan areas such as the Washington, DC, area. Third, access to an MLS is generally restricted to its real estate professional members; real estate buyers and sellers are not generally given access to the MLS database.[1] This may force buyer and seller to make decisions based on imperfect information and of course places real estate professionals in a privileged "information have" position relative to their "information have not" clients. Finally, online MLS systems lack user-friendly search, querying, and visualization capabilities, which can play an important role in the realization of optimal housing transactions.

GIS technology is becoming influential in leading the market toward the development of nationwide computerized open-access residential property databases that are competitive with and improve upon existing MLS databases. New online databases offered via the Internet will soon allow real estate professionals to access information on all types of residential property, including newly built homes, for-sale-by-owner homes, and brokerage-listed homes regardless of whether they have an MLS listing. The MLS of the future will also offer databases of commercial, industrial, and agricultural real estate. By embedding GIS and multimedia functionality into MLS software, it is possible to display real estate information in map format and conduct spatial searches on the basis of user-specified property and neighborhood characteristics. All of this is likely to lead to the development of consumer-oriented data and tools to facilitate the home-buying process on the Internet.

Consumer-Oriented Transaction Software and Data

GIS is inherently a visual medium. GIS technology can help serious prospective buyers to target quickly the right house for them by presenting relevant information in maps, tables, and images. Consumers can perform searches using criteria along structural attributes of properties, such as the architectural style, the number of bedrooms or bathrooms, and the amenities desired, such as basement or fireplace. In addition, GIS allows spatial queries—that is, queries based on location and geographic relationships. Location-related queries can include information on a prospective buyer's place of work, preferred shopping or other desired destination, and preferred distance or travel time from home to the specified destinations. GIS has the ability to calculate in real time specified geographic relationships and identify objects (such as homes for sale) that meet the specified criteria. These applications have the potential to make residential location decisions more intuitive and thereby enable better judgment by the prospective buyer.

Rapid development software tools have allowed some companies to develop such consumer-oriented real estate applications. One such product is IRIS—an online parcel-based GIS software targeted to real estate professionals and consumers. With IRIS, buyers can "tour" MLS properties by previewing them on a computer screen. Users can view full-color pictures of every property along with tax records, lot sizes, neighborhood demographics, points of

[1] This restriction may have arisen because of the contract between seller and agent that binds the seller to pay for the services of the agent. If the buyer can bypass the selling agent, a lower price might be negotiated. So limitations on information flow have been designed to preserve the buyer-seller-agent relationship. In the past, information could be restricted and was also costly to provide and obtain. Today, the technological and cost barriers for information provision are in no way an impediment. Marketplace competition will therefore force a change in the traditional buyer-seller-agent relationship.

interest, and even who lives next door. IRIS has a search function that allows users to input up to 14 fields of information at a time. The IRIS service includes providing a mobile crew and specially equipped van that takes photographs of the parcels. Program users can then create and print full-color brochures of each property. Although the IRIS GIS is currently available for only a few metropolitan areas, the project's stated goal is to develop a seamless nationwide property information network.

The National Association of Realtors has begun work on a nationwide initiative called the Realtor Information Network (RIN) to provide real estate offices with standardized seamless computer databases and software. If fully implemented, RIN could become a de facto national MLS. A RIN-like product would enable real estate professionals to match buyers with sellers of homes more quickly and successfully. RIN data are designed to be accessed via the Internet and its central real estate database could be updated by the minute. The cost of the RIN network could be covered by a transaction fee for each use. RIN was developed by ESRI (Environmental Systems Research Institute Inc.); GDT (Geographic Data Technology) provides the geographic and demographic data.

RIN has evolved into the realtor.com site on the Internet; there are currently more than 1.3 million listings on the site. RealSelect administers the site for the National Association of Realtors, and ESRI hosts the mapping portion of the site from its headquarters in Redlands, CA. Listings are updated weekly and there is no charge for posting them. Most of the local realtor boards are currently posting listings on realtor.com. Individual brokers may post their listings to the site even if the local board of realtors has opted not to participate. There have been numerous stories about people finding their "dream homes" on the site. Images may be seen at http://www.realtor.com under the option, "find a home."

While the future of GIS technology is intriguing, one concern regarding consumer-oriented GIS applications is that their use will reinforce and possibly heighten existing residential segregation in metropolitan areas. The technology allows prospective buyers to choose accurately neighborhoods on the basis of demographic and economic factors such as racial and income composition and religious orientation. Because the home purchase is for most U.S. households the single largest lifetime investment, prospective buyers search for locations with a goal to minimize economic risk and social conflict. Inexperience with housing markets, however, can lead the consumer to engage in more tightly focused housing searches than is necessary to meet their long-term best interest.

The development of consumer-oriented applications will require that the vendor be both a software developer and a manager of data. Software development is not a significant bottleneck in this industry. Rather, the barriers to entry are the capital required for marketing and the skills needed to maintain continually changing real estate information. Most software development companies lack the skills required for data maintenance, and most data vendors do not have the required software development skills. The real estate GIS-MLS market niche requires the blending of the two, making the acquisition of sufficient capital difficult. Companies that survive in this niche will not survive on the basis of their advanced software technology and design. Rather, they will survive on the basis of superior management, marketing, and capital acquisition ability.

Land Transaction Data and Software

Information on legal real estate transactions is used for property assessment that determines property taxes and other real estate taxes. Most states, except Texas and Michigan, have open record laws on real estate transactions, making information on them available to the public. The data can be expensive and difficult for the general public to acquire, however, and may not be in a form that is easily usable.

These impediments to public access to information on real estate transactions have created a market for data value-added resellers (DVARs). A DVAR purchases the property assessment files from the local government and restructures them in an easy-to-read format, such as the popular DBF file format that most GIS and spreadsheet software can read. The DVAR's product may include a software program specific to the data, which allows the user to search and query by data field, create subsets of data, and generate reports. DVARs may provide further value by adding latitude and longitude coordinates to the data records, allowing the property assessment file to be used with a GIS software program as a fully spatial database.

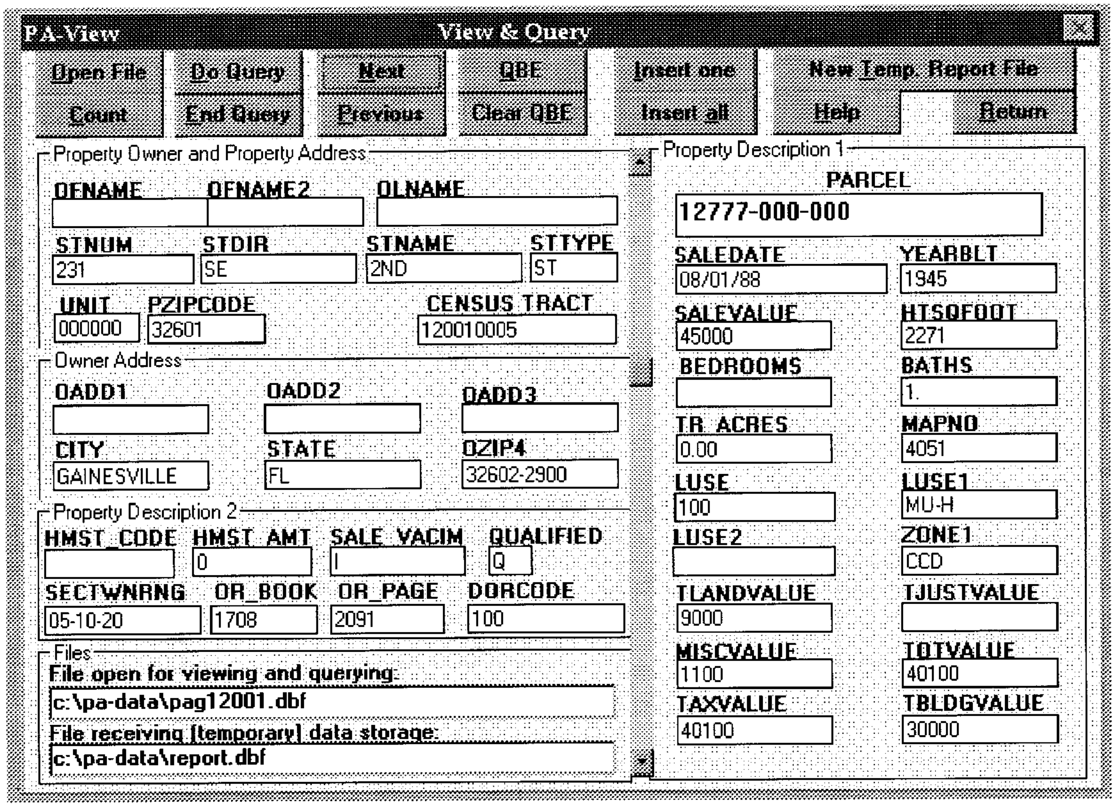
One example of a DVAR property assessment data file software and data product is PA-View (Property Assessment Viewer) developed for Alachua County, FL. PA-View allows the user to access the property tax roll information, perform queries on that information, produce tables of information on selected records (e.g., all single-family homes built since 1990 that sold for over $250,000 in ZIP Code 32605), and produce summary market reports by small area (figure 1). PA-View is user friendly and is targeted to users with very little computer expertise. Although not a GIS application per se, PA-View allows the user to easily import data in dBase format into general purpose desktop GIS software programs such as MapInfo and ArcView. Figure 2 displays the distribution of mobile homes by ZIP Code for Alachua County using the mobile-home records extracted with PA-View.

There are several other examples of similar products from DVARs. Multiple Choice from Multiple Choice Software Company is a product that links MLS data with electronic tax parcel maps, real property data, and other map layers via the Internet. Multiple Choice can be customized for any county. Another similar product is from Information Delivery Service (IDS of Indianapolis), which markets GIS-ready real estate data for Indianapolis. Stewart Title's BACA LANDATA is an example of an Internet-based DVAR. This is a public access site for address/parcel lookups and is a gateway to fee services offered by Stewart Title.[2] Also, some large firms such as TRW are starting to provide combined local real estate transactions data and software products for multiple markets.

These examples point in the direction of an emerging market for combined data and software products for using local public real estate records. These applications mostly benefit from the integrated medium GIS technology offers for spatial data management, extraction, query, and visualization. Prior to desktop GIS software, and before DVAR products, the display and analysis of information from the local tax assessment records would have been extremely time consuming, very costly, and possibly not feasible at all. With PA-View and

[2] The Internet site was built using ESRI's MapObjects Internet Map Server to access Spatial Database Engine-powered Microsoft SQL Server and Informix Online Dynamic Server relational database management systems.

Figure 1. **Data Display and Search and Query Form of PA-View**



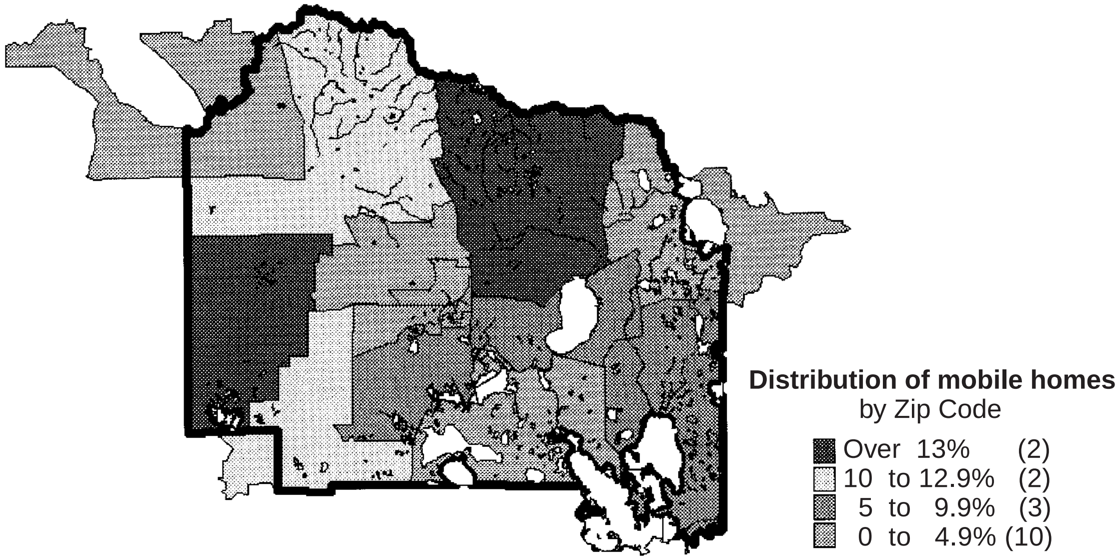
MapInfo, the Alachua County mobile-home example, took fewer than 15 minutes to create the map displayed in figure 2.

Land Information from Satellite and Air Photo Imagery

Satellite and air photo imagery is part of the world of GIS technology. Indeed, GIS can be argued to have had its beginning as a spin-off technology of satellite and air photo imagery. Whereas desktop GIS relies on vector databases—points, lines, and polygons—satellite and air photo imagery relies on raster databases.

There have been few applications of raster images in real estate analysis because property assessment data files have more usable information for most real estate applications. However, raster images can be useful supplements to traditional real estate information. For example, rooftop pictures from air photos can be useful for both direct and subsidiary real estate analyses. Property appraisal of large tracts of undeveloped land can be an expensive and tedious process. A raster image can be processed to detect acres in various types of vegetation and land slope. This information can be used along with comparable sales by land type to derive an estimated value of the acreage.

Figure 2. **Distribution of Mobile Homes in Alachua County, FL, by ZIP Code**



Note: This map was generated in MapInfo using a point-in-polygon procedure. The data from PA-View was used to determine the number of mobile homes in each ZIP Code in 1996. $N = 4{,}688$.

Satellite and air photo imagery is useful to detect new road networks not yet recorded in the TIGER/Line or other public databases. It can be used to document the underlying landscape topography—and thereby show the absence of road connectivity—and to document the presence of important natural features including shorelines, streams, and rivers. It can also be used to support a first estimation of whether the property is in a flood plain.

Satellite and air photo imagery has not been used in real estate analysis as much as vector-based GIS because the quality of available images has been inadequate. Real estate applications require at least 1-meter resolution of raster images. Coverage today is available to the public at 5-meter or 10-meter resolution. A recently formed data firm, MapFactory, has a goal to provide 1-foot resolution for all U.S. counties that are part of metropolitan statistical areas (MSAs). The present technology available to the public requires that MapFactory databases be created with air photo images. Figure 3 shows an example of a raster-based image used for site selection analysis.

Appraisal

Appraisal is a key function in the real estate industry. Property appraisal is required for housing transactions, local governments need to assess market values of properties for residential tax purposes, and lenders periodically need to estimate the value of loans in their

Figure 3. **Air Photo Raster Image.**

Note: Digital imagery provided by The MapFactory (www.mapfactory.com). Used by permission.

portfolio to assess loan loss reserves. For real estate transactions, appraisal is typically done on a single-property basis by an appraiser (certified member of the Appraisal Institute) who performs a market analysis and makes an educated guess as to the market price of the property. Today, the price of appraisal for a single-family dwelling is about $250. Although this amount may not be a large component of the overall closing costs on housing transactions, it may become a considerable administrative expenditure if it involves a large number of properties. For example, Alachua County, FL, has about 35,000 single-family dwellings, which would cost as much as $8,750,000 in property tax evaluations.

The high cost of manual appraisal of large numbers of properties led to the use of computerized automated mass assessment (CAMA) systems for residential tax assessment and portfolio management purposes. The aim of CAMA is to automate appraisal to both increase accuracy by reducing human error and decrease the cost of appraising properties by increasing productivity.[3] Currently, CAMA systems are based on statistical models that use information on existing sales to estimate the market values of properties that have not sold. This is different from the comparable sales approach used in manual appraisal in which appraisers use recent selling prices for similar properties to estimate the market value of a property.[4] Typically, a value estimate is generated using three recent nearby comparable sales adjusted for differences in the physical characteristics of the property and the neighborhood. The comparable sales approach therefore takes into account recent market information in assessing the market value of properties.

Perhaps the largest problem associated with the use of the comparable sales approach for portfolio assessment and tax purposes is the prohibitive cost and therefore operational infeasibility of finding comparable properties when large numbers of properties are involved. Spatial query capabilities of a GIS can greatly help in this regard. With a GIS, one can select not only a larger number of comparable properties but also those that more closely match the subject property. This is important because the use of more and better comparables will more accurately reflect the local market conditions and lead to more accurate estimates of market values. Researchers have begun developing advanced spatial analytical tools that come very close to replicating a manual sales comparison approach in a GIS environment (Fung, Kung, and Barber 1995; Rodriguez, Sirmans, and Marks 1995).

A GIS-based system would also allow the use of information specific to the geographic location and the neighborhood of the house being evaluated. A recent working example of a GIS-based automated appraisal system has been implemented at Seafirst Bank in Seattle. Seafirst's system is built around an integrated spatial data core that provides information on the comparables as well as the physical, socioeconomic, and demographic characteristics of the neighborhoods in which properties are located. Thus far, the Seafirst experience is showing that 80 to 85 percent of the time the results from the automated valuation system are adequate for underwriting mortgage loans. Moreover, the system informs the user of the need for additional review, inspection, or reappraisal by site inspection. Based on the experience so far, the system is expected to significantly reduce the reviewer processing of the initial valuation request and subsequently reduce the cost of obtaining a mortgage.

In addition to its contribution to residential appraisal, GIS will make commercial property estimation less costly and more accurate. Typically, commercial property is evaluated using the replacement cost approach because there are fewer comparable commercial properties than houses. Marshall & Swift's Commercial Estimator is an example of a computer-assisted real estate appraisal system for commercial and industrial buildings using the cost approach. The mathematical calculations performed by Commercial Estimator incorporate, at the scale of the five-digit ZIP Code, variation in expected costs and other market conditions. The software also adjusts for different heating and cooling systems, story heights, and other building characteristics. Thus, Marshall & Swift's offering has the promise of improving both productivity and accuracy. In addition to the cost approach, with GIS, commercial prop-

[3] At this time, sites on the Internet will for a fee of $15 provide a CAMA estimate of a home's value.

[4] Another property valuation method is the replacement cost method. The replacement cost approach begins with the determination of replacement cost—namely, how much it would cost to build or reproduce the property today. Replacement cost depends on the features of the property, its design and materials (including land), and local construction costs.

erty values can be estimated based on the revenues generated from the location. When sales figures are absent, or if a property is underutilized, geographic analysis can be used to derive highly accurate estimates of the expected sales revenues generated from a site. For a discussion of the techniques and use of GIS for this type of analysis, see Thrall and del Valle (1997a, 1997b) and Thrall, del Valle, and Hinzmann (1997, 1998a, 1998b, 1998c, 1998d, 1998e).

Not only can GIS help develop more accurate estimates of market values, it can also be used to assess the spatial equity of property tax assessments by local governments. This can be done by examining the spatial distribution of the ratio of assessed values to market values. Thrall (1979) proposed the use of geographic surfaces to monitor the quality of property assessments. Given that the expected assessed value–to–market value ratio would be a flat surface (i.e., an even plane), one can identify geographic areas with significant clustering of high and low ratios by identifying variations from this flat surface. Thrall (1979), in his examination of Hamilton, Ontario, found that high assessed value–to–market value ratios clustered in low-income neighborhoods with high concentrations of recent immigrants or racial or ethnic minorities and neighborhoods affected by negative externalities such as noise and pollution. He also found low assessed value–to–market value ratios clustered in high-income neighborhoods harboring positive externalities such as attractive hillside views. Low ratios were also found in neighborhoods undergoing transition from a lower population density to a higher population density through redevelopment.

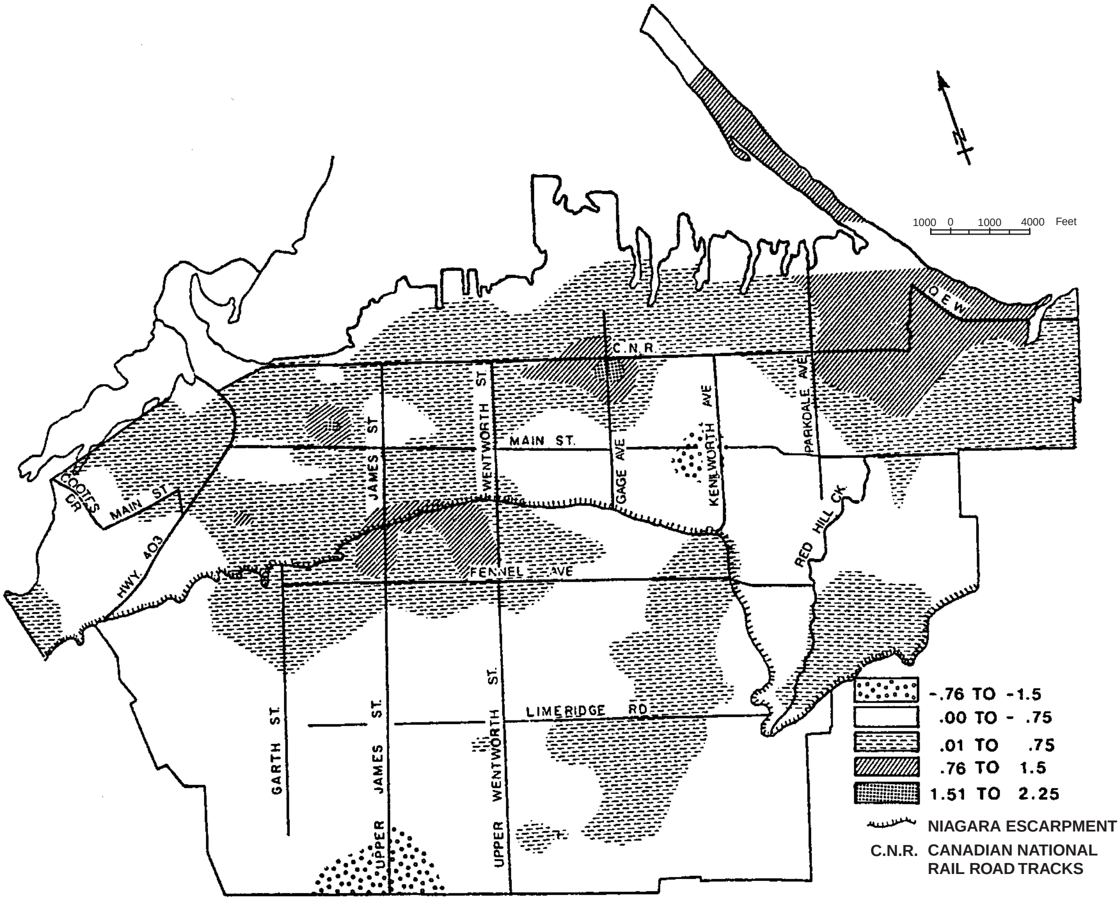
Geographic surfaces and spatial statistical measurements of assessed value–to–market value ratios can be calculated on a routine basis (for a cautionary note, see Thrall 1998e). In this manner, spatially nonrandom clustering of high or low ratios could be revealed, thereby signaling to the property assessor to reevaluate assessments in that neighborhood and to make modifications as necessary to ensure equitable property assessment. Today, because of GIS technology, Thrall's geographic criterion for property tax assessment equity can be applied to any assessment district in a few minutes (Thrall, Thrall, Ruiz, and Sidman 1993). Figure 4 shows Thrall's (1979, 1987) geographic surface of the assessed value-to-market value ratio (see Thrall 1998e for issues that should be considered when using and interpreting such geographic surfaces).

Insurance Underwriting

Many real estate transactions could not occur without the promise that the mortgage lender and owner can—and will—be insured against loss. Geographic Underwriting System (GUS[5]) by Datamap, Inc., is a GIS tool for insurance underwriters that links specific addresses with risk information and policy pricing variables, eliminating costly and time-consuming manual lookups. GUS is designed to streamline insurance underwriting by incorporating geographic information and GIS technology to forecast losses associated with place-based environmental hazards including fire, hurricanes, storms, floods, and earthquakes. GUS services include the detection of risk and verification that the risk is appropriately charged. A major benefit of GUS is the reduction of costs of getting location-based information for underwriting and rating risk and the subsequent increase in underwriting precision and efficiency.

[5] GUS is a registered trademark.

Figure 4. **Geographic Surface of Assessed Value–to–Market Value Ratios**



Source: Thrall (1979, 1987).

Another example of a GIS-based software program for the insurance and banking industry interface is Harvard Design & Mapping Company's FloodInfo Florida, which evaluates flood risks by address and displays Digital Flood Insurance Maps produced by the Federal Emergency Management Agency. The product includes a runtime version of MapInfo, statewide street data, and flood data for 21 counties in Florida.

GIS-based insurance risk software should be used with great caution. GIS data may, on average, provide sufficient accuracy. However, the risk factors for some properties may be incorrectly identified, such as by including a property in a flood zone when it is not, or listing a property as being outside a flood-prone zone when in fact the property is prone to flood hazards. Such errors of geographical inclusion and exclusion are expected to occur and may also result from the inherent geographic inaccuracy of the boundary and street data available. Making decisions based on whether a property is inside or outside a flood zone requires geopositional and resolution accuracy down to, say, a foot. For any geographic analysis used in management decisions, the level of geopositional and resolution data accuracy must be at least as great as the geographic scale that the judgment requires. The major limitation is the quality of the geographic data.

Regulatory Compliance

Real estate transactions normally require financing. Market conditions and regulations that affect the financial markets then also affect the real estate markets. Federal government requirements that directly affect the combined real estate and financial industries include the Community Reinvestment Act (CRA) and related Home Mortgage Disclosure Act (HMDA).

Requirements for compliance with HMDA and CRA are inherently spatial, making GIS an excellent vehicle for efficient reporting of such compliance (see Cassettari 1994; Henry 1994; Iida 1991; Schieber 1990; Zahodiakin 1993). GIS can help in several ways. First, it can assist in creating CRA compliance reports and supporting documentation—a complex task given the large databases involved. Spatial database management capabilities of GIS can greatly aid in the organization, tracking, and analysis of the mortgage databases.

Second, the use of GIS as part of routine internal compliance monitoring can help a financial institution become proactive and avoid repercussions from failing compliance. GIS, for example, can help identify profitable markets that have been inadvertently missed in the past, or identify markets where there is overexposure and needless investment within the derived market area of the financial institution. Both would certainly translate into increases in the financial institution's market share and revenues (Thrall, Fandrich, and Thrall 1995). Once census tracts with little market penetration have been identified, the proactive financial institution can obtain name and address listings from commercially available databases and use an appropriate advertising medium to contact commercial and residential prospects (see, for example, Thrall and Thrall 1993). Documentation of having aggressively provided information on the range of services and products available can help the financial institution defend itself against accusations that it is avoiding making loans in certain census tracts. Compliance with CRA does not require the financial institution to make bad loans or otherwise act without the strongest adherence to fiduciary responsibility. Rather, it requires that the financial institution demonstrate that it has made a good faith effort to make its products and services available without bias (at the scale of the census tracts).

There are several commercially available CRA/HMDA compliance software products, which range from free Federal Reserve Board compliance software to very sophisticated GIS-based software programs. Software by Rata and Centrax (Colby 1993) is specifically designed for HMDA compliance. The Federal Reserve Board's HMDA Uniform PC Software allows financial institutions to fill out the standard register and submit it electronically to the appropriate regulator. UJB Financial (Princeton, NJ) offers a GIS-based product for CRA reporting and the identification of CRA market potential using information from the financial institution's customer and applications files, census tract data, and market data (Radding 1991).

Software firms, such as EDS Corporation (see Sullivan 1993), Tactician[6] Corporation, and Spatial Decisions & Analysis, Inc (SD&A), offer more comprehensive software products for CRA/HMDA monitoring and compliance. For example, Tactician's CRA Analyzer is a Microsoft Windows–based software program that includes geographic and census data, a geocoding system, unit record, and summarized HMDA data. CRA Analyzer includes six standard CRA Delineation Area reports: market share performance, minority lending activity, census tract summary, application income classification by census tract, market rank, and loan portfolio analysis. Also, users can view summarized HMDA data for any census tract: total applications, total reporters, total applications by race, total applications by type of loan, race, income category, gender, action taken, and other key CRA statistics and indexes.

CRA software from SD&A uses GIS-constructed maps to generate compliance and marketing reports. The software first derives the market area using the actual spatial patterns of lending by the financial institution. Second, demographic information is used to identify the location of low- to moderate-income census tracts in a lender's market area. Third, overlay maps are constructed that show where mortgage applications originated and where mortgage loans are approved and/or denied. Fourth, overlay maps are used to show the relative concentration of activity by census tract. GIS-based reports make apparent whether the financial institution is obtaining mortgage applications from the residents of low- and moderate-income census tracts in the lender's market area and whether the lender is approving mortgage loans in those areas. These reports can be used to evaluate the appearance of redlining and to assist in demonstrating compliance with the HMDA requirements.

A related benefit of the GIS-based CRA/HMDA reporting systems to financial institutions is that the same databases used for the CRA and HMDA analyses can also be used to identify market opportunities. For example, GIS can be used to create reports of household banking profiles that agglomerate multiple accounts that belong to a single household (see Graham 1992). GIS technology can simplify such agglomeration by geocoding the household locations. The resulting geocoded household profile can be associated with other consumer information to form household profiles. These profiles could inform the financial institution about the types of households, as well as the range of services, that are most profitable to their enterprise. This information can then be used to perform focused target marketing to increase the base of most profitable customers. The household banking profiles in combination with tax roll databases can be important sources of information about potential customers for banking and real estate services.

Market Analysis

Real Estate Site Analysis

Some real estate firms and financial institutions offer value to their customers through the strategic location of their agencies, branches, and headquarters. Financial institutions also

[6] Tactician is a registered trademark.

spatially distribute automatic teller machines as a service to their clientele. Commercial site evaluation is a key factor in deciding where to locate services.

Formal locational analysis that was unattractive to practitioners in the past because of its complexity and cost is now becoming more attractive because of the heightened productivity in the GIS industry associated with the overall technological transformation of the personal computer industry. Businesses are increasingly more technologically oriented and are interested in using GIS to examine business opportunities systematically and to develop locational strategies accordingly. What may have been considered an optimal distribution of sites may instead become after a merger duplicative and inefficient. Which sites should be closed and which should remain open? And what was once an appropriate location based on surrounding demographics might subsequently become inappropriate as household consumption patterns change. If those households remain in place, then what may have been a desirable retail site may instead become undesirable.

Certain locations offer distinct advantages over other locations. As Ritchey (1984, 319) states in the context of retail analysis, "All retailing operations are complex but most executives would agree that location (and its associated attributes) contributes more to the long term success of the retail unit than does any other factor." Ritchey also argues that the sales above and beyond what the site can create for itself are what contribute to success, so location in the marketplace actually produces the profitability of the retail unit. Therefore, having the right location for the retail or service industry is critical because it is by way of the outlet's location that customers access the offerings of the business (Brown, Brown, and Craig 1981). Usually, the locational advantages are measured in increased sales and profits. The location of a retail or service outlet can be the characteristic that distinguishes those outlets that meet or exceed sales performance objectives from those that do not. GIS provides the looking glass for differentiating between sites before the investment is made, enabling the site analyst to simultaneously analyze unique local market conditions, land use patterns, and demographics. This can help develop a customized location strategy, eliminating the need to follow a highly structured "cookie-cutter" approach to real estate site location. Thus, with GIS, the site analyst will be less likely to overlook good sites and more likely to quickly eliminate inferior sites from consideration.

Site location questions in real estate are best addressed when GIS is used in conjunction with formal locational analysis (see Birkin and Clarke 1998 for a detailed discussion). GIS, without formal locational analysis, would become a "black box" and would be more detrimental than beneficial since one can easily apply the wrong methods at the expense of individual experienced judgment.[7]

The World Wide Web may also change site location strategy for many institutions (Thrall 1997). For example, households may access basic real estate, banking, and mortgage finance services through the Internet or other forms of electronic access links. The more a household

[7] There is a vast literature in geography on the analysis of the location of retail sites (see, for example, Barnett and Okoruwa 1993; Haynes and Fotheringham 1984; Thrall and del Valle 1996a, 1996b, 1996c, 1997a, 1997b; Thrall, del Valle, and Hinzmann 1997; Thrall and Thrall 1990).

interacts with commerce in e-space (electronic space) the fewer geographic (g-space) sites will be required. The locations of those fewer g-space sites allowing face-to-face interaction are going to be more critical to the business than when g-space sites densely covered the landscape. Retail firms will also use the Internet to help them more precisely define their market areas and thereby improve their site location strategy (Thrall 1997).

Measuring Housing Demand

Forecasting the demand for housing by price and location is a necessary ingredient when deciding whether a housing construction loan should be given, and at what rate. The rate reflects market risk. Analysts have traditionally evaluated housing demand by tracing the trajectory of average growth within an area, such as a county or smaller submarket over time, and then forecasting future demand for that area by extending the historic housing absorption pattern to the future. The most common statistical technique used to forecast housing absorption patterns is the Autoregressive Integrated Moving Average (ARIMA) model. The ARIMA model uses the historical trend of a data set and extends that trend into the future. A problem with this approach is that historical patterns of growth often make no sense when extended into the future. In real estate, we know that historical patterns can produce reliable estimates for only very short time horizons, and only for the middle stages of housing development by submarket.

A target housing submarket may be conceptualized as having four stages of housing absorption: first stage—no absorption; second stage—small levels of housing growth spill over to the target submarket from nearby more mature submarkets that are becoming saturated; third stage—the rate of growth of the target submarket quickens; and fourth stage—eventually the target submarket becomes saturated and housing absorption is reduced to levels equal to the first stage. The ARIMA models, although expedient, are incapable of capturing this complex and more realistic stage pattern of housing development.

With GIS, more complex geography can be included in the modeling and statistical procedures, thereby allowing explanation to fit more closely the real world. In the context of housing prediction, GIS can facilitate the positioning of the correct information within each submarket and the subsequent analysis of the submarket specific data. If, for example, we want to calculate for a specific neighborhood the rate of housing absorption six years into the future, a space-time forecast would take into consideration the following factors: historical growth of the neighborhood (i.e., a census tract); historical growth of the neighborhoods surrounding the "target" neighborhood; limitations on future growth attributable to zoning and/or environmental constraints; the expected population increase by demographic category for the region (i.e., the county) surrounding the target neighborhood; and the stage of development of the housing submarket for housing absorption as explained previously.

Using the above conceptualization, Thrall, Sidman, Thrall, and Fik (1993) developed and calibrated a space-time model called the Cascade GIS Diffusion Model, with the aid of GIS technology. The term *cascade* in this model refers to the mixture of geographic scales and the identification of how phenomena at different scales are linked and interdependent. The model takes into account the impact of market conditions and higher levels of geography (such as county and region) in predicting residential single-family development patterns. The calibration of this model using parcel-specific data for St. Lucie County, FL, resulted in forecasting error that generally did not exceed 3 percent in the scenarios tested.

Thrall, McClanahan, and Thrall (1995) introduced a GIS procedure for visualizing the growth of various land use types in an urban area through time and location. Based on the entire legal property records for St. Lucie County, FL, from its beginnings in 1900 through 1992, they documented the spatial patterns of urban growth using GIS. Similar to the findings in Hoyt (1933, 1939, and 1966), they found that urban growth is not symmetric in its development but exhibits a sectoral pattern. Thrall, McClanahan, and Thrall (1995) also documented the succession of land use, including that retail development follows in-place demographics as measured by housing construction.

Geodemographics

Geodemographic systems provide sophisticated marketing tools by combining GIS functionality with a variety of electronic databases, including government census data, updated census-like data, and lifestyle databases (for more discussion, see Birkin and Clarke 1998). A major provider of geodemographic products, Claritas, offers industry-specific desktop market analysis and mapping systems built on their general-purpose COMPASS and CATALYST software platforms. The COMPASS/Banking software and commercial data product allows the user to access dozens of databases on a fee-for-use basis; COMPASS/GIS allows the program user to link with desktop computer GIS software; CATALYST provides online access to current market information. These Claritas products allow the user to perform analysis at geographic scales meaningful to the financial institution including the small geography of the "neighborhood." And Claritas offers an up-to-date alternative to once-a-decade U.S. Bureau of the Census information.

Intercensus-year estimates and projections provided by commercial data vendors may not be as accurate as the user requires, thereby leading to possible errors of judgment. Little has been done to verify the quality of the data the vendors use in forecasting market potential and sell to their customers. Because of the uncertain data quality and high cost of commercial data, some consumers of demographic data continue to rely on U.S. Bureau of the Census measurements, which may be acceptable for those neighborhoods not undergoing significant development or demographic change.

Several alternatives to Claritas exist. For example, Scan/US version 1.16 is targeted to the business professional who wants to perform geodemographic analysis and related market evaluation tasks and at the same time avoid the complexities of desktop GIS software. Argus Technologies offers its Argus Professional to a business niche similar to that targeted by Scan/US. The Argus product differentiates itself from the Scan/US product by offering a corporatewide enterprise solution where common geographic databases can be shared, as well as Argus map windows, map objects, map layer definitions, script language reports and graphs, and map analysis functions.

Two of CACI's GIS-based geodemographic products are also relevant. First, CACI Coder/plus (Thrall 1998c) assigns latitude-longitude coordinates to individuals and households on the basis of their street address, and then uses that geographic information to assign demographic and lifestyle-segmentation indexes to these records. CACI's Site Reporter (Thrall

1998d) creates ring reports around an address; it generates reports containing demographic, lifestyle-segmentation, and expected expenditure projections for the current year and the next five years. The Site Reporter program user specifies the width of the circular band and its distance from the address point. Ring-study information is generally the starting point for corporate real estate decisions, including but not limited to retail site location decisions.

Real Estate Application Software: Tools to Create GIS Real Estate Business Applications

GIS applications are being introduced in the market to meet the needs of the end user as outlined in the above categories. The software developer can meet application development needs with new rapid development programming languages such as Microsoft's Visual Basic. The wide array of "preprogrammed" functionality offered by Visual Basic can be added as component modules to the language environment. Component programming relieves the professional software developer from continually "reinventing the wheel." However, until recently, GIS has been absent from the list of tools available to Visual Basic programmers. (For an extended discussion of the role of Visual Basic rapid development tools and their anticipated effect on the GIS end user applications market, see Thrall 1996a.)

Rapid development software tools will allow GIS functionality to be included in any software application where spatial analysis makes sense. Because the programming time and effort is reduced with the new technology, the cost of development and time to market for the software is greatly reduced. This means that a greater variety of real estate software applications will be introduced to the market, at increasingly lower costs. The new software development tools also allow the software to be developed with user interfaces that require little or no training. As the technology is introduced into the marketplace, it will change the ways in which real estate is practiced and real estate decisions are made.

The history of GIS programming development tools begins with Strategic Mapping Incorporated (SMI), which introduced in the early 1990s what could have been a breakthrough in GIS programming component tools. SMI's GIS-enabling programming tools were compatible with Microsoft Visual Basic. However, SMI's management outlook was oriented to the short term and missed the opportunity to become the market leader in this software component category. SMI and other GIS vendors seemed more frightened of the market for programming component tools than they were enthusiastic about the new market niche. SMI's management seemed to be overly concerned with how software developers might use SMI's programming tools to compete with their general-purpose GIS software and seemed not to have a vision that the future of GIS technology was in its use in industry niche applications and not more general-purpose GIS software products. SMI's suite of GIS component tools was prohibitively expensive and overly restricted by complex licensing agreements. Also, the company deliberately limited the programming tools for use only with its expensive proprietary database format. Finally, SMI's product also suffered from the absence of documentation and poor design. The result was that few software firms adopted SMI's pioneering software tools. SMI subsequently dissolved as a company, and ESRI purchased its GIS software division.

The gap created by management at SMI and the other major GIS software firms choosing not to offer GIS programming modular tools became an opportunity for small and innovative firms to enter the market, such as the three-person SylvanMaps of Santa Fe, NM. In the fall of 1995, SylvanMaps released SylvanMaps/OCX, the first GIS modular programming component tool to reach the general market (for a review, see Thrall 1996b). SylvanMaps/OCX included all the standard TIGER/Line polygon files such as census tracts and county and state, and national boundaries. During the first quarter of 1996, a second GIS programming component tool for Visual Basic was added to the market from Pepperwhite, Inc. Pepperwhite Street includes all the standard TIGER/Line streets and polygons.

The combined presence of SylvanMaps' and Pepperwhite's products forced the larger firms that offered general purpose GIS software products, such as ESRI, to unbundle their GIS functionality (see Thrall, del Valle, and Thrall 1995) as well as component programming tools. ESRI has subsequently introduced MapObjects, an OCX component programming tool that can be used with programming environments such as Visual Basic, Visual C++, and PowerBuilder. Following the introduction of ESRI's MapObjects, a host of GIS programming tools were offered by leading GIS technology vendors. Moreover, because of the explosive growth of the Internet, these software firms released versions of their GIS software and programming tools that were Internet enabled. By 1997 software developers could easily and inexpensively make Web sites fully geographically enabled.

Rapid development languages—such as Visual Basic and Visual C++—and modular component GIS software development tools will allow new software to be brought inexpensively to the market. New software will be targeted to the applications needed by the real estate industry.

The U.S. Department of Housing and Urban Development's (HUD) Community 2020 is an example of a GIS software application that is built on a general GIS software platform (Maptitude from Caliper Corporation) targeted to the computer novice. Community 2020 brings to the general real estate industry the wealth of HUD data, as well as automated thematic mapping and the power of a general-purpose GIS software program. For a review of Community 2020 see Golant and Thrall (1998) and Thrall and Golant (1998).

General-Purpose GIS Software

Although the future is with real estate application software using GIS technology, such as CensusCD+Maps and HUD's Community 2020, general-purpose GIS software programs today still fill a needed role of performing geographical analysis and geographic data visualization. General-purpose GIS software requires knowledge of geographically enabled data, geographical analysis, and the procedures that must be executed and the GIS functions accessed as required to perform geographical analysis. Unlike so-called black-box applications that distance the program user from the intricacies of the software, this burden does ultimately fall on the user of general-purpose GIS software. Large corporations try to make successful decisions as repeatable as possible. As GIS becomes more integrated into the decision-making process of business, application-specific GIS software will replace general all-purpose GIS software in those business markets.

Quality desktop GIS software abounds from companies like Intergraph, Autodesk, ESRI, MapInfo, Caliper, and others. The appendix provides a sampling of GIS functionality available in three popular general-purpose GIS software programs: MapInfo from MapInfo Corporation, ArcView from ESRI, and Maptitude from Caliper Corporation. Not included in the appendix are several recently released very high quality general-purpose GIS software programs including GeoMedia from Intergraph Corporation and Autodesk World GIS from Autodesk Corporation. GeoMedia has been reviewed by Thrall (1998b). Autodesk World GIS has been reviewed by Thrall (1998a).

GeoMedia is part of a true enterprise solution, ideal for large corporations with many offices and many divisions sharing a large common database. GeoMedia and the vertical line of software from Intergraph follows the Open GIS (OGIS) architecture where it does not matter what format the geographic data are stored in: MapInfo, ArcView, ARC/INFO, and AutoCAD. The intent of OGIS is to transparently utilize all that information.

Autodesk World GIS, like GeoMedia, has a contemporary design. The software is compatible with Microsoft's Office suite, including Excel, Word, and Access. Autodesk World GIS is also fully compatible with Autodesk's other software including AutoCAD.

Conclusion

Commercial and residential real estate, more than any other sector of our economy, are sensitive to location, and consequently, the ability to measure the impact of location is critical. Only with the advent of GIS has it become possible for real estate professionals to measure the true impact of location and then make appropriate judgments based on the knowledge of that impact.

Recent GIS business applications in real estate have mostly been fueled by the transfer of academic work to practitioner needs. An evaluation of the benefits of geographic analysis compared with its cost has forever changed in favor of performing geographic analysis in the business community. Technological advances in the personal computer industry, including faster computation processing and the emergence of a highly competitive industry for geographic and demographic data, have greatly facilitated the application of academic knowledge to practitioner needs.

As the full potential of GIS is realized, the real estate market will move to higher levels of efficiency and productivity. Greater efficiency and productivity will come with a human cost, however; fewer professionals will be required to meet the needs of consumers. Also, an unintended consequence of the increasing use of GIS in real estate and related markets may be greater market segmentation through submarkets. Perhaps the most important contribution that geographic technology will have on the real estate and housing finance industries is an increase in accuracy and timeliness of information that is accessible to both real estate professionals and the general (consuming) public. Thrall and Thrall (1991) have stated that real estate is "information arbitrage." GIS will become the real estate information management tool. We can already see the impact of GIS on the real estate world, a world where location is critical to every decision. It is only with the use of GIS that we can measure the impact of location on each decision.

Appendix

GIS Software Programs and Their Functions

GIS Functions	ArcView	MapInfo Professional	Maptitude
General-purpose GIS	Yes	Yes	Yes
Thematic mapping	Yes	Yes	Yes
Contour and surface	No (available as an add-on)	No (but forthcoming)	No (available with GIS+)
Distance Calculations: Single or Batch Mode			
Single mode	Yes	Yes	Yes
Batch mode	Yes	No	Yes (accessed via the Edit-Fill command, can fill a field with distances between a feature and the closest map feature in another layer)
Measurement Types			
Road distance	Yes (available as an add-on with ESRI's Network Analyst)	No (available for purchase from third-party vendors)	Yes
"As the crow files" distance	Yes	Yes	Yes
Manhattan distance	No	No	No
Database Import/Export: Point			
dBase	Yes	Yes	Yes
Lotus	Yes	Yes	Yes
ASCII	Yes	Yes	Yes
ARC/INFO	Yes	Yes	Yes
ODBC	No	No	Yes (allows import of Lotus, Excel, etc.)
Polygon Vector Import/Export			
TIGER/Line	No	No	Yes (import only)
MapInfo	Yes	Yes	Yes
ARC/INFO	Yes	Yes	Yes
ARCView	Yes	Yes	Yes
AtlasGIS	Yes (AGF to Shapefile converter available free from ESRI Web site)	No	Yes
Database Relational			
Link files	Yes	Yes	Yes
Link attributes to object	Yes	Yes	Yes
SQL (Structured Query Language)	Yes	Yes	Yes
Conditional select	Yes	Yes	Yes

GIS Software Programs and Their Functions *(Continued)*

GIS Functions	ArcView	MapInfo Professional	Maptitude
Layering and Aggregation: Point and Polygon Overlays			
Polygon to polygon	Yes	Yes (accessed via thematic mapping feature)	Yes
Polygon to point	Yes	No	Yes
Larger polygon to smaller	Yes	Yes (accessed via thematic mapping feature)	Yes
Smaller polygon to larger	Yes	No	Yes
Print and Graphics Quality: Creation			
Includes a layout form	Yes	Yes	Yes
Ease of producing good thematic maps	Excellent	Excellent	Excellent
Exports screen image	Yes	Yes	Yes
Includes true type fonts for symbolization	Yes	Yes	Yes
Type			
Graduated color	Yes	Yes	Yes
Graduated symbol	Yes	Yes	Yes
Unique value	Yes	Yes	Yes
Dot density	Yes	Yes	Yes
Contour and surface	Yes (with the 3-D analyst extension)	No	No (available with GIS+)
3-D surface	Yes (with the 3-D analyst extension)	No (but forthcoming)	No (available with GIS+)
Pie and bar for each map object	Yes	No	Yes
Automatic data normalization	Yes	Yes	Yes
Built-In Statistical Functionality			
Moments about the mean	Yes	Yes	No
Bar and pie charts	Yes	No	Yes
Regression analysis	No	No	No
Morans I	No	No	No (included with GIS+)
Object Creation: On Screen			
Object reshape or move	Yes	Yes	Yes
Polygon/line join	Yes	Yes	Yes (part of topological editing of map areas)
Polygon/line split	Yes	Yes	Yes (part of topological editing of map areas)

GIS Software Programs and Their Functions *(Continued)*

GIS Functions	ArcView	MapInfo Professional	Maptitude
Adding and Deleting Objects			
Polygons	Yes	Yes	Yes
Points	Yes	Yes	Yes
Lines	Yes	Yes	Yes
External ditizer support	Yes	Yes	Yes
Feature snapping support	Yes	Yes	Yes
Auto completion of polygons	Yes	No	Yes
Multipart feature support	Yes	No	No
Point Georeferencing			
Street level address matching	Yes	Yes (requires additional purchase of geographic data)	Yes (includes as standard the required geographical data and software)
Five-digit ZIP Code matching	Yes	Yes (requires additional purhcase of geographic data)	No (user must supply the required geograpic data from third-party vendor)
ZIP + 4 matching	No (but available as an add-on from many third-party vendors)	No (but available as an add-on from many third-party vendors)	No (user must supply the required geographic data from third-party vendor)
Conversion between different projections	Yes	Yes	Yes
Use of externally derived points	Yes	Yes	Yes
Query			
Polygon, points, vectors	Yes	Yes	Yes
Spatial relationships query	Yes	Yes	Yes
Buffering			
Around polygon, points, vectors	Yes	Yes	Yes (can do multiple buffers at same time)
Raster Base Map			
Display	Yes	Yes	Yes
Registration	No	Yes	Yes
Rubber sheeting	No	Yes	No
Automated Capability			
Macro creation	Yes	No (available with purchase of MapBasic from MapInfo Corp.)	No (available with purchase of GISDK from Caliper Corp.)
Customizable interface	Yes	No (available with purchase of MapBasic from MapInfo Corp.)	No (available with purchase of GISDK from Caliper Corp.)
Third-party applications	Yes	Yes	Yes

GIS Software Programs and Their Functions *(Continued)*

GIS Functions	ArcView	MapInfo Professional	Maptitude
Labeling			
Automatic labeling	Yes	Yes	Yes
Automatic labeling: Multiple layers	Yes	Yes	Yes
Labeling conflict resolution	Yes	Yes	Yes
Balloon-text boxes	Yes (requires use of free software downloaded from ESRI's Web site)	Yes	Yes
Network (Routing) Analysis			
Point-to-point routing	Yes (requires purchase of ESRI's Network Analyst)	No (available through purchase of third-party application)	Yes
Best route between N Number of points	Yes (requires purchase of ESRI's Network Analyst)	No (available through purchase of third-party application)	Yes
Drive-time/distance calculation	Yes (requires purchase of ESRI's Network Analyst)	No (available through purchase of third-party application)	Yes (time requires purchase of additional data if available)
Closest facility routing	Yes (requires purchase of ESRI's Network Analyst)	No (available through purchase of third-party application)	No (available with Transcad from Caliper Corp.)
Data			
Geograpic Data			
Street	No (available with StreetMap Extension or from third-party vendors)	No (available for purchase from MapInfo or third-party vendor)	Yes (national street data on one CD)
Major roads	Yes	No (available for purchase from MapInfo or third-party vendor)	Yes (included with street data CD)
Highways	Yes	No (available for purchase from MapInfo or third-party vendor)	Yes (included with street data CD)
State, city, and county boundary	Yes	No (available for purchase from MapInfo or third-party vendor)	Yes
Landmark points	Yes	No (available for purchase from MapInfo or third-party vendor)	Yes
Census tract	Yes	No (available for purchase from MapInfo or third-party vendor)	Yes
Census block group	No	No (available for purchase from MapInfo or third-party vendor)	No (available at additional cost)
Census block	No	No (available for purchase from MapInfo or third-party vendor)	No (available at additional cost)

GIS Software Programs and Their Functions *(Continued)*

GIS Functions	ArcView	MapInfo Professional	Maptitude
Atrtribute Data			
U.S. Census of population	Yes (a subset)	No (available for purchase from MapInfo or third-party vendor)	Yes
U.S. Census of housing	Yes (a subset)	No (available for purchase from MapInfo or third-party vendor)	Yes
Current year population estimates	No (available from vendor or third-party vendors)	No (available from vendor or third-party vendors)	No (available from vendor or third-party vendors)
World Data			
International subnational boundaries	Yes	No (available for purchase from MapInfo or third-party vendor)	No (available for additional charge)
International landmark	Yes	No (available for purchase from MapInfo or third-party vendor)	No (available from third-party vendors)

Source: Updated from Clapp, Rodriguez, and Thrall (1997).

References

Barnett, Albert, and Ason Okoruwa. 1993. Application of Geographic Information Systems in Site Selection and Location Analysis. *Appraisal Journal* 61(2):245–83.

Birkin, Mark, and Graham Clarke. 1998. GIS, Geodemographics, and Spatial Modeling. *Journal of Housing Research* 9(1):87–111.

Brown, L. A., M. A. Brown, and C. S. Craig. 1981. Innovation Diffusion and Entrepreneurial Activity in a Spatial Context: Conceptual Models and Related Case Studies. In *Research in Marketing,* ed. J. N. Sheth. Greenwich, CT: JAI Press.

Cassettari, Seppe. 1994. Geography Is the Key. *Banker* 144(825):93.

Clapp, John M., Maurcio Rodriguez, and Grant Ian Thrall. 1997. How Can GIS Put Urban Economic Analysis on the Map. *Journal of Housing Economics* 6(4):368–86.

Colby, Mary. 1993. Gearing Up for the Next Round of Mortgage Lending Scrutiny. *Bank Management* 69(4):46–52.

Fung, D., H. Kung, and M. Barber. 1995. The Application of GIS to Mapping Real Estate Values. *Appraisal Journal* 63(4):445–52.

Golant, Stephen, and Grant Ian Thrall. 1998a. Community 2020 (HUD Community Planning Software). *Geo Info Systems* 8(2):49–51.

Graham, Ken. 1992. Data Base Marketing with a PC-Based MCIF. *Journal of Retail Banking* 14(2):17–24.

Haynes, Kingsley, and A. Stewart Fotheringham. 1984. *Gravity and Spatial Interaction Models.* Scientific Geography Series, vol. 3. Newberry Park, CA: Sage.

Henry, Shannon. 1994. CRA Focuses Mapping Firm's Sights on Banks. *American Banker,* September 1, p. 6.

Hoyt, Homer. 1933. *One Hundred Years of Land Values in Chicago.* Chicago: University of Chicago Press.

Hoyt, Homer. 1939. *The Structure and Growth of Residential Neighborhoods in American Cities.* Washington, DC: Federal Housing Administration.

Hoyt, Homer. 1966. *According to Hoyt: 50 Years of Homer Hoyt (1916–1966).* Washington DC: Homer Hoyt Institute.

Iida, Jeanne. 1991. Banks Pushed to Track Lending. *American Banker,* December 23, p. 1.

Radding, Alan. 1991. Going with GIS. *Bank Management* 67(12):28–35.

Ritchey, J. 1984. Developing a Strategic Planning Data Base. In *Store Location and Store Assessment Research,* ed. R. L. Davies and D. S. Rogers, 319–31. New York: Wiley.

Rodriguez, M., C. F. Sirmans, and Alen Marks. 1995. Using Geographic Information Systems to Improve Real Estate Analysis. *Journal of Real Estate Research* 10(2):163–72.

Schieber, Paul H. 1990. HMDA New Reporting Burdens. *Mortgage Banking* 50(6):23–25.

Sullivan, Deidre. 1993. EDS Offers Help on CRA Compliance. *American Banker,* May 10, p. 3.

Thrall, Grant Ian. 1979. A Geographic Criterion for Identifying Property Tax Assessment Inequity. *Professional Geographer* 31(3):278–83.

Thrall, Grant Ian. 1987. *Land Use And Urban Form.* London: Routledge/Methuen.

Thrall, Grant Ian. 1993. Using a GIS to Rate the Quality of Property Tax Appraisal. *Geo Info Systems* 3(3):56–62.

Thrall, Grant Ian. 1995. New Generation of Mass-Market GIS Software: A Commentary. *Geo Info Systems* 5(9):58–60.

Thrall, Grant Ian. 1996a. Modular Component Programming: The Foundation of GIS Applications. *Geo Info Systems* 6(2):45.

Thrall, Grant Ian. 1996b. SylvanMaps/OCX First Impressions *Geo Info Systems* 6(2):47.

Thrall, Grant. 1997. The Web-ulous World of GIS. *Geo Info Systems* 7(3):52–55.

Thrall, Grant Ian. 1998a. Autodesk World GIS 1.0. *Geo Info Systems* 8(2):44–46.

Thrall, Grant Ian. 1998b. GeoMedia from Intergraph. *Geo Info Systems* 8(2):46–48.

Thrall, Grant Ian. 1998c. CACI Coder/plus version 1, Review. *Geo Info Systems* 8(6):43–46.

Thrall, Grant Ian. 1998d. CACI Site Reporter with Scan/US, Review. *Geo Info Systems* 8(6):46–49.

Thrall, Grant Ian. 1998e. Common Geographic Errors of Real Estate Analysis. *Journal of Real Estate Literature* 6(1):45–54.

Thrall, Grant Ian, and Paul Amos. 1996. GIS within Real Estate and Housing Mortgage Industries: Agendas for the Near Future. Paper presented at the Fannie Mae Research Roundtable. Washington, DC.

Thrall, Grant Ian, and Juan del Valle. 1996a. Retail Location Analysis: Antecedents. *Geo Info Systems* 6(6):48–52.

Thrall, Grant Ian, and Juan del Valle. 1996b. William Applebaum: Father of Marketing Geography. *Geo Info Systems* 6(8):50–54.

Thrall, Grant Ian, and Juan del Valle. 1996c. Calibrating an Applebaum Analog Market Area Model with Regression Analysis. *Geo Info Systems* 6(11):52–55.

Thrall, Grant Ian, and Juan del Valle. 1997a. Antecedents of Applied Geography: Marketing Geography. *Applied Geographic Studies* 1(3):207–14 .

Thrall, Grant Ian, and Juan del Valle. 1997b. The Calculation of Retail Market Areas: The Reilly Model. *Geo Info Systems* 7(4):46–49.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1997. Retail Location Analysis with GIS: Seven Strategic Steps. *Geo Info Systems* 7(10):42–45.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1998a. Applying the Seven-Step Site Selection Methodology to Red Lobster Restaurants: Steps One and Two. *Geo Info Systems* 8(2):40–43.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1998b. Retail Location Analysis, Step Three: Assessing Relative Performance. *Geo Info Systems* 8(4):38–44.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1998c. Retail Location Analysis, Step Four: Identify Situation Targets. *Geo Info Systems* 8(6):38–43.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1998d. Retail Location Analysis, Step Five: Assess Market Penetration. *Geo Info Systems.* 8(9):46–50.

Thrall, Grant Ian, Juan del Valle, and Gordon Hinzmann. 1998e. Retail Location Analysis, Step Six: Identify Markets for Expansion. *Geo Info Systems* 8(11):42–45.

Thrall, Grant Ian, Juan del Valle, and Susan Thrall. 1995. Four Mass Market GIS Software Programs. *Geo Info Systems* 5(9):60–65.

Thrall, Grant Ian, Judy Fandrich, and Susan Thrall. 1995. The Location Quotient: Descriptive Geography for the Community Reinvestment Act. *Geo Info Systems* 5(6):18–22.

Thrall, Grant Ian, and Stephen Golant. 1998. Community 2020 (HUD Community Planning Software). *Journal of Real Estate Literature* 6(2):147–50.

Thrall, Grant Ian, Mark McClanahan, and Susan Thrall. 1995 Ninety Years of Urban Growth as Described with GIS: A Historic Geography. *Geo Info Systems* 5(4):20–27.

Thrall, Grant Ian, Charles Sidman, Susan Thrall, and Tim Fik. 1993. The Cascade GIS Diffusion Model for Measuring Housing Absorption by Small Area with a Case Study of St. Lucie County, Florida. *Journal of Real Estate Research* 8(3):401–20.

Thrall, Grant Ian, and Susan Elshaw Thrall. 1990. A Computer Assisted Decision Strategy for Evaluating New Satellite Hub Sites for a Local Utility Provider. *Computers, Environment, and Urban Systems* 14:37–48.

Thrall, Grant Ian, and Susan Elshaw Thrall. 1991. Reducing Investor Risk: A GIS Design for Real Estate Analysis. *Geo Info Systems* 1(10):40–46.

Thrall, Grant Ian, and Susan Elshaw Thrall. 1993. Commercial Data for the Business GIS (Part One). *Geo Info Systems* 3(7):63–68.

Thrall, Grant Ian, Susan Thrall, Marilyn Ruiz, and Charles Sidman. 1993. Using GIS to Analyze and Visualize Spatial Data. *Geo Info Systems* 3(5):59–65.

Zahodiakin, Phil. 1993. Mapping Helps Banks Point to Compliance. *American Banker* 158(172):6.